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Bid amount decision making

for large integrated infrastructure projects by EPC contractors in the Netherlands

TU Delft

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By

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Preface

This master thesis deals with the processes in which Dutch engineering, procurement and construction contractors determine the bid amount for large infrastructure tenders with design and construction integrated in a single contract.

This subject raised my interest during my master's studies in Construction, Management and Engineering at TU Delft. In the course of my studies, I observed news items covering the procurement of large infrastructure projects that surprised me. For instance, I came across a tender in which a consortium was willing to take on constructing a lock for €100 million euro less than its closest competitor. This amazed me. After all, an offer of €10 million less would have been more than sufficient to acquire the project. Some time later, the same project appeared in the press again. It had faced setbacks, resulting in major cost overruns. News items like these one sparked my interest for contractors' bid amount determination processes.

Through my studies, I became familiar with procurement processes and contracts, project and process management, corporate finance and risk management. However, contractor's decision-making regarding the bid amount remained a mystery to me. Therefore, I decided to examine this matter in my thesis.

S.B. Stoll
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Abstract

In the Netherlands, from time to time, remarkable bids can be observed among the results of tenders for large infrastructure projects with design and construction integrated in a single contract. This observation sparked interest in the decision-making processes that Dutch contractors apply. Contractors determine their bid amount with the mark-up approach; the construction costs are marked-up, to account for; risk, general overhead and profit. Decision makers balance the profit with the probability of winning the tender, by adjusting the mark-up. This is challenging, because they are faced with little information, limited time and large uncertainties. The mark-up decision is made based on a mixture of experience, individual beliefs and gut feelings. This makes the decision-making susceptible to biases and emotional responses to external pressures. Hence, the research question is; how can the bidding price determination process for large infrastructure projects by Dutch EPC contractors be improved? The general viewpoint in literature is that the decision-making would greatly improve if it would be more rational. Over the years, several methods have been proposed to assist decision makers in their mark-up decision, however, they are not used by Dutch contractors. A literature study of the proposed mark-up models and decision-making literature was used to compile a theoretic framework. Semi-structured interviews are conducted with six of the largest Dutch infrastructure contractors to obtain a notion of contractors' bid determination processes. The obtained notion is compared with the theoretic framework, which resulted in the finding that multi-criteria mark-up models are most congruent with current practice. In addition, a barrier to rationalizing a contractor's bid determination is identified. There is a misalignment between the phase in which the contractor conceptualizes the tender and the final phase in which the bid amount is determined. The misalignment is present at different levels; 1) between a structured tender process and a unstructured mark-up decision process, 2) between a focus on data during the tender which disappears when other, more intangible items are considered in the bid amount decision as well and 3) between bounded rational decision-making during the tendering phase and a more entrepreneurial type of decision making at the mark-up decision. Implementing a multi-criteria mark-up model is recommended to reduce the misalignment and subsequently improve the decision-making. This model is most congruent to contractor's current processes. In addition, it promotes a more complete, well-considered decision-making, which reduces the sensitivity to biases.

Acknowledgements

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In addition, I would like to thank Dr. D.F.J. Schraven for your role as secondary supervisor. Your literature recommendations and insights regarding research methodologies proved invaluable. In addition, you often brought forward a different perspective, which lead to fruitful discussions. Finally yet importantly, I thank you for your contagious enthusiasm.

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1 Introduction

This MSc thesis focusses on the procurement process of integrated infrastructure projects from an EPC (engineering, procurement and construction) contractor's point of view. EPC contractors typically obtain new infrastructure projects via tendering processes. The tendering process is roughly outlined by Takano, Ishii & Muraki (2018) and contains the following steps. First, a client announces a new project and invites contractors to submit a bid. The submitted bids are not revealed to competing contractors. The lowest bid tends to determine the winning contractor, who is then paid the bid price and executes the project.

A contractor draws up a bill of quantities stating the estimated quantities of the project, based on the drawings and specifications in the tender documents. Next, each quantity is transformed into a monetary value with a schedule of unit prices. All amounts are then added to obtain an amount that corresponds with the costs involved in constructing the project. However, this amount is never directly submitted as the bid amount (Wilson & Hillebrandt, 2006).

Instead, the construction costs are either marked up or sometimes discounted by the contractor's decision makers. A mark-up is added on top of construction costs to obtain a return on the investment and covers issues such as risks, overhead and profit. Occasionally, instead of a mark-up, a discount is applied to increase the probability of winning the tender and thus obtain the opportunity to construct the project. The decision to what extent to mark-up or discount, which in turn determines the final price, is a vital commercial and business consideration. This MSc thesis focusses on this final part of the bid determination process.

The problem of setting an appropriate bid price

Each contractor aims to submit a bid amount that maximizes the chance of winning the project and simultaneously minimizes the difference between competitors' bids (Shash, 1993). Predicting the optimum mark-up/discount during a tender process is a challenge. In the decision process during the tender, decision makers in contractor organizations are faced with large uncertainties, little time and limited information. Therefore, decisions are made based on a mixture of gut feelings, guesses and past experiences (Ahmad, 1990) and are subjected to emotional responses to external pressures (Fayek, 1998; Xu & Tiong, 2001).

Motivation

In the bidding processes of large infrastructure projects remarkable bids can be observed from time to time. Take the expansion of the IJmuiden sea-lock for example. The winning bid was circa €350 million (after discounting), while the second and third bid were circa €450 (after discounting) (Houtekamer & Duursma, 2016). With such a large difference in bid amount, the winning EPC could likely have offered a substantial higher amount and still won. Easy to say in hindsight, of course. Nevertheless, there might be a considerable gain for EPC contractors if they can submit offers that are more accurate.

Knowledge gap

The general viewpoint in literature regarding bid amount decision making is that the performance and competitiveness of contractors would greatly improve if the pricing decisions were not based only on subjective considerations, but instead based on more objective information regarding a broad range of factors that could influence the bid amount (Abotaleb & El-adaway, 2017; Mochtar & Arditi, 2001; Perng & Chang, 2004). The expectation is that contractors can offer more accurate bid amounts if the process of establishing the amount is transformed from an irrational one to a more rational one. Which in turn will result in larger profit margins. Therefore, there is a perceived need for

models or tools that can support the mark-up decision of contractors during tender processes. However, what type of rational process would be best suitable is still unclear.

Since the 1950s, several methods have been proposed to assist decision makers in determining an appropriate mark-up/discount. The main branches among these models are; statistical models (Friedman, 1956; Gates, 1967), multi-criteria models (Ahmad & Minkarah, 1987; Christodoulou, 2004; Dozzi, AbouRizk, & Schroeder, 1996; Hegazy & Moselhi, 1994) and game theory models. Despite the availability of a multitude of methods, it is still unclear whether a useable method for Dutch infrastructure tenders is available among the proposed models.

Objective

The research objective is to recommend which objective method is most suitable to support a contractors bid amount decision-making and aims to do so by assessing to what extent mark-up models are congruent with current practices at the Dutch infrastructure contractors.

This research has a scientific and a societal goal. The research is intended for people involved in (strategic) tender management and is particularly aimed at the decision makers involved in final bid price setting like tender managers, heads of acquisitions, higher management and boards of civil contractors. On the other hand, the research is of interest for the academic community and provides a rare and in-depth image of decision making in private construction companies.

Research questions

The previously stated problem of setting a selling price and the objective to identify which model would be better able to support this decision raises an interesting question; *How could the bidding price determination process for large infrastructure projects by Dutch EPC contractors be improved?*
The term "improving" is defined as rationalizing the process via the use of a mark-up decision support model. The sub questions are;

1. Which mark-up methods exist, what are their characteristics and restrictions?
2. What are the characteristics of the Dutch tendering processes and market environment?
3. Which method is most in line with the rudimentary bid amount determination process for large infrastructure projects used by Dutch EPC contractors?
4. How can EPC contractors improve their bidding processes for large integrated infrastructure projects?

Research approach

Firstly, a literature study about the Dutch tendering procedures and market environment is performed to identify their characteristics. Secondly, existing methods for modelling the mark-up/discount are studied. Their characteristics and limitations are investigated to create a framework to compare practice with. Third, decision models are studied to be able to soundly investigate contractor's decision-making in practice. Forth, interviews with key decision makers are held to obtain an understanding of the mark-up decision making in practice. Fifth, by analysing theory and practice, the suitability of the mark-up support methods for the Dutch infrastructure market is assessed.

Scope

This thesis focusses on the procurement process that an EPC contractor goes through during a tender process to determine its final bid price for large Dutch infrastructure projects. These are so-called integrated projects. Integration takes place at three levels;

1. Both design and construction are carried out by a single party, the EPC contractor. The scope also includes additional forms of integration of project phases, like design & build extended with maintenance, financing, operation, etc.

2. Several engineering disciplines are integrated into one project, for example rail and/or roadworks and the construction of a bridge or tunnel.
3. The projects are generally procured not by one party but in a partnership or consortium, integrating multiple businesses into a project specific organisation and venture.

The scope of the research is limited to the last phase of the EPC contractor's procurement process for these large integrated infrastructure projects in the Netherlands. For reference, the last couple of weeks before a tender is submitted. However, complete tender processes can take years. In this last phase decision makers of an EPC contractor gather to discuss the final offer and set the bid price. Thus, previous phases which include the decision to bid for a project are excluded from this research. It is assumed that that decision has already been taken and that the tendering process in which the EPC contractor aims to offer a bid has started.

Structure of report

The next chapter is a literature study, which provides an overview of the procurement process and suggested methods to assist in the determination of an optimum bid price. Then, the methodology used in the thesis is explained in more detail, explaining the approaches taken in the research. Both the literature study and expert interviews and the successive analysis are covered. The fourth chapter displays the results of the analysis. The obtained results are discussed in the next chapter, where the findings of the expert interviews are reflected vis-à-vis the findings of the literature study. Lastly, conclusions are drawn in chapter 6 and the research question is answered and further recommendations for practice and scientific continuation of the research are provided.

2 Literature study

In this section theory regarding the tendering process of large infrastructure projects is investigated. Three subjects are studied. First, the procurement process. Starting from the generic acquisition process and gradually particularising to the Dutch procurement process of large infrastructure projects. The procurement process is studied from the perspective of both the client and the contractor. Secondly, the main branches of bid mark-up methods are covered. This covers several methods which are proposed by scholars to assist decision makers in the challenge of setting a bid price. The narrative zooms in on their particular characteristics, requirements and limitations. These particularities are captured in a mark-up model framework that will be used later on in the analysis of data. Thirdly, besides these mark-up support methods, literature is also studied regarding general models regarding decision-making. A framework of three decision models is compiled. This framework is used to analyse the mark-up decision making in practice later.

2.1 Procurement process

This section sets the scene of the procurement process of large infrastructure projects. First, a general overview of the different phases of an infrastructure projects is presented. Subsequently, the focus shifts to the acquisition and procurement process itself.

Procurement in its context

Acquisition is a specific phase of a project. To illustrate the position of acquisition and procurement in the process, a generic overview of a project is sketched out (Rijkswaterstaat, 2014).

Figure 1 - generic project phases of infrastructure projects

Every projects starts with an initiative. This first phase of each project is about identifying a problem or opportunity. The initiative phase is succeeded by an explorative phase. In this phase the problem is investigated and possible solutions are scanned. The third phase is a phase of elaboration. It starts with sketching up a schedule of requirements. Next, possible solutions are devised, compared and a final alternative is selected. In the next phase, the acquisition process starts. First, the acquisition is prepared and planned. This involves deciding on the procurement strategy, project delivery model, contract type and conditions, procurement method and award criterion. Next, the procurement process is executed according to the procurement plan. Received bids are judged and subsequently the project is awarded. Then, the project itself is executed. When construction is completed, handover takes place and the maintenance phase begins.

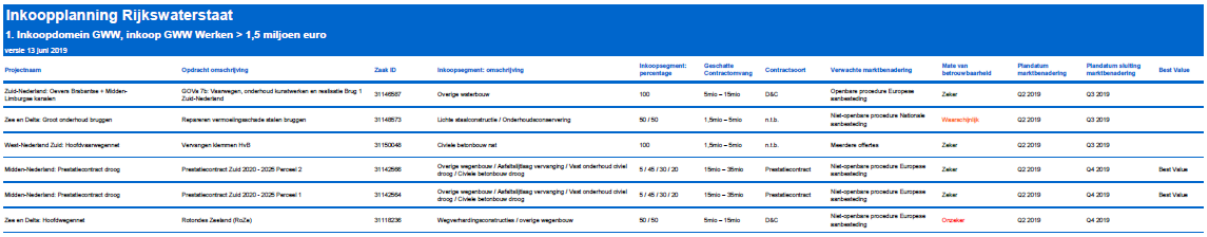
2.1.1 The acquisition process of Dutch infrastructure from the clients' perspective

Rijkswaterstaat is the main contracting authority of infrastructure projects in the Netherlands. This section covers their purchasing policy and the implications of this policy to the bid price decision problem.

Initiative

The initiative to start large infrastructure projects is taken by the government, formal agreement is required by the House of Representatives in Parliament. In the Netherlands, infrastructure projects are part of the domain of the Ministry of Infrastructure and Water Management. As its executive agency, Rijkswaterstaat represents the ministry as client.

Large scale infrastructure projects are planned years in advance (Rijkswaterstaat, 2010). The Dutch governments has a multi-year program in place to manage its investments in infrastructure, called the Multi-year Infrastructure, Spatial development and Transportation program (in Dutch: MIRT Meerjarenprogramma Infrastructuur, Ruimte en Transport). With this program investment in infrastructure and water management are budgeted. Two government funds are available for this purpose; the Infrastructure and Delta fund. Yearly, on the third Tuesday of September, the ministry of Infrastructure and Water Management presents it budget plans. The budget plans are then transformed into an acquisition schedule by Rijkswaterstaat. Projects are prioritized and scheduled based on; an analysis of the problem, effects, costs and consultations with the market and stakeholders. Every four months an acquisition schedule for the coming year is published.



Inkoopplanning Rijkswaterstaat

1. Inkoopdomein GWW, inkoop GWW Werken > 1,5 miljoen euro

versie 13 juni 2019

Projectnaam	Opdracht omschrijving	Zaak ID	Inkoopsegment: omschrijving	Inkoopsegment: percentage	Geschatte Contractomvang	Contractsoort	Verwachte marktbenadering	Mate van betrouwbaarheid	Plandatum marktbenadering	Plandatum sluiting marktbenadering	Best Value
Zuid-Nederland: Gerwen Brabantse + Midden-Limburgse kanalen	GOVe 7b: Vaarwegen, onderhoud kunstwerken en realisatie Brug 1 Zuid-Nederland	31146587	Overige waterbouw	100	5mio – 15mio	D&C	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q3 2019	
Zee en Delta: Groot onderhoud bruggen	Reparaties vermoeiingsschade stalen bruggen	31146573	Lichte staalconstructie / Onderhoudsconservering	50 / 50	1,5mio – 5mio	n.t.b.	Niet-openbare procedure Nationale aanbesteding	Waarschijnlijk	Q2 2019	Q3 2019	
West-Nederland Zuid: Hoofdvaarwegennet	Vervangen klemmen HvB	31150048	Civiele betonbouw nat	100	1,5mio – 5mio	n.t.b.	Meerdere offertes	Zeker	Q2 2019	Q3 2019	
Midden-Nederland: Prestatiecontract droog	Prestatiecontract Zuid 2020 - 2025 Perceel 2	31142566	Overige wegenbouw / Asfaltwegdek vervanging / Vast onderhoud civiel droog / Civiele betonbouw droog	5 / 45 / 30 / 20	15mio – 35mio	Prestatiecontract	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	Best Value
Midden-Nederland: Prestatiecontract droog	Prestatiecontract Zuid 2020 - 2025 Perceel 1	31142564	Overige wegenbouw / Asfaltwegdek vervanging / Vast onderhoud civiel droog / Civiele betonbouw droog	5 / 45 / 30 / 20	15mio – 35mio	Prestatiecontract	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	Best Value
Zee en Delta: Hoofdwegennet	Rotondes Zeeland (RoZe)	31116236	Wegverhardingsconstructies / overige wegenbouw	50 / 50	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Onzeker	Q2 2019	Q4 2019	

Figure 2 - part of the acquisition schedule in June 2019 by Rijkswaterstaat (see Appendix I – Acquisition schedule June 2019 for more detail).

Exploration

The second phase entails exploratory work to prepare for the next phases of the project. This includes; analysing the problem, conceiving the requirements of the product or service required and its supplier and determining possible solutions by compiling and analysing alternatives. A market analysis and market consultation are part of this phase too. An inventory of knowledge and experience in the market is made to assess possible solutions, preferences and the potential of innovation and sustainability in the project.

Elaboration

The third phase is a phase of elaboration. Based on the exploration and a market consultation several alternative solutions for infrastructure projects are examined further. The effects of each solution are investigated. The results are presented for perusal. The minister of Infrastructure decides on a preferred solution. This solution is elaborated in a track decision (in Dutch; tracébesluit).

Acquisition

The acquisition phase of a project is the most relevant phase to this thesis, therefore it is covered in more detail. To fully grasp the acquisition processes that are utilized for large infrastructure projects by Rijkswaterstaat first their procurement philosophy is introduced, then the acquisition processes are covered in more detail.

Rijkswaterstaat's acquisition strategy

Economic downturns over the last two decades caused political pressures to economize the government to emerge. A compact yet flexible government became desirable, without compromising output levels. In 2015, Rijkswaterstaat adopted a new acquisition strategy to achieve this.

This strategy, 'the Market Vision', was jointly created with the infrastructure supply chain; Rijkswaterstaat and het Rijksvastgoedbedrijf representing the government as a client and with associations of engineers, contractors, installers and electricians. The main purpose of 'the Market vision' is to restore the disruptions in the public-private domain arisen from the economic crisis (Kernteam Marktvisie, 2016). Low bids and an inappropriate division of risks led to cost overruns in projects, heavy financial losses by contractors meant the sector's image suffered. The momentum was there for a new way of working, a movement towards a culture and relations focused on mutual collaboration and respect.

One of the actions concluded in 'the market vision' is to utilize leading principles that were identified earlier during 'het TOP overleg bouw'. These are five principles which are all related to acquisition and the bid price to some extent. This connection is strongest with the fifth principle of pricing; all parties involved in the supply chain strive for decent margins, a decent risk increment and contractors will not submit a bid with unreasonable margins. The third principle of EMVI 2.0 states that Rijkswaterstaat will use Economic Most Advantageous Tender as award criterion for its projects. This should result in a proper balance of quality and price in projects and should enable contractors to differentiate themselves based on their skills, knowledge and quality.

EMVI is the Dutch abbreviation for Economically Most Advantageous Tender (EMAT). However, EMVI 2.0 was introduced in 2016, which turned out to be confusing. Since 2016 EMVI is used as an umbrella term for three types of award criteria available to Rijkswaterstaat. They are;

1. Best Price Quality Ratio (BPQR) (in Dutch: Beste Prijs Kwaliteit Verhouding (BPKV),
2. Lowest lifecycle cost (LLC), and
3. Lowest price.

Thus, since the introduction of EMVI 2.0, which used to be known as EMVI is currently known as BPQR.

Rijkswaterstaat's acquisition process

The acquisition phase of Rijkswaterstaat can be divided into three sub phases; preparing the acquisitions, the tendering process and the awarding of the project.

Preparation

First, the acquisition of the project is prepared and planned. This preparatory work can also be part of the elaboration phase. It is clarified whether procurement regulation is applicable and if public procurement is required. This is usually the case for infrastructure projects. Thus, an acquisition plan is conceived covering the project delivery method, procurement procedure and selection and award criteria.

Rijkswaterstaat procures large infrastructure projects with one of three tendering procedures; a public procedure, a restricted procedure or in the case of complex projects with a competitive dialogue procedure with prior selection (Rijkswaterstaat, 2014). With the public procedure all interested parties are free to tender. With a restricted procedure again any interested party can apply as a candidate for the project, but only five will be selected to submit a bid based on previously published selection criteria. The competitive dialogue is slightly different. Similar to the restricted procedure candidates are selected, usually three. With the selected candidates a dialogue is conducted, generally in successive phases. During these successive dialogues the number of candidates and thus offered solutions is reduced to three. The dialog continues until solutions are found which

meet all the requirements set by the client. The candidates then submit a final tender offer based on their solutions. The received solutions are then assessed and the project is awarded based on the published award criteria, like the public and restricted procedure (Bruggeman, Chao-Duivis, & Koning, 2010). The assessment will be covered more comprehensibly in the next section.

Rijkswaterstaat has standardised the use of project delivery methods for its projects. Generally, Rijkswaterstaat concludes integrated contracts; contracts where design and construction are allocated to one party. This applies to the projects tendered with a public or restricted procedure. The particularly complex projects which are usually tendered with a competitive dialog procedure have farther-reaching integration of design and construction and even have Design, Build, Finance & Maintain contracts (Rijkswaterstaat, 2014).

Tendering

Next, the procurement process is executed according to the procurement plan. A tendering procedure consists of the following steps (Bruggeman et al., 2010; Rijkswaterstaat, 2014);

1. A contract notice is published.
   This notice introduces the project to the market and is an invitation for candidates to participate. With the introduction of the Procurement law 2012 it became mandatory for Rijkswaterstaat to use electronic procurement with the TenderNed platform. Notices, rectifications and any announcements regarding the awarding of projects all occur via TenderNed. The notice includes the documents composed in the preparation phase of the acquisition. They consist of an description of the project, a tender guideline with selection and award criteria and the purchasing and contract conditions.
2. Information rounds take place.
   During these rounds interested parties can request elucidation of the contents of the published documents. Rijkswaterstaat publishes its replies to all interested parties and posts them on TenderNed. This practice guarantees transparency and prevents information asymmetry among the tenderers (Bruggeman et al., 2010).
3. Application to tender (restricted procedure).
   Interested parties submit their applications to participate in the tender. This happens electronically via TenderNed. After the latest moment of submission Rijkswaterstaat opens the applications. The application consists of a uniform European single procurement document (ESPD) which serves as preliminary evidence that a candidate complies with the tender requirements, a declaration of conduct and some reference projects.
   Rijkswaterstaat first checks if a candidate indeed complies with the exclusion criteria and suitability requirements. Rijkswaterstaat's acquisition policy is to select a maximum of five parties in order to keep the acquisition process efficient and keep transaction costs low. In case more than 5 parties qualify, the five most suited candidates are selected based on selection criteria published in the tender guideline.
4. Submissions of bids.
   The tenderers submit their bids via TenderNed. The content of the bidding documents differs and depends on the tender procedure and method of awarding.
5. Awarding
   Received bids are assessed. A winner is selected based on the award criteria mentioned in the tender guideline. The winner is announced to all tenderers and sometimes publicly announced. This will be elaborated more in the next section.
6. Standstill period
   Any contracting agency, and thus also Rijkswaterstaat, must provide tenderers who did not win the project, the opportunity to appeal the award decision and

institute summary proceedings. For this reason a standstill period is set, the duration of the period depends on the procurement procedure.

7. Contract
   After the expiration of the standstill period or after resolution of any appeals, Rijkswaterstaat can enter into contract with the winner. Generally, a message is sent to the winning contractor stating that there are no (further) objections and that the agreement can be finalized. Although core provisions are set, like the amount of the bid amount and the project's requirements, several secondary conditions are still to be agreed on. Therefore, the winning contractor and Rijkswaterstaat enter into final contract negotiations. In principle, the winner, bid amount and the total final value of the project or the lowest and highest bids must be published (PIANOo, n.d.)

Assessment of proposals/bid and project awarding.

Steps 5 till 7 of the tendering process just described form the project awarding part of the acquisition process. These steps are now covered in more detail.
In the EMVI 2.0 three types of (EMAT) award criteria are available to Rijkswaterstaat; Best Price Quality Ratio (BPQR), Lowest lifecycle cost (LLC), and Lowest price. As mentioned Rijkswaterstaat has composed its own acquisition policy and process, which comply with 'the Market Vision'. In its procurement, Rijkswaterstaat endeavours efficient procurement processes, optimum price-quality ratios and sustainability (Rijkswaterstaat, 2017). Therefore, Rijkswaterstaat utilizes BPQR as the general award criteria. This enables them to consider more aspects in an offer than just the price. Only projects that are expected to be impossible for contractors to create added value and thus to differentiate themselves from their competition other than through price, the project will be awarded based on the price only (Rijkswaterstaat, n.d.-b).

With BPQR projects are awarded based on the ratio of quality and/or added value and the bid price. Comparing the offered quality of a bid is not clear-cut. Rijkswaterstaat deviates from the standard BQPR approach of expressing the ratio of quality and price in percentages and prescribes to use monetary values. The use of monetary values makes it possible to determine the ratio of quality and price. For each quality related criterion a maximum obtainable monetary value is assigned which represents the 'quality value' that can be achieved. This gives the bidders insight in the potential reward for the created value of their bid.

The question remains how the value of the quality of a bid can be determined. All participating bidders receive a tender guideline describing the process to be followed, Rijkswaterstaat's targets for the project, the selection and award criteria and the maximum value associated with each award criterion (Rijkswaterstaat, n.d.-b). The BQPR criteria are defined in a table and supplemented with a calculation sheet displaying how the value calculation takes place. Two methods are being used to calculate the ratio of quality and price; the method of ratio and the method of price correction (Rijkswaterstaat, n.d.-a). The ratio method is straightforward; the ratio between quality and price is determined to produce the added value per Euro. The method of price correction entails that a fictitious bid price is calculated, with a discount based on the quality offered per criterion. Rijkswaterstaat applies the principle of price correction to determine the best quality-price ratio of its tenders (Rijkswaterstaat, 2017).

Each bidder submits its bid price separately from the qualitative part of the bid. This part contains documents that describe how the contractor plans to execute the project and deal with risks. An independent assessment team scores the qualitative documents, based on the issued tender guideline. At least two assessors are assigned to each criteria, which is related to their area of expertise.

Each bid is scored individually per BPQR criterion. A distinction is made between quality related criteria and performance based criteria. Performance based criteria are scored by

multiplying the offered performance with a performance unit. Quality related criteria are scored per (sub)criterion by the assessment team with an integer mark between 2 and 10, with 6 a neutral position. Table 1 provides an overview of the marks and their relations to the monetary value that will be subtracted for the quality offered for a certain quality criterion.

Score	Assessment	% of maximum quality value
10	excellent – lots of added value	100
9	very good – much added value	75
8	good - more than sufficient to substantial added value	50
7	reasonable – sufficient added value	25
6	neutral – little or no added value	0
5	insufficient – partly inadequate / detrimental / risky	-25
4	largely insufficient - largely inadequate / detrimental / risky	-50
3	poor - very inadequate / detrimental / risky	-75
2	very poor – extremely inadequate / detrimental / risky	-100

Table 1 - Quality assessment; relations between score, assessment and quality value (Rijkswaterstaat, 2017, p. 36)

Thus, the result of BQPR calculation is a fictitious tender bid; it consists of the actual bid reduced with a monetary representation of the offered quality. The lowest fictitious bid is the economic most advantageous bid with the best quality-price ratio.

Project execution

Then, the project itself is executed. When construction is completed, handover takes place and the maintenance phase begins.

2.1.2 The acquisition process from an EPC contractor's viewpoint

Project acquisition by an Engineering, Procurement and Construction contractor

An EPC has two ways to secure new projects; either by direct negotiation with an owner or by means of competitive bidding (Shash, 1993). As covered in the introduction and the previous section that described the acquisition process followed by Rijkswaterstaat, this thesis deals with acquiring large infrastructure projects in the Netherlands via competitive bidding.

The acquisition process of an EPC contractor participating in competitive bidding for infrastructures is initiated when a contractor receives the opportunity to participate in the tender. The invitation to take part in a tender is formally known as a Request For Proposal (RFP). A RFP prompts several actions, which combined form the acquisition process carried out by the contractor.

These actions can be subdivided into 4 actions, each of which are related to a specific stage of the acquisition process (Hillebrandt, 2000; Wilson & Hillebrandt, 2006);

1. Considering whether to bid or not to bid;
2. Estimation of the project's cost;
3. Assessment of the lowest acceptable worthwhile price (or lowest mark-up) at which the work should be taken;
4. Setting the final mark-up.

The bid/no-bid decision

Whether to participate in the tender or not is the first of two key considerations in a tender for a company. This decision is of importance due to financial consequences that follow. Participating in a tender equals investing financial resources and allocating human resources to the opportunity to obtain work. This amounts to substantial costs. These costs are only recoverable if the project is indeed obtained (Shash, 1993).

Upon receiving a RFT a contractor first preforms a preliminary analysis of the proposed project. The analysis is followed by the decision whether to participate in the tender and submit a bid later on. This is the bid or no-bid decision, also known as the tender decision (Ishii, Takano, & Muraki, 2011). To be able to make the bid/no-bid decision the project's technical feasibility is assessed. Also, an exploratory cost estimate is made based on the limited information supplied with the RFP and contractor's past experience. Due to the limited information at this time the cost estimate has a large uncertainty, an inaccuracy of +/- 30% is not uncommon in this phase (Towler & Sinnott, 2012). The estimate is used to roughly anticipate a price level, which subsequently is used to get a first estimation of the potential profitability. The results of the analyses are then sent to the contractor's senior managers, who make the decision to bid or not, while considering thing like the RFT, the analyses of feasibility and profitability, the competitive environment (Ishii et al., 2011).

Ali Shash (1993) studied 85 contractors in the UK to uncover which factors are of importance for decision by contractors whether to bid or not. His questionnaire identified the most important factors to be (in order of importance); the need for work, the number of competitors tendering, experience in similar projects, the current workload, the client, the contract conditions, the project type, previous profits in such projects, project size, tendering method, risks related to the nature of the work, the project's location, contract type, availability of qualified staff and 41 other factors. The complete list is enclosed in Appendix J – Attributing mark-up factors.

A complicating factor in this investment decision is that at the time the decision has to be made, it is unclear what de outcome will be. If the contractor does not participate in the tender, he loses the opportunity of making a profit. If the contractor does participate in the tender, the opportunity to gain a profit still holds, but additional costs are incurred

during the tendering process. It will remain unclear whether this was worthwhile until the project is completed, that is if the tender was indeed won (Shash, 1993).

Estimating the project cost

Traditionally, cost estimations are derived from a bill of quantities. Based upon a design and work plan the necessary materials are logged in table format. Commonly this is provided by the client and is part of the request for proposal. The contractor determines a unit price for each item in the bill of quantities. The unit prices are multiplied with the calculated unit costs to determine the cost of the materials needed (Wang, 2004; Wilson & Hillebrandt, 2006).

However, accurately estimating a project's cost is difficult and requires very detailed analysis. When projects become large it becomes ever so complicated to accurately assess all items. Besides, there will be some mistakes and errors of judgement in this process. The issue becomes more troublesome with regard to calculating the unit prices (Hillebrandt, 2000). A contractor may have an idea of the unit cost for items that he regularly supplies. But the quantities of bill of quantities may differ, resulting in different unit prices. Moreover, contractors assess unit costs during the tender phase, but the items are bought after the tender is won. During this period prices may fluctuate, thus the contractor must forecast changes in prices (Wilson & Hillebrandt, 2006).

Estimating the project's costs is subjected to considerable uncertainties and risks. One speaks of a risk when an undesired event could occur resulting negative consequences with some probability (Knight, 1921). Hence, risk is often defined as the probability of an undesired event multiplied by the consequences. Uncertainty occurs when the probability cannot be determined. An example of an uncertainty is a rise of the global oil price. One knows that the price is not stable, but instead fluctuates. However, it impossible to estimate the probability of a rise in oil price. A contractor can opt to anticipate the risks and uncertainties that could affect the project by adding a risk margin to its cost estimate.

The process of estimating the costs for a tender is, in fact, the reverse of what is generally found in the manufacturing industry, as pointed out by Wilson & Hillebrandt (2006). Common practice in manufacturing is that the producer of the product determines the price only after its manufacturing is completed and all costs are known. In addition, normally the manufacturer controls the conditions of the sale. But in construction the price and conditions are set before construction has begun.

Assessing the lowest acceptable price

When a contractor has analysed the project's costs, risk and uncertainties, it can compose a picture of the range of possibilities around its best cost estimate, ranging from the worst to the best case scenario. From this range a contractor determines the lowest price at which he is willing to execute the project (Wilson & Hillebrandt, 2006). Shash (1993) studied which factors are assessed to determine the lowest worthwhile bid. The most important factors are the present workload, the degree of technical difficulty and the risks involved. The complete list is listed in Appendix J – Attributing mark-up factors. As it turned out, these factors differ from the factors considered when setting a mark-up, as the table below shows.

Bid/no bid decision factors	Mark-up decision factors
Need for work	Degree of difficulty
Number of competitors tendering	Risk involved owing to the nature of the work
Experience in such projects	Current work load
Current work load	Need for work
Owner/promoter client identity	Contract conditions
Contract conditions	Anticipated value of liquidated damages
Project type	Owner/promoter client identity
Past profit in similar projects	Past profit in similar projects
Project size	Completeness of the documents
Tendering method (selective, open)	Project size
Risk involved owing to the nature of the work	Risk involved in the investment
Project location	Type of contract
Type of contract	Rate of return
Availability of qualified staff	Contractor involvement in the design phase
Rate of return	Project type
Project cash flow	Experience in such projects
Tendering duration	Project cash flow
Availability of other projects	Risk in fluctuation in labour prices
Availability of labour	Quality of available labour
Completeness of the documents	Availability of labour
Risk involved in the investment	Risk in fluctuation in material prices
Quality of available labour	Project location
Designer/architect/engineer	Reliability of company cost estimate
Anticipated value of liquidated damages	Availability of other projects
Type and number of supervisory persons available	Degree of hazard (safety)
Competitiveness of competitors	Designer/architect/engineer
Contractor involvement in the design phase	Design quality
Confidence in company work force	Number of competitors tendering
Degree of difficulty	Competitiveness of competitors
Company strength in the industry	Owner's special requirements
Reliability of company cost estimate	Tendering method (selective, open)
Design quality	Confidence in company work force
Risk in fluctuation in labour prices	Availability of qualified staff
Degree of hazard (safety)	Project duration
Availability of required cash	Availability of required cash
Risk in fluctuation in material prices	Type and number of supervisory persons available
Labour environment (union/non-union)	Labour environment (union/non-union)
Identity of competitors	Portion subcontracted to nominated subcontractor
Owner's special requirements	Portion subcontracted to domestic subcontractors
General (office) overhead	Company strength in the industry
Public exposure	Identity of competitors
Project start time	General (office) overhead
Portion subcontracted to nominated subcontractors	Project start time
Project duration	Type and number of supervisory persons required

Availability of equipment	Job related contingency
Type and number of supervisory persons required	Public exposure
Job related contingency	Tendering duration
Portion subcontracted to domestic subcontractors	Qualification requirements
Qualification requirements	Availability of equipment
Policy in production cost savings	Policy in production cost savings
Policy in economic use of building resources	Policy in economic use of building resources
Bond requirements	Government regulations
Government regulations	Insurance premium
Insurance premium	Bond requirements
Tax liabilities	Tax liabilities

Figure 3 - Comparison of factors considered at the bid/no-bid decision and mark-up decision respective, ranked in order of importance (Shash, 1993, p. 116,117)

Setting the final bid amount

Determining the final bid amount is all about balancing the probability of winning the project with the associated profit at the winning bid price. Each contractor aims to offer a bid that is low enough to win the tender, yet is as close as possible to the second lowest bid. Hence, a contractor pursues a bid that both maximizes the chance of winning and minimizes the difference to the bids of its rivals (Shash, 1993). In this process, the contractor's profit is highly dependent on the choice of the mark-up amount (Takano et al., 2018).

This challenge of setting a bid amount is not isolated to the contractor itself. Winning a tender also depends on other bidders. In particular, their workload influences the need for work and thereby their final bid. Besides the current and future workload of competitors, other aspects come into play. Such as their perception of the contract conditions, their unit cost price levels, accuracy of their cost estimate and their risk appetite.

These issues are all difficult to assess. Furthermore, the contractor and his competitors may behave strategically. A contractor may anticipate variations from the client or over budgeted contingency allowances, an competitor with a high future workload, or even gamble on the likelihood of a certain scenario among the identified range and adjust its final bid price accordingly (Wilson & Hillebrandt, 2006). Since decision makers are confronted with limited information, large uncertainties and limited time to make a decision, the mark-up is often determined based on intuition and past experience (Fayek, 1998).

2.1.3 The cost plus mark-up pricing model

Traditionally, the cost plus mark-up pricing model is applied to the problem of setting the final bid price. This entails that a contractor calculates the project's direct costs of materials and the indirect costs of labour and equipment. The direct and indirect costs constitute the project's construction costs. Next, the estimated construction costs are marked-up by the contractor with a percentage. The mark-up serve to cover overhead costs, contingencies and a profit as return on the investment (Shash, 1993).

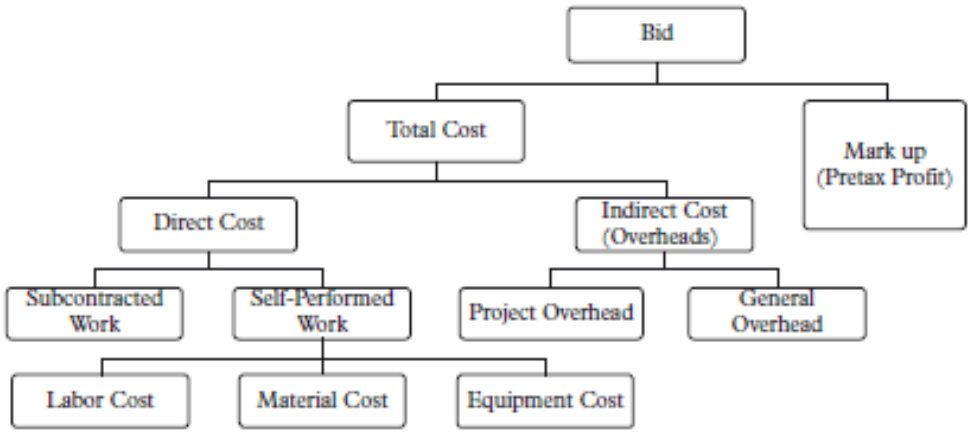


Figure 4 - structure of the bid amount (Yuan, 2011)

Yuan (2011) published a paper that proposed a correlated bidding model. In this paper he presented a more detailed hierarchical breakdown of the bid amount. A bid consists of two main components; the estimated total costs to complete the projects and a mark-up. A bid is bottom-up composed, starting with estimation of the cost components. Labour, material and equipment costs are quoted or estimated. These costs amount to the direct construction costs of the contractor. Often, not all work is completed by the contractor himself. Portions of the work are contracted out to specialised subcontractors. Quotations of subcontractors are added to the contractor's estimated construction costs to determine the direct cost of the project. Besides the direct cost, indirect cost are also part of the project's total cost. Yuan combines two sources of indirect costs. The first component is the project's overhead cost. These are indirect costs which are directly associated with the project, like renting office space and hiring project staff. The second component is general overhead. This covers a portion of the general costs incurred by the contractor. These costs are not directly linked to a project, for example the costs of the head office, human resources staff, etc. The indirect and direct costs amount to the total costs. The final item to be included in a bid amount is the mark-up, which can be viewed as the expected pre-tax profit. Setting the mark-up is a challenge as mentioned on the previous page. Luckily, several methods are proposed to assist decision makers in this decision. The next section provides an overview of them.

But first we focus on the differences between the way Shash (1993) and Yuan (2011) apply the cost plus mark-up model. At first glance they have a similar approach. With both, the bid consists of an estimation of the project's cost and a mark-up. Both divide the projects costs in direct and indirect costs. However, there is a major difference between them. This difference involves the working definition of the project's direct costs and in particular the overhead costs. What Yuan calls project overhead is just called indirect costs by Shash. Shash does not include the general overhead cost into the project's direct cost, but includes it in the mark-up. Thus although both approaches appear to be identical, there is a difference in what is included in the indirect costs and what is included in the mark-up.

2.2 Mark-up models

Methods to assist decision makers in setting the appropriate mark-up emerged from the 1950s. Since then different methods have been proposed by scholars. Generally, they entailed from newly developed techniques, often mathematical or computational. These techniques have later been applied to the problem of setting a mark-up, resulting in a variety of mark-up methods. Researchers have used different classifications of competitive bidding models. Some of the classifications used are addressed below to illustrate their reasoning and finally the distinction used in this research is introduced.

Classification based on theoretical foundation

The main way of classifying bidding models is based on the theoretic concept that the model is derived from. Generally, the distinction between game theory, utility theory and decision theory is used (Abotaleb & El-adaway, 2017; Rothkopf, 2007). This classification is chronologically aligned with the emergence of the theories. Friedman (1956) published the first competitive bidding model in an academic paper as a dissertation from his PhD. His paper kicked-off the emergence of decision theory based mark-up methods. Decision theory methods determine an optimum mark-up for a tender based on inferences from analysing competitors' bidding patterns.

The next development area was game theory. Since the 1970s, game theory is applied to tackle economic problems (Ahmed, El-adaway, Coatney, & Eid, 2016). In the construction field, game theory is used to explain and predict outcomes of tenders. To do so, game theory methods model the bidding situation as a statistic non-cooperative game. This game is utilized to explore possible interactions between rational agents to establish equilibrium strategies (Abotaleb & El-adaway, 2017). Of particular interest in this regard is auction theory, a sub-discipline of game theory (Ahmed et al., 2016; Klemperer, 1999).

In 1988 Ahmad & Minkarah questioned 239 of the top 400 general contractor/construction firms in the USA in an attempt to uncover how bid decisions were actually made. They identified 31 underlying factors that affect the mark-up decision. This initiated new research in the subject, on the premise that contractors consider multiple criteria to determine the mark-up (Dozzi et al., 1996). Since then, numerous multi-criteria mark-up models have been developed; multi-criteria prospect models (Cheng, Hsiang, Tsai, & Do, 2011), multi-criteria utility models (Christodoulou, 2004), multi-criteria utility models (Dozzi et al., 1996), analytic hierarchy process multi-criteria models (Cagno, Caron, & Perego, 2001) and artificial neural network multi-criteria models (Hegazy & Moselhi, 1994; Liu & Ling, 2005).

Classification based on the 'structuredness' of the problem

Moselhi, Hegazy, & Fazio, (1993) introduced an alternative classification of the problem by means of a classification based on the level of structure in the problem of deciding on a bid price that is incorporated in a bidding model. They refer to Shapiro & Spence (1997) for the concept of structure, which concerns the underlying relationships between variables. According to Shapiro & Spence problems lie on a continuum of 'structuredness', ranging from ill-structured to well-structured problems. Ill-structured problems are those problems for which widely accepted decisions rules do not exist yet. On the other hand, decisions rules are established which result in an acceptable solution for well-structured problems.

Some researchers, particular the earlier ones (Carr, 1983; Friedman, 1956; Gates, 1967; Hegazy & Moselhi, 1994) viewed the bid price decision as a structured problem, which resulted in the development of probability based models. Later, additional variables were identified and added (Ahmad & Minkarah, 1987). This initially led to the perception that the problem was unstructured and that expert systems should be used (Tavakoli & Utomo, 1989). Secondary, developments in computational analysis, in particular in

artificial intelligence, contributed to a revised perception of a semi-structured problem (Christodoulou, 2004). This led to a variety of decision models to address the problem; Neural networks, Fuzzy Set theory, Analytical Hierarchy Processes, Case Based Reasoning, Generic Algorithm, etc. (Chou, Lin, Pham, & Shao, 2015; Dikmen, Birgonul, & Gur, 2007; Hegazy & Moselhi, 1994; Marzouk & Moselhi, 2003).

The classification used in this research

In this thesis the traditional classification is used, which distinguishes between game theory, multi-criteria and statistical based methods. This way of classifying methods has been adopted, due to its acknowledged nature in literature.

2.2.1 Statistical methods

This section provides an overview of the methods proposed in literature to determine an optimum bid price in competitive bidding situations in which closed bidding is used. The methods covered in this section are the statistical methods of Friedman, Gates and Carr.

Seminal work by Friedman

Modelling of bid mark-ups started with the fundamental model of Lawrence Friedman (1956). His academic paper based on his PhD in operations research focused on sealed bid auctions and presented a decision theory model for an optimum mark-up. In his method bidding patterns of conceivable competitors are determined. This information is used, together with an estimated probability distribution of the project's cost, to determine a bidding strategy. In this relatively simple approach, the probability of winning the tender is obtained for all competitors simultaneously. To base the bid mark-up decision of a contractor in a future bid on the statistical analysis of historical bidding patterns of competitors is typical to this kind of decision models (Abotaleb & El-adaway, 2017).

Friedman identified that the bidding behaviour of a company is related to a specific strategy based on a certain objective. He stated that maximizing the total expected profit is the most likely objective of the bidder. Alternative objectives are 1) to gain at least a percentage of investment, 2) to minimize expected losses or 3) to minimize the profits of competitors. However, he based his method on the assumption that the companies' only objective is profit maximization.

Friedman presented a method to determine the optimal bid with the objective of profit maximization. First, he addressed how the expected profit could be determined. Friedman argued that the expected profit of a project depends on the difference between the bid amount and the project's costs multiplied by the probability of acquiring the project at that bid amount.

At the time of bidding, the exact costs of completing the project are unknown, only a cost estimate is available. So instead, Friedman looked at the ratio between the actual project costs and the estimate. With historic data, he composed a probability density function showing the variance between the actual and estimated costs. Figure 5 shows the established distribution of the ratio of the actual cost and the estimated cost. He reasoned that a project obtained with bid amount x will generate an expected profit of (x –SC). With S representing the ratio between the estimated and actual costs and C the estimated costs required to fulfil the contract.

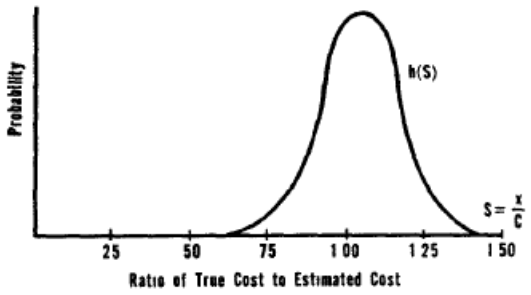


Figure 5 - Distribution of the true cost as fraction of the estimate. With C representing the estimated costs, S the ratio between the actual cost and estimate cost and x representing the bid amount (Friedman, 1956).

Next, he tackled the problem of determining the probability of obtaining a project at a certain bid amount x, P(x). Friedman turned to the results of previous biddings. For a given competitor, the ratios between the competitor's bids and the cost estimates of the company under review is studied. These ratios are then summarized with a probability density function. This function is considered to cover the bidding behaviour of a competitor. Similarly, the bidding behaviour of other competitors can be captured in probability density functions as well. Figure 6 illustrates probability density functions of three competitors.

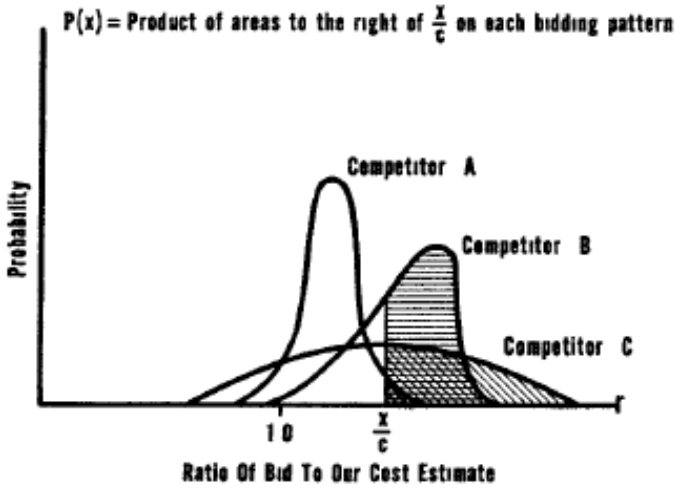


Figure 6 – Estimated probability density functions of competitors bidding behaviour (Friedman, 1956).

Subsequently, the probability of winning over a competitor at a certain bid can be computed. On the x-axis x/c =1.0 is marked, this is the level where a bid amount equals our cost estimate. The mark x/C represents a certain mark-up (compared to our own cost estimate). The area to the right of this mark, represents the probability that a contractor submits a bid x at a higher mark-up than our own contractor did (marked red). Since all bids to the right side are more expensive than our bid, this area represents the probability of winning over competitors.

These density functions can also be used to determine the probability that a bid is the lowest. Friedman uses the product of the individual probabilities for this. With the underlying assumption that the bidding behaviour of each competitor is independent of the behaviour of the others. Although this is a questionable assumption, it is used by others too (Carr, 1983; Gates, 1967).

With both the expected profit at a given bid amount and the probability of winning known, the expected profit E(x), at bid amount x can be determined by multiplying.

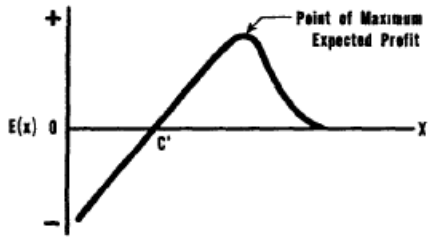


Figure 7 - Expected profit given a bid amount x (Friedman, 1956).

In addition, Friedman made an attempt to model a bidding situation where the competitors are unknown. This approach is accommodated in Appendix H – Friedman's model of bidding against unknown competitors

Successive work by Gates.

The work of Friedman was succeeded by a method proposed by Marvin Gates (1967). Gates, as did Friedman, claimed that the probability of winning a new tender can be determined from the results of previous tenders. Gates also asserts that the optimal strategy to determine the bid amount is to maximize the expected profit. Both models use the same underlying information and follow the same basic approach (Crowley, 2000).

However, Gates derived a different formulation of the probability of winning at a certain bid amount. Each contractor's bidding behaviour is modelled as an independently distributed random variable. For contractor N this random variable is denoted as X_N. From each distribution one value is taken, for example x_A, x_A,…,x_N. Then, the probability that a value of x_i is the lowest among the range of values from x_1, x_2,…,x_N is (Crowley, 2000);

$$P_i = \frac{1}{\frac{1-P_A}{P_A} + \frac{1-P_B}{P_B} + \frac{1-P_C}{P_C} + \ \ldots + \frac{1-P_N}{P_N} + 1}$$

Gates considered the probability of obtaining a lowest value among several independently distributed random variables. The lowest value corresponds to the optimal bid that a contractor should submit in order to win the tender and the other independent random variables represent historic bid distributions of competing contractors. Gates, in contrast to Friendman's concept of an 'average bidder', considered competitors that would behave equally as the contractor who's bid is under consideration (Skitmore, Pettitt, & McVinish, 2007).

Runeson & Skitmore (1999) point out that Friedman's strategy for a single bid is developed into a generic strategy by Gates. They claim that by doing so, Gates transformed a single decision support model into a generic economic theory to determine the price of construction projects.

Carr

The models of Friedman and Gates have led to decades of debates, mainly concerning the two different formulations of the probability of winning a tender. However, in the 1980s, some scholars set out to conceive methods that do not require combining individual probabilities of winning over a competitor. Working around the issue of determining the correct formulation of the probability of winning. Instead, they reformulated the problem as one of determining the optimum bid amount with lowest opposing bids.

Carr investigated the assumptions used in Friedman's and Gates' models. He focussed on situations with large variations in the cost estimates of competitors and used this to point out limitations in Friedman's model. Carr proposed his own model, which he claimed is less restricted in its application compared to the models of Friedman and Gates. However, it still relies on the contractor's cost estimate in relation to the estimated distributions of contractors' bidding behaviour. Carr starts with estimating the competitors' costs; estimated average cost of competitor i to complete the project is denoted as C_i. Next, Carr determines an average cost estimate, $\bar{C}$.

$$\bar{C} = \frac{\sum_{i=1}^{k} C_i}{k}$$

With this average cost estimate, he standardizes the estimated cost for competitor i;

$$C_i^{\cdot} = \frac{C_i}{\bar{C}}$$

The contractor knows from past experience how his own cost estimate for a given project is related to the bid amount of competitor j.

$$\left(\frac{B}{C}\right)_{ijk} = \frac{B_{jk}}{C_{ik}} = FBC_{jk}\frac{C_{jk}}{C_{ik}}$$

With $\left(\frac{B}{C}\right)_{ijk}$ the bid-cost ratio corresponding to the bid of contractor j to the project cost of contractor i for project k. B_{jk} is the bid of contractor j for project k.

This expression covers one project only, project k. The ratio for N projects is

$$MBC_{ij} = \frac{\sum_{z=1}^{N}\left(\frac{B}{C}\right)_{ijz}}{N}$$

With MBC_{ij} corresponding to the average ratio of the bids of competitor j to contractor i's cost estimate. Carr expanded this to cover other competitors

$$MBC_i = \frac{\sum_{z=1}^{N}\sum_{j=1}^{n_z}\left(\frac{B}{C}\right)_{ijz}}{\sum_{z=1}^{N} n_z}$$

MBC_i represents the average bid-cost ratio of all (z) competitors bidding against contractor i, based on N previous projects.

Now, Carr determines the probability that a competitor submits a higher bid than the standardized costs of the contractor is

$$P_w = P\left[\left(\frac{B}{C}\right)_{ij} > b\right] = \int_{-\infty}^{\infty} f\left(\frac{B_j}{C_i}\right)dx = \int_{-\infty}^{\infty} f\left((\dot{C}_i)P(\dot{B}_j > b\dot{C}_i)\right)dx = \int_{-\infty}^{\infty} f(\dot{C}_i)\int_{b\dot{C}_i}^{\infty} f(\dot{B}_j)\,dxdx$$

Which corresponds to the area under $f\left(\frac{B_j}{C_i}\right)$, on the right side of b.

Since projects are usually awarded with lowest price as criterion, the bid should be lower than the competitor's. Put differently, the lowest competitor's bid-cost ratio should exceed the amount of the bid b, so that the cheapest competitor is still more expensive. This lowest bid-cost ratio is denoted as LBC_{ij}. Subsequently, the probability of winning when the project is awarded based on lowest price becomes;

$$P_w = P(LBC_{ij} > b) = \int_{-\infty}^{\infty} f(\dot{C}_i)\left(\prod_{j=1}^{k}\left(\int_{b\dot{C}_i}^{\infty} f(\dot{B}_j)dx\right)\right)dx$$

Later, Carr (1983) investigated the impact of the numbers of bidders on the bid amount, something that Friedman touched upon at the end of his paper. Carr concluded that when contractors pursue the highest expected value, they will lower their mark-up as the number of competitors increases to compensate for the lower probability of winning. He reasoned that the competing contractors will behave in the same way. He included this phenomena by modifying his general bidding model from 1980. He claimed that a similar modification can be made using Gates' model, but not with Friedman's model.

General characteristics of statistical methods

Carr claimed that his model was not restricted by the assumptions used in the models of Friedman and Gates. When King & Mercer (1987) investigated the controversy regarding different formulations of the probability of winning the tender, they looked at the assumption underlying Carr's model as well . They found that, in contrast to Carr's claims, his model depends largely on the same assumptions as Friedman and Carr.

King & Mercer (1987) concluded that the bidding models proposed by Friedman, Gates and also Carr are founded on four basic assumptions;

1. Contractor's aspire a single objective; maximising expected profit,
2. The bidding behaviour of competitors is static,
3. Adequate data from previous tenders is available to model the bidding behaviour of competitors,
4. Past bids originate randomly from distributions with constant parameters.

2.2.2 Multi-criteria models

A new branch of models to assist decision makers in setting an optimum mark-up emerged in response to studies which tried to identify which factors contribute to the mark-up. Ahmad & Minkarah (1988) recognized that bidding as modelled in the statistical models is of a theoretical nature. Therefore, they set out to investigate how bid decisions are made in the construction industry. Therefore, an American study was performed. It was similar to Shash's (1993) questionnaire among the top 300 UK contractors resulting in a ranking of over 50 factors that contractors considered when setting a mark-up, mentioned in the procurement process section. A questionnaire was sent by the department of Civil and Environmental Engineering of the University of Cincinnati to 378 general contractors in the US, 239 of which belonged to the top 400 of the country in terms of annual revenue. Each contractor was asked to score 31 potential factors on a 5 point Likert scale to indicate the degree of perceived importance to the mark-up. Results of both questionnaires are displayed in table 2 on the next page.

Ahmad & Minkarah (1988) found that contractors assess multiple factors, besides the number of competitors and expected profit, in determining their mark-up. The time available to prepare the bid, the quality of the received documents, prestige and public exposure and the relationships with potential and existing clients proved to be important factors. Furthermore, they confirmed the notion that contractors rely on 'experience, judgement and subjective assessment' (Ahmad & Minkarah, 1988, p. 232) to determine their bid amount, and thus do not apply the statistical models purported to support them.

The findings of these studies renewed the interest in methods to support mark-up decisions. Numerous methods were developed in the next decades that utilize multiple factors to determine an optimum mark-up. In general, these models use a number of factors, which are scored. These scores are subsequently transformed into an optimum mark-up. For the transformation to a mark-up different techniques are suggested over time. Prevailing techniques are Utility functions, Fuzzy Preference Relations, Analytical Hierarchy processes/Analystical Neural Networks (Cagno et al., 2001; Cheng et al., 2011; Christodoulou, 2004; Dozzi et al., 1996; Hegazy & Moselhi, 1994; Liu & Ling, 2005).

Shash (1993), UK		Ahmad & Minkkarah (1988), USA	
Bid/no bid	Mark-up	Bid/no bid	Mark-up
Need for work	Degree of difficulty	Type of job	Degree of hazard
Number of competitors tendering	Risk involved owing to the nature of the work	Need for work	Degree of difficulty
Experience in such projects	Current work load	Owner	Type of job
Current work load	Need for work	Historic profit	Uncertainty in estimate
Owner/promoter client identity	Contract conditions	Degree of hazard	Historic profit
Contract conditions	Anticipated value of liquidated damages	Location	Current work load
Project type	Owner/promoter client identity	Labour environment	Risk of investment
Past profit in similar projects	Past profit in similar projects	Strength of the firm	Rate of return
Project size	Completeness of the documents	Size of job	Owner
Tendering method (selective, open)	Project size	Economic condition	Location
Risk involved owing to the nature of the work	Risk involved in the investment	Competition	Need for work
Project location	Type of contract	Risk of investment	Reliability of subcontractors
Type of contract	Rate of return	Current work load	Design quality
Availability of qualified staff	Contractor involvement in the design phase	Degree of difficulty	Size of job
Rate of return	Project type	Rate of return	Economic condition
Project cash flow	Experience in such projects	Confidence in workforce	Competition
Tendering duration	Project cash flow	Uncertainty in estimate	Confidence in workforce
Availability of other projects	Risk in fluctuation in labour prices	Supervisory persons	Labour environment
Availability of labour	Quality of available labour	Design quality	Strength of the firm
Completeness of the documents	Availability of labour	Reliability of subcontractors	Project cash flow
Risk involved in the investment	Risk in fluctuation in material prices	Project cash flow	Contingency
Quality of available labour	Project location	Contingency	Subcontracted amount
Designer/architect/ engineer	Reliability of company cost estimate	Duration	Supervisory persons
Anticipated value of liquidated damages	Availability of other projects	Subcontracted amount	Duration
Type and number of supervisory persons available	Degree of hazard (safety)	Capital requirement	Capital requirement
Competitiveness of competitors	Designer/architect/ engineer	Job start time	General overhead
Contractor involvement in the design phase	Design quality	Labour requirement	Labour requirement
Confidence in company work force	Number of competitors tendering	General overhead	Equipment requirement

Table 2 - Identified factors of the bid and mark-up decision in the UK and USA respectively (Ahmad & Minkarah, 1988; Shash, 1993)

Multi-criteria utility models

Multi-criteria utility models consider many practical factors to estimate the bid mark-up based on utility theory. For a new project an expected utility value is determined based on predetermined criteria. The expected utility value is compared to a mark-up utility function to obtain the appropriate mark-up (Abotaleb & El-adaway, 2017; Christodoulou, 2004; Dozzi et al., 1996; Takano et al., 2018).

The first to apply (multidimensional) utility theory in the bidding of construction projects were Ahmad & Minkarah (1987). In their model the mark-up is divided in three separate categories; overhead, loss and profit. A utility function is assigned to each of the categories. The functions are then multiplied with a weight to form one utility curve. This curve is integrated over probability distributions to derive a final expected utility curve (Dozzi et al., 1996). The maximum utility value of this curve provides the bid mark-up. An important drawback of this model is that is difficult to apply it to the bidding process of infrastructure projects, because numerous constants are required to develop the exponential utility curves (Dozzi et al., 1996). The model derived by Carr, mentioned previously, can also be considered as a multi criteria model. Fuzzy Set Logic, in particular Fuzzy Preference Relations (FPR) is often applied to determine appropriate weights. As do Cheng, Hsiang, Tsai, & Do (2011), they determined a mark-up that best conforms with the preferences of the primary decision maker with an Multi-Criteria Prospect Model, that links Fuzzy Preference Relations and Cumulative Prospect Theory.

The concept of applying utility theory to a multi criteria mark-up support model is now illustrated with the model of Dozzi et al. (1996). They created a mark-up model which is based on utility theory only. 21 weighted criteria are used to score a new project. This score represents the utility or goodness value of the project. Subsequently, a utility function is used to transform the utility score into a mark-up. This utility function represents the preference of decision makers.

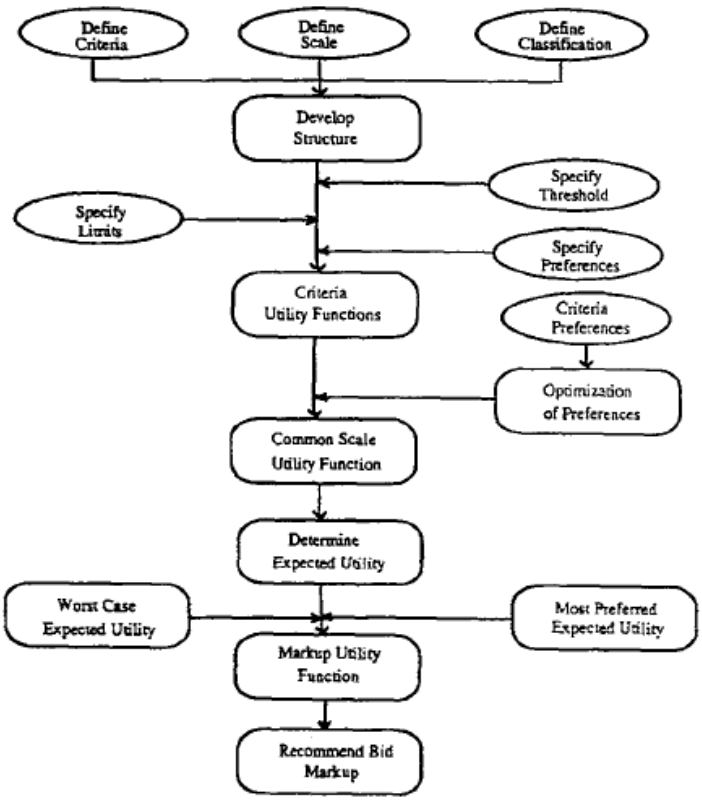


FIG. 1. Flowchart of Utility Theory Model

Figure 8 - Procedural steps in applying a utility model to determine a mark-up (Dozzi et al., 1996, p. 119)

Dozzi et al., (1996) use a specific utility function for each criterion. Input scores can be numerical values or subjective inputs, like a Likert scale. For reference, Figure 9 displays a section of the 21 criteria used and shows how the corresponding utility function is defined. Each individual utility function represents how the range of each criterion is preferred, usually on a scale ranging from 0 to 100. Using a separate utility function for each criterion enables to compare and combine the different criteria.

TABLE 1. Definition and Scale of Bidding Criteria

Hierarchy block (1)	Criterion name (2)	Definition (3)	Criterion scale (4)
1.1.1	Location	Is project within company boundaries	Yes = 100 No = 0
1.1.2	Labor reliability	Is local labour well trained, skilled	Good = 100 Fair = 50 Poor = 0
1.1.3	Labor availability	Is local labor available or difficult to obtain	Easy = 100 Difficult = 50 Impossible = 0
1.2.1	Market conditions	Other projects currently out for tender (relative to number of competitors bidding)	Many = 100 Average = 50 Few = 0
1.2.2	Competition	Expected number of serious competitors bidding on the project	Number (#)
1.2.3	Future projects	Forecast of upcoming projects	Many = 100 Average = 50 Few = 0
1.3.1	Historic profit	Amount of profit obtained on past projects of similar nature	Percent (%)
1.3.2	Historic failures	Past known failures for this project type/owner, etc.	Many = 100 Few = 50 None = 0
2.1	Current workload	Volume of all current projects relative to capacity of firm	High = 100 Medium = 50 Low = 0
2.2	Required rate of return	Required rate of return on investment required by firm	Percent (%)
2.3	Market share	Ratio of current market share to expected share	Percent (%)
2.4	Overhead recovery	Indirect overhead recovered this annum (relative to forecasted)	Percent (%)
2.5	Home office	Amount of project to be completed by home office forces	Percent (%)
3.1	Project type	Project type (is type within the scope of the firm)	Yes = 100 No = 0
3.2	Project size	Estimated project dollar volume	Dollars ($)
3.3	Owner	Relationship between owner and firm	Good = 100 Average = 50 Poor = 0

Figure 9 - Part of the criteria used by Dozzi et al. (1996) *along with their definition and criteria scales.*

Not all criteria are equally important to the mark-up. This was constituted from the questionnaires of Ahmad & Minkarah's (1988) and Shash's (1993). Hence, the criteria are individually weighted. The weighting is arranged so that the total score is again in a 0-100 range. This weighting represents the decision makers' preference and is likely to be dynamic. Criteria weights can be obtained by identifying preferred trade-offs between criteria. Figure 10 is an example of such trade-offs. In the example, the market conditions are considered twice as important as competition. With linear algebra the scaling factors are subsequently obtained. This process is described in detail by Saaty (1978).

TABLE 2. Matrix of Preferences for Bidding Criteria

Bidding criteria (1)	Market conditions (2)	Competition (3)	Future projects (4)
Market Conditions	1.0	2.0	5.0
Competition	—	1.0	4.0
Future projects	—	—	1.0

Figure 10 - Preference scores (Dozzi et al., 1996)

Summing up the weighted individual utility scores of all criteria gives the expected utility score for the project. This utility score is transformed into a mark-up suggestion with a mark-up utility function, like the one shown in Figure 11. In this example, a proposal with a low utility is undesirable, and hence is only acceptable with a high mark-up. On the other side of the spectrum is a highly desirable project, hence a low mark-up is acceptable.

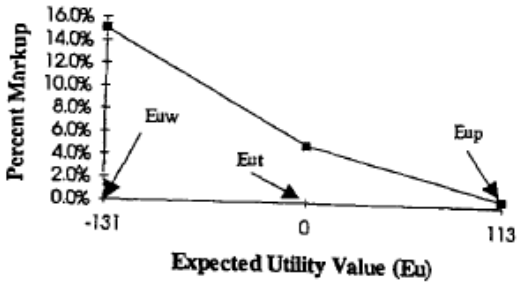


Figure 11 - Total utility function displaying the relation between an expected total utility value and the corresponding mark-up percentage (Dozzi et al., 1996, p. 121)

Multi criteria utility models enable to determine a mark-up on both quantitative and subjective information regarding the project. It is possible to adjust mark-up for preferences in terms of relative importance of criteria (weights) and risk appetite (utility mark-up function).

Artificial Neural Networks

Estimating an appropriate mark-up is challenging. Assessing several factors which may influence the mark-up does not necessarily make it any easier. Identifying the related factors and in particular their relative importance or weights is a cumbersome task (Moselhi et al., 1993). A mark-up in practice is derived from intuition, which is based on a combination of '*gut feelings, experience, and guesses'* (Ahmad, 1990, p. 595). Which suggests that a solution analogy occurs based on a kind of pattern analysis of previous results, opposed to a deliberate computation (Moselhi, Hegazy, & Fazio, 1991). Hence, it is argued that this kind of unstructured problem should be tackled with methods which are more analogy-based. A commonly applied method is an artificial intelligence (AI) method known as Neural Networks (NN) (Hegazy & Moselhi, 1994).

Artificial Neural Networks (ANN) were originally introduced by McCulloch & Pitts in 1943 to mathematically model the biological nervous system. ANNs are used to apply the patterns underlying human reasoning into conceptual models. Since the early 1990s they have been applied to the mark-up problem to deal with the increased complexity due to the inclusion of more parameters (Bee Hua, 2008).

The basic processing elements in an ANN are artificial neurons or nodes. These nodes are the processing elements in the network; interconnected units with computational properties. The nodes are arranged in layers. Several layers are needed to accurately model the intended process. Generally, nodes perform summation and/or a transfer function to determine an intermediate value. They receive some input, process it to transform it into an output which is passed along. More specifically, a set of inputs from a

previous layer is multiplied by connection weights and then summed to compute an activation value, which is then modified by a transfer function to determine the intermediate value. Which, in turn, is part of an input set for the following layer. In the total network of interconnected nodes information flows from an input layer onto an output layer, although connections between nodes could be bidirectional (Moselhi et al., 1991; Polat, Bingol, Gurgun, & Yel, 2016). Figure 12 - general layout of an artificial neural network *(Moselhi et al., 1991)*. Figure 12 displays the general structure of a network.

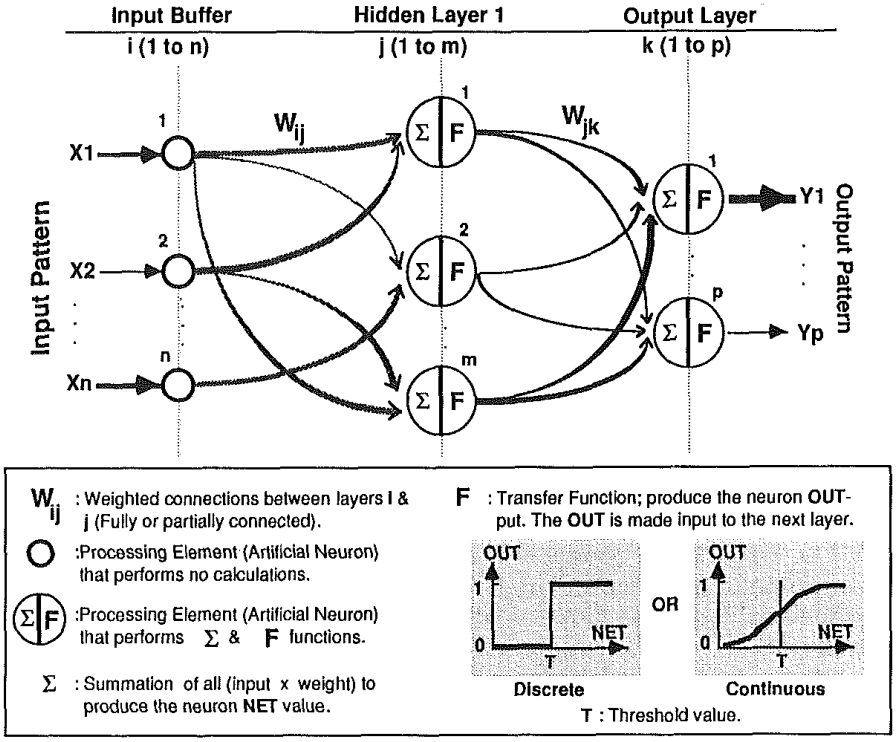


FIG. 2. Example of Simple (Two-Layer) Neural Network

Figure 12 - general layout of an artificial neural network (Moselhi et al., 1991).

Artificial neural networks can be dynamic and self-adjusting. In that case, the networks are called 'recurrent' or self-learning. Networks obtain this learning capability from feedback connections. A network learns from training examples; pairs of input and associated output vectors. In training over a number of examples, the network generalizes the process by adjusting the weights of the connections until the outputs correlate with the inputs. After the training, a network can estimate the output associated with a new case based on the training analogy (Hegazy & Moselhi, 1994; Moselhi et al., 1991). Two types of learning can be distinguished; structured and unstructured learning. Structured learning entails introducing a number of inputs and outcomes as training examples. The outcomes serve as the desired outcome and enable the network to calibrate its weights. On the contrary, in unstructured learning only inputs are provided and the network is stimulated to adjust itself accordingly (Moselhi et al., 1991).

Artificial neural networks and mark-up determination

The application of ANN to the mark-up problem is now shown by demonstrating a decision support system designed by Hegazy & Moselhi (1994). They used all the factors identified by Ahmad & Minkarah (1988) (see Appendix J – Attributing mark-up factors). A feedforward network with a backpropagation training algorithm was used, since they established that this combination was the most suited for the mark-up problem a year earlier (Moselhi et al., 1993). The inputs were a large number of executed projects by 78 contractors in the USA and Canada. Of the available data 65 training examples were composed, and a further seven for testing and validation. With 100.000 training cycles, the network was able to be trained adequately. However, when the network was used in testing and validation the network still had a relatively high estimation error of 15.11%. This indicates a generalization problem, which Hegazy & Moselhi contribute to be inherent to the application of ANNs and specifically with backpropagation, which may stem from the high level of training and inclusion of errors in the data due to subjective and irrational aspects.

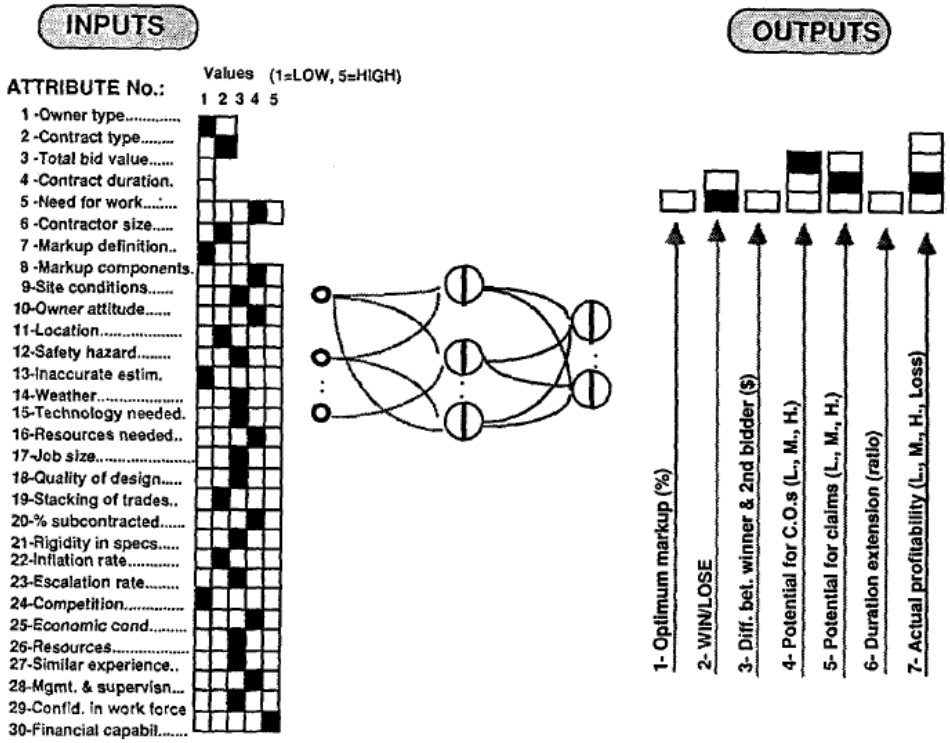


FIG. 2. System of Single ANN for Optimum Markup Problem

Figure 13 – The input and output buffers (layers) of an ANN mark-up decision support model designed by Hegazy & Moselhi (1994, p. 77).

2.2.3 Game theory methods

Game theory can be viewed as a 'bag of mathematical tools designed to help us understand the phenomena we observe when decision-makers interact' (Osborne & Rubinstein, 1994, p. 1). It has existed since 1928, when John von Neumann published his paper *On the Theory of Games of Strategy*. However, it was not until the 1970s before game theory was used to analyse strategic situations in a variety of fields; economics, business, politics, economic relations, etc. As the name suggests, game theory stems from attempts to increase players' gains in gambling games. Therefore, the terminology of games was introduced, which is still being used. Nonetheless, the mathematical concepts of game theory are general and widely applicable (Hermans & Cunningham, 2018). That being said, game theory is particularly useful to study interactions between decision makers.

Game theory can be described as '*an intellectual framework for examining what various parties in a decision should do, given their possession of inadequate information and different objectives*' (Hutton, 1996, p. 249). It is suitable for situations in which the actions of the parties involved have an impact on others and vice versa, but when these interactions and impacts are not clearly defined. Faced with such a situation, decision makers are not making a decision in isolation. Instead, their decision-making is also based on the expectations of the other parties. This independency is called static interdependence, these situations are called games of strategy and the parties involved are known as players (Carmichael, 2005).

As mentioned at the beginning of this chapter, interdependence between the players and the information available to them are crucial aspects of game theory. The players are aware that their outcomes are affected by their own, as well as the actions from the other players. Hence, possible actions and counteractions are taken into account when making a decision. However, players often have limited information. It is not clear to them which actions are available to the others and what the exact outcomes would be. Hence, players are forced to make conjectures. Game theory is useful in these strategic situations to increase the situational awareness and predict which outcomes are likely (Carmichael, 2005).

Situations with a strategic setting, like when key decision makers determine an appropriate mark-up, are modelled as a game. Games are highly abstracted representations of the decision situation, used to study the situation it represents. Within a game a wide range of game theoretic phenomena can be studied, like the Nash equilibrium, mixed strategy equilibrium, the core, etc. For an explanation of these phenomena I recommend A *course in Game Theory* by Osborne & Rubinstein (1994). Thus, a game is an abstract model, describing a strategic setting. Each game has a set of players participating. Every player has the ability to perform certain actions, which are called moves. These moves represent the interaction that could occur between the players. Often multiple variations of interactions are conceivable. Each variation can be modelled in a separate game, resulting in a family of games (Hermans & Cunningham, 2018).

A game can be represented in various ways. Three ways are common; games in extensive, strategic and characteristic function form. Each form is a more abstract representation than the previous (Rapoport, 2001). The strategic form is frequently used, hence it is also known as the normal form.

Figure 14 - extensive, strategic (normal) and characteristic forms of a game.

Games are defined and classified by the rules of that game. The rules state who the players are, what information they possess, the moves (possible actions) available to them and the expected outcome in terms of a pay-off. They also describe how the behaviour of a player will affect the pay-offs. For pay-offs any unit of measurement could be used. However, payoffs are often expressed in monetary terms or in utility. Which is a subjective, abstract concept used in economics to describe units of satisfaction. In order to determine utility, often a ranking between alternatives is used (Carmichael, 2005).

It is assumed that players in a game act rationally when deciding on which actions to take in order to secure the highest pay-off possible. Rational decision makers prefer more utility over less utility. Hence, they will prefer a strategy with more utility as pay-off. This means that players are assumed to be self-interested and pursue a specific goal. However, given the strategic setting of games, there is interdependence between players' pay-offs. Consequently, players will adapt their strategy to the other's players expected behaviour (Carmichael, 2005).

As mentioned before, games are classified by their rules. Games can be classified in several ways;

1. cooperative and non-cooperative,
2. Normal or extensive form,
3. Simultaneous or sequential moves,
4. Constant sum, zero sum, non-zero sum,
5. Symmetric and asymmetric games.

Commonly, games are characterization based on the moves. Games in which all players make their action or move at the same time are known as static or simultaneous move games. On the other hand, when players move in a predetermined order the game is a dynamic or sequential move game (Carmichael, 2005). Since Rijkswaterstaat acquires its large infrastructure projects with either a public procedure, a restricted procedure or in the case of complex projects with a competitive dialog procedure with prior selection (Rijkswaterstaat, 2014). These procedures correspond with a static game, since all parties are restricted to submitting one bid each, which are opened simultaneously. The competitive dialog procedure could be modelled as a dynamic game.

In the simultaneous move games, the players make their moves simultaneously. The action of a player remains unknown to the others when they make their action. Therefore, they cannot react on the actions of competitors, but are forced to depend on their expectations of the moves the other players will make. These games are generally denoted in a strategic form. On the contrary, in sequential move games there is a certain order in which the players make their moves. In this type of games, the other players are able to see the move made by an player and can subsequently respond. These games are difficult to capture in strategic form, hence the extensive form is used.

A division is made between games that occur once and repeated games. The repeated or, multi-stage, or n-stage, games differ in respect to the strategies that players adopt. The players also need to consider subsequent moves at each stage and at each repetition of the game, which is called a meta-strategy (Carmichael, 2005).

Cooperation in game theory is slightly differently defined than one might expect. Within game theory cooperation refers only to the ability to communicate, regardless of the level of cooperation that might subsequently develop. A game is cooperative if communication between players is allowed and players can be held responsible to stick to a strategy if prior agreements were made (Carmichael, 2005). This characteristic of enforcement of agreements impacts the way the game is played and hence the way of analysis. These situations are analysed with cooperative game theory, which is more focused on strategies with joint incentives or collective outcomes.

Information is an important aspect in games, since players use it to determine their strategies. There are different ways to model information is games. First, there are games with perfect information. In these games, players know their opponents' moves. Secondly, there are games with incomplete information sets. Here, there is some external influence. This is modelled by including a pseudo-player, whose moves are random and are not known to the other players. Thirdly, when the players do not have the same information the game is asymmetric (Osborne & Rubinstein, 1994).
In games in which the information among the players is anything but perfect, uncertainty arises concerning the objectives, possible moves and relevant rivals. This uncertainty makes the game more risky. Hence, the outcome of the game becomes uncertain. This uncertainty can be incorporated in a game by adjusting how the players are modelled. In particular, in how they perceive certain outcomes in terms of the pay-off or utility assigned to that outcome. Risk is generally modelled with probability density functions. In a game too, probabilities can be incorporated. This is done by composing an expected outcome, by multiplying each pay-off with the probability of occurrence. Basically, weighting the pay-offs.

Analysis of games

To illustrate the analysis of games, analysis of simultaneous move games is covered here. Since this type of game conforms with the simultaneous submission of tender offers.

In a tender setting it is uncertain if other players submitted a bid and if they did, what their offer is. Thus, information is hidden from the other players, and the game is one with asymmetrical information. Therefore, the others have to make reasonable assumptions on who the players are, what their objectives are and how the game could evolve in order to be able to make a rational decision on which move to take. (Carmichael, 2005)

The analysis of games is built on the assumption that the players behave rational. They pursue expected profit maximisation. Hence, they will opt for the strategy that assures the highest possible pay-off. And they are aware that the other players will act similarly (Carmichael, 2005). The players will only settle for mutually consistent strategies. This is the case when none of the players could improve their pay-off by switching to another strategy. Then, there is no incentive to unilaterally change the strategy and an equilibrium arises. Dominant-strategy, iterated-dominance strategy and a Nash equilibrium are the main equilibrium concepts used to analyse simultaneous move games (Carmichael, 2005).

A dominant strategy is a single strategy that responds best to all possible opponents' strategies. In a situation where all players have a dominant strategy, an equilibrium occurs. All players will play their dominant strategy and have no incentive to alter their

strategy. As long as all players behave rationally, as assumed, and the game is properly modelled, the way it will be played can be very well predicted (Carmichael, 2005).

Unfortunately, a dominant strategy equilibrium rarely occurs in practice. An iterated-dominance strategy equilibrium is more likely. This occurs when a player with a dominant strategy and a player with either a strong or a weak dominant strategy are in a game. A strong dominant strategy is a strategy where the pay-offs of playing this strategy are higher than any other strategy that could be played, in response to a move of other players. A weak dominant strategy is a strategy in which the pay-offs of playing this strategy are at least as high as an alternative strategy that could be played and in which they pay-offs are higher than at least one alternative strategy in response to the other player's move.

The iterated-dominance equilibrium can be summarized as an equilibrium found by deleting strongly or weakly dominated strategies until only one pair of strategies remains (Carmichael, 2005, p. 30) It is a combination of strategies. It occurs in the following situations;

For one player, their equilibrium strategy is one which;

- is as good any other strategy and better than some alternatives in response to all the non-dominated strategies of the other player, and
- is the best response to the equilibrium strategy of the other player.

For the other player, the equilibrium strategy is;

- the best response to the equilibrium strategy of the first player.

The Nash equilibrium

A Nash equilibrium can occur if all the players adjust their strategy to best respond to the strategies of the others. A situation occurs where all the players opt to play a strategy that differs from their equilibrium strategy. But, a player's Nash equilibrium strategy is not necessarily the best response to a particular opponent's strategy (Carmichael, 2005; Hermans & Cunningham, 2018). In fact, there is always at least one equilibrium to a game. Recall that the players in the dominant strategy equilibrium and the iterated-dominance equilibrium also incorporate opponents' responses, since these strategies are by definition the best responses. Hence, these equilibriums are also Nash equilibriums (Carmichael, 2005; Hermans & Cunningham, 2018).

Predicting the game (Backwards induction)

An equilibrium is in fact a prediction of what the probable outcome of a game will be. The Nash equilibrium is found by contemplating what the other player will do, given that they always select a strategy with the highest pay-off. In order to predict which strategy one would select, it is helpful to consider the dominance of possible strategies. A strategy dominates another strategy if its payoffs are equal or higher. Since players are assumed to behave rationally, they will one select dominant strategies. Hence, an equilibrium outcome can be induced by elimination of all inferior strategies until the dominant strategies remain (Hermans & Cunningham, 2018).

2.3 Mark-up model framework

Three main mark-up models have been identified and studied; statistical, multi-criteria and game theory based models. Each type has its own theoretic foundation, philosophy and inherent properties. This section compares the models' characteristics, resulting in a mark-up framework used in the analysis of the data.

Statistical mark-up models

Statistical methods are the oldest of the three. The issue of setting a optimum mark-up is simplified considerably with these models. Statistical methods based their mark-up suggestion on historic data that describes the bidding behaviour of competitors compared to the contractor's cost estimate. This implies that for each tender, both in the past and present, the competitors are known. Although the market is small, with only eight capable Dutch contractors, competitor's behaviour is not completely clear. Often, the results of a tender are not published. Also, contractors keep the reasoning behind a certain bid to themselves. Another factor is that contractors partner up and form consortia. This makes a wealth of competitor combinations possible. In addition, contractors from other European countries can enter into the tender as well. Besides, the same competitors must have tendered in a sufficient number of tenders to be able to accurately model their behaviour. This is problematic, since large infrastructure tenders are not common. To illustrate, only three design and contract infrastructure projects exceeding €100 and one exceeding €500 were scheduled to start in 2020 (Rijkswaterstaat, 2019).

The models also presume bidders to be rational bidders. This entails that all bidders pursue profit maximisation, thus optimize the product of the mark-up and the corresponding probability of winning. Moreover, these models assume that competitors will bid as they have done in the past. However, as Friedman himself recognizes, contractors could pursue different objectives, to minimize expected losses for example. Finally, statistical bidders presume that the tender is awarded based on lowest price, whereas most large integrated infrastructure tenders in the Netherlands are awarded not just based on price, but also to some degree based on quality. The aforementioned issues make statistical mark-up models a self-defeating prophecy.

Multi-criteria mark-up models

As the name implies, multi-criteria models can deal with a variety of input variables. The input variables can consist of internally oriented inputs, like the current workload as well as externally oriented inputs, such as the number of competitors for example. Each input variable can be either numerical or a more ambiguous input, like rankings on a five point Likert scale. Although some studies have been performed into factors that contractors consider, there is not yet an undisputed list of variables to include to model tendering for large Dutch integrated infrastructure projects. In addition, it is unclear which method can best be used to transform the input variables into a useable mark-up suggestion output. There are various techniques proposed to transform the inputs. In general, different weights are attributed to the variable inputs to suggest a mark-up percentage. Although other outputs are possible as well, such as the extent the tender project is favoured. A multi-criteria mark-up model provides an overview of the strengths and weaknesses of the tender. This provides additional information to decision makers. In general, multi-criteria mark-up models excel in their ability to consider a wide range of variables and adjustment options. However, this also makes them difficult to implement. Since, a contractor must define which variables to include, the relative importance of each variable, scores for each variable for each tender and a method to generate the output.

Game theoretic mark-up models

Game theory is a technique that maps likely outcomes in situations with interdependence between the parties concerned. It can be used to get a notion of how a situation may unfold. The contractor's best course of action is based on the modelled behaviour of competitors. All tenderers are assumed to be rational, they pursue the course of action that results in the highest possible pay-off. To model a tender the participating competitors must be known and incorporated in the model. Their options and the corresponding pay-off or relative preference of each particular outcome must be entered. A game theoretic model produces insight in achievable and likely outcomes, which results in an optimum course of action.

	Statistical	Multi-criteria	Game theory
Focus	External, based on internal cost estimate	Both internal and external	External
Preconditions	Closed bidding, awarding based on lowest price Rational bidders pursuing profit maximisation Static bidding behaviour of competitors	Clearly defined tender proposal, criteria and weights A suitable method to transform scores into mark-up suggestion, i.e. neural networks, fuzzy sets, etc.	Rational behaving contractors Interdependence of contractors' strategies Clear and enforceable rules
Input	Own cost estimate Bidding behaviour of competitors over sufficient past projects Competing companies known	Relative importance of criteria (weights) Quantitative or qualitative evaluation of proposal per criterion	Likely competitors, their options both in terms of solution and pricing strategy For each strategy an estimate outcome or relative preference
Output	Probability of winning Mark-up suggestion	Overview of strengths/weaknesses vis-à-vis criteria Mark-up suggestion	Insight in achievable outcomes and suggestion for course of action
Limitations	Considers monetary values only (bids in relation to own cost estimate)	Compensability of criteria	A clear recommendation is not guaranteed.

Table 3 - Overview of the characteristics of the main mark-up models

2.4 Decision-making models

Dealing with uncertainty

When deciding on the final bid amount, decision makers are confronted with limited time and information and large uncertainties. Before we explore the theory behind decision-making, we address the concept uncertainty. It is essential to make a distinction between uncertainty and risk, since the methods of dealing with them differ. Risk is 'a measureable probability' (Knight, 1921, p. 41), whereas 'uncertainty cannot be measured' (Knight, 1921, p. 41). Uncertain events or their potential outcomes are to a lesser extent understood generally (Knight, 1921).

There are three fundamental ways of dealing with uncertainty (Slovic, Finucane, Petere, & MacGregor, 2004, p. 311). Please note that although Slovic et al. describe ways of dealing with risk, they actually refer to dealing with uncertainty if the definition of uncertainty of Knight is followed as mentioned in the previous paragraph.

Uncertainty as feelings

The first way is as feelings (Slovic et al., 2004, p. 311). This refers to an instinctive reaction, fast and intuitive. Evaluation of uncertainty is predominately done with our instinctive, visceral feelings. Besides visceral feelings, such as fear, affect plays a role. Affect is an intuitive response, which automatically associates a feeling state of either good or bad to the emotion. Relying on visceral emotions and affect is often a quicker and more effective way to deal with complex and uncertain situations than a systematic analysis (Slovic et al., 2004).

Affect plays a key role in dual-process theories of how we think, obtain knowledge and process information (Slovic et al., 2004). The binary aspect in these theories comes from the assertion that we utilize two fundamental ways of thinking (Epstein, 1994, p. 710; D Kahneman, 2011). The first is known as an experiential system and the second is an analytical system. The experiential system is assumed to be strongly associated with experienced affect (Epstein, 1994). In emotional significant situations, the experiential system automatically searches its memory pool for related events and the corresponding emotions. If the recalled affect is positive, people are motivated to think and act similarly as in the recalled event. If on the other hand the recalled affect is negative, people are motivated to avoid a similar experience.

Uncertainty analysed

The second way of dealing with uncertainty is in an analytical way. With a slower, more cautious, effortful and explicit approach of logic reasoning (Frankish, 2010, p. 915; Slovic et al., 2004, p. 311). This is associated with serial, rule-governed information processing (Frankish, 2010) and resonates with the second fundamental way of thinking (Epstein, 1994, p. 710). The analytical processes serve to process en reflect upon the relevant knowledge and beliefs produced by the first fundamental system of thinking in order to derive inferences or judgements (Epstein, 1994; Johathan Evans, 1989, 2006).

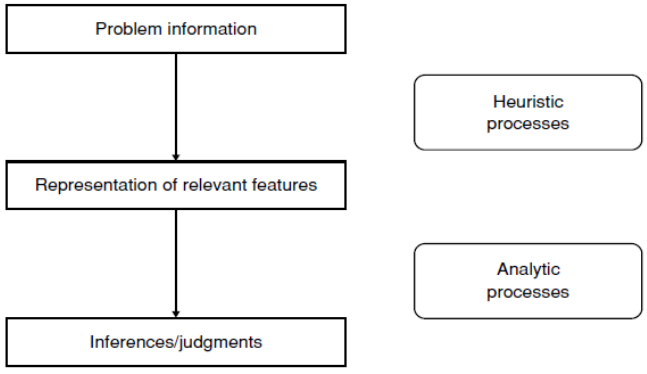


Figure 15 – Representation of the heuristic-analytic theory by Evans (1989).

Experiential System	Analytic System
1. Holistic	1. Analytic
2. Affective: pleasure-pain oriented	2. Logical: reason oriented (what is sensible)
3. Associationistic connections	3. Logical connections
4. Behavior mediated by "vibes" from past experiences	4. Behavior mediated by conscious appraisal of events
5. Encodes reality in concrete images, metaphors, and narratives	5. Encodes reality in abstract symbols, words, and numbers
6. More rapid processing: oriented toward immediate action	6. Slower processing: oriented toward delayed action
7. Self-evidently valid: "experiencing is believing"	7. Requires justification via logic and evidence

Figure 16 – Comparison of the two fundamental ways of thinking; the experiential and analytic system, derived from Epstein (1994).

The analytical system participates whenever hypothetical thinking takes place (J Evans, Over, & Handley, 2003). Hypothetical thinking entails imagining possibilities beyond the received factual knowledge. Three principles of hypothetical thinking are established;

1. The singularity principle;
   People consider a single hypothetical possibility, or mental model, at one time,
2. The relevance principle;
   People consider the model which is most relevant (generally the most plausible or probable) in the current context,
3. The satisficing principle;
   Models are evaluated with reference to the current goals and accepted if satisfactory.

Uncertainty as politics

The third way of dealing with uncertainty is political and arises when the feelings produced by our instinct regarding uncertainty do not match with rational analyses (Slovic et al., 2004, p. 311). This typically occurs in networks, in which interdependent actors have different interests. In such situations, actors can exploit the mismatch between rational analysis and feelings in order to achieve their own objectives. This is known as strategic behaviour (Bruijn, Bruijn, & Heuvelhof, 2008).

Decision making process

Decision making is 'the processes commonly portrayed as occurring early in the "problem solving processes" - the sensing, exploration, and definition of problems or opportunities- as well as the generation, evaluation, and selection of solutions' (Huber, 1980, p. 576). This process of choosing a course of action for dealing with a problem or opportunity consists of five basic steps (Hitt, Black, & Porter, 2012);

1. Recognizing a problem or opportunity and defining it,
2. Identifying and analysing courses of action,
3. Selecting a preferred course of action,
4. Implementing the selected course of action,
5. Evaluating the results and undertaking of corrective action as necessary.

This means that decision-making involves two aspects: the act and the process. In the context of determining the bid amount; the process involves identifying a suitable tender, analysing the tender documents and determining bid amounts, the act corresponds with choosing the bid amount out of the set of alternative amounts.

Decision making models

Determining the bid amount is a challenging task, with risks and uncertainty increasing the complexity of decision making (Miller & Lessard, 2000, p. 76). Decision-making models are designed to guide decision makers through the process. Three primary types of decision models exist; descriptive models, prescriptive models and ideal types. Descriptive models are aimed at describing and explaining the decision-making setting, so that it can be understood. The prescriptive models describe how the decision-making situation ought to unfold. While the ideal types are about hypothetical decision making situations 'with entities that exist nowhere in real life but which can help us to understand and explain real phenomena and to formulate or refine statements of what is desired' (Hogwood and Gunn, 1994, p. 43). In other words, they are specific forms encountered in the descriptive models.

Four prescriptive decision-making concepts are introduced in this chapter; the classic model of rational decision-making, the bounded rationality or the administrative model, and the retrospective decision-making model and decision making as an organizational routine. Some more peculiar conceptualisations of decision-making are accommodated in appendix A.

2.4.1 The rational model

The classical model, also known as the rational model, is the oldest model. This model is more detailed than the five basic steps process described on the previous page. Seven steps are used to describe the decision making process (Abotaleb & El-adaway, 2017; Hitt et al., 2012).

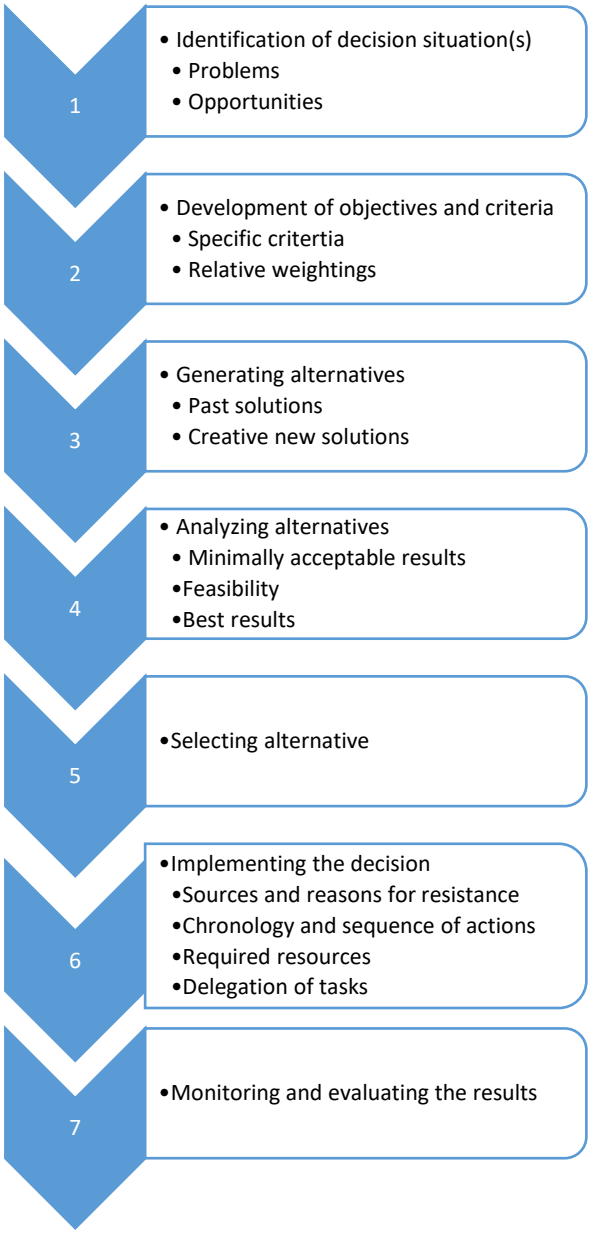


Figure 17 - Classical decision making model by Hitt, Black & Porter (2012)

The decision-making starts with recognising that a problem (or opportunity) exists. A problem is defined as a gap between existing and desired performance. On the other hand, an opportunity arises when chance is detected to achieve a more desirable state compared to the current one.

Then, criteria need to be determined to be able to select an alternative later on. Usually, multiple criteria are used, often weighted. The next step is to generate alternatives that achieve the desired result.

If the current problem is similar to a problem encountered in the past, past solutions can be effective. But, new problems demand creative new solutions.

Then, the generated alternatives are analysed. First, the alternatives that yield minimally acceptable results are selected. Next, the feasibility of the selected alternatives is assessed. Finally, the most favourable result of the feasible alternatives is determined.

After the analysis, a solution can be selected from the feasible alternatives. The classical model assumes that decision makers will opt for the alternative that maximizes the desired outcome.

Within the classical model, effective implementation has four components. First, sources and reasons for resistance to the selected solution are assessed. Secondly, a plan is made which states the sequence of actions designed to overcome potential resistance. Thirdly, assessing the resources required to execute the plan and ensure effective implementation of the solution.
The final step is the monitoring and evaluation the achieved results.

Assumptions of the classical rational model

The classical model by (Hitt et al., 2012) has some underlying assumptions, which should be kept in mind when this model is considered;

- The problem or opportunity is clear to the decision makers,
- The firm's objectives are clear to the decision makers,
- Decision makers agree on the criteria and weights used to make the decision,

- All alternative courses of action are known to the decision makers,
- All consequences of courses of action can be anticipated (and compared) by the decision makers,
- The decision makers are making decisions based upon rational principles;
    - They are not biased,
    - They process all relevant information,
    - They examine all the immediate and future consequences of the decision,
    - They search for the alternatives that maximize the results they desire.

A substantial body of research has shown that in the process of decision making people are often not as rational as assumed in the classical model. An obvious point of criticism is that it is practically impossible to obtain full information. The time and resources are simply not available. In addition, the ability of individuals to make truly rational decisions is reduced by personal factors such as;

- Information bias; a reluctance to give or receive negative information,
- Uncertainty absorption; a tendency for information to lose its certainty as it is passed along
- Selective perception; a tendency to ignore or avoid certain information, especially ambiguous information
- Stereotyping, deciding about an alternative on the basis of characteristics ascribed by others,
- Cognitive complexity; limits on the amount of information people can process at one time,
- Stress reduction of people's ability to cope with informational demands
- In addition more mundane aspects such as the unavailability or impossibility of obtaining the proper information in order to make a rational decision.

To sum up, the rational model is useful as a descriptive model, but it has some shortcomings when used as a prescriptive model.

2.4.2 The bounded rationality model

An alternative model has been developed by Herbert Simon, the bounded rationality model. This model is not bounded by the assumptions stated above. Individual rationality is not assumed, but instead, it is assumed that people actually settle for much less. Because the decisions they typically face they demand more information and more time than is available. Therefore, people pursue a 'bounded' or 'limited' rationality.

The bounded rationality model describes the decision making process in terms of three mechanisms (H. A. Simon, 2013). The first mechanism concerns the alternatives; people do not generate all alternatives before one is chosen. People explore possible solutions one at a time. This is called sequential attention to alternative solutions. When an acceptable solution is found, people stop exploring other options.

The second mechanism is the use of heuristics. In the bounded rationality model it is assumed that instead of using explicit criteria and weights to score alternatives, people use heuristics. A heuristic is a rule that limits the search to areas that have a high probability for yielding success (Hitt et al., 2012, p. 337). Often, a heuristic is based on past experiences. It is argued that decisions makers use heuristics to reduce large complex problems into manageable propositions, so that decisions can be made more rapidly.

Third is the mechanism of satisficing. People tend to select a minimal acceptable solution, rather than going through the struggle of finding the best alternative. This is in contrast with the rational model. According to Simon an optimal alternative meets two criteria; there must be criteria to assess all alternatives against and the alternative must score better than the other alternatives.

The bounded rationality decision process comprises of the following steps (Hitt et al., 2012);

1. Define the problem you want to solve and/or set the goal,
2. Establish a minimum performance level,
3. Apply heuristics to narrow the alternatives to a single promising alternative,
4. If this yields an unfeasible solution, lower the aspiration level (repeat the second and third step),
5. After identifying a feasible alternative, evaluate its acceptability,
6. If the individual alternative is unacceptable, search for a different solution (repeat steps 3 to 5). If the alternative is acceptable, implement it,
7. Follow the implementation, evaluate the extent to which the goal is achieved and raise/lower the level of desired performance accordingly on future decisions.

To conclude, the approach followed in the bounded rationality models differs from the rational model in the type of solution that is desired. The rational model aims for the best solution, while the bounded model searches for an acceptable solution.

2.4.3 The retrospective decision model

A third model focusses on how decision makers attempt to rationalize their choices after they are made. This model is known as the retrospective decision model or implicit favourite model. The model shows how decision makers attempt to justify an intuitively made decision.

Soelberg (1967) hypothesized that decision makers engage in perceptual distortion, they highlight the positive features of their implicit favourites more than the positive features of the other alternatives. He noticed, however, that the implicit favourite alternative typically scores superior to the other alternatives only for one or two of the criteria. Yet, the decision makers believed they considered all factors and thus were making a rational decision.

Similarly, de Leeuw (2002) states that decision makers tend to make their decisions based on gut feelings. Deeply felt and occasionally emotionally loaded convictions, beliefs and persuasions, which greatly influence how decisions are made, compared to explicit arguments and considerations. The arguments then provide the rationalism that legitimizes the decision made based on gut feelings.

This kind of intuitive decision-making is not necessarily wrong. Some research shows that intuitive decisions are often made more quickly and the outcomes are as good or even better than decisions made with a more rational foundation (Hodgkinson & Starbuck, 2008; Loveman, 2003). Intuition is an implicit form of rationality which cannot be made more explicit, which is based on past experiences and other learning processes (de Leeuw, 2002, p. 253).

2.4.4 Entrepreneurialism

Entrepreneurialism is a normative decision making model based on the notion that 'most of the important decisions are made on a basis of observation, intuition and experience' (Scherpereel, 2006, p. 1258). This is a departure from the assumption of rational models where a decision is based on a deliberation of alternatives. Central to entrepreneurial decision models is the concept of the entrepreneur; 'a person who habitually creates and innovates to build something of recognized value around perceived opportunities' (J. L. Thompson, 2004, p. 244). Entrepreneurs differ from others due to their superior ability to recognize and exploit opportunities, combined with solid problem solving skills (Pech & Cameron, 2006). Entrepreneurs possess a very distinct cognition, they greatly rely on heuristics when processing information and their individual beliefs heavily impact their decision making (Mitchell et al., 2002; Wright, Hoskisson, Busenitz, & Dial, 2000). The cognitive behaviour of entrepreneurs is different from managerial decision making, which is more systematic, structured and coordinated (Pech & Cameron, 2006).

The entrepreneurial model of Pech & Cameron (2006, appendix B) is an extension of the general decision making framework by Wickens & Flach (1988, appendix A) to suit the decision making characteristics of the entrepreneur. Heuristics, as well as emotional and attitudinal factors are added to the general framework. The model is composed of quadrants, which together represent entrepreneurial decision-making. The top left corner of the model displays informational cues. Entrepreneurs actively search for opportunities to exploit among the received information. These cues are subsequently filtered, as is depicted in the top centre. On the right, potentialities are considered and assessed to arrive at a decision. The right-hand side of the model shows the intrinsic decision making, while emotional and attitudinal factors that influence the process are displayed in bottom left corner. The entrepreneurial model is not to be viewed as a linear process model. It describes information flows and decisional filters, which may be serial, recursive or even parallel and have feedback and feedforward loops. Although the model shows distinct, isolated clusters of decision activation patterns, in real world decision making these would integrate and overlap each other (Pech & Cameron, 2006).

This entrepreneurial way of decision-making, based on heuristics combined with characteristic emotional and attitudinal filters enables entrepreneurs to excel in dynamic and uncertain environments. It enables them to effectively evaluate and exploit opportunities despite restrictions of limited time and information (Bryant, 2007; Pech & Cameron, 2006).

However, the reliance on heuristics and emotional and attitudinal filters makes it prone to human errors and biases (Bryant, 2007). Common biases are;

Tunnelling of attention

Before the final decision is made the entrepreneur might desire additional information. Given the entrepreneur's enthusiasm for an identified opportunity, the quest for information may result in an even larger desire for additional information. As a result of the entrepreneur's focus on one aspect, other aspects could be overlooked or even neglected. This cognitive aspect is known as tunnelling of attention (Pech & Cameron, 2006). Hence, an entrepreneur is not able to capture and process all the relevant information in their decision-making, which bounds their rationality (Bryant, 2007, p. 735).

Heuristic biases

Entrepreneurs rely heavily on heuristics in their decision-making. But if the entrepreneur has had high levels of success and effectiveness from past decisions, a bias arises to utilize opportunity seeking decision rules to determine the profit potential, probability of success, risk and resource requirements of an opportunity (Pech & Cameron, 2006, p. 13). Estimating frequencies of occurrence or probabilities of an event based on heuristics can be flawed (Tversky & Kahneman, 1974). The availability heuristic is used when probabilities are estimated based on recalling the number of occurrences in a length of time. However, relying on availability is prone to leading to biases. The first issue is that there is a difference in the ease with which events are recalled, for example due to their salience or frequency. The ease with which an event can be recalled in relation to context in which someone searches for the observed occurrence also plays a role. For some events there are no observations stored in memory, instead the number is constructed by generating several events and subsequently estimating the frequency. This is problematic because the ease with which events are constructed does not accord with the natural frequency of occurrence (Tversky & Kahneman, 1974).

Deliberate manipulation

Not all faults in entrepreneurial decision making originate from internal factors, like biases. There are also external factors, which degrade the quality of the decision-making. These are deliberate intentions to manipulate an entrepreneur's decision-making, like advertising and marketing (Slovic et al., 2004).

2.4.5 Routines

Routines are a useful concept when one aims to understand an organisation. They are particularly useful for analysing how an organisation functions, understanding how knowledge is retained and transferred through the organisation and developing organisational policies and strategies (G. M. Hodgson, 2008). In the context of this thesis organisational routines are used to study decision making at large infrastructure contractors in the Netherlands. To get a grasp of organisational routines, the concept of habit is presented first, because routines are the organizational equivalent of individual habits (G. M. Hodgson, 2008).

A habit differs from behaviour. A habit is an acquired proclivity or capacity, which may or may not be expressed in current behaviour (G. Hodgson, 2004). Put differently, habits are submerged repertoires of potential behaviour; they can be triggered or reinforced by an appropriate stimulus or context (G. M. Hodgson, 2008, p. 16). Thus, a habit is an acquired tendency to a mode of response in a particular situation. While habits are triggered by context, a routine is triggered by an individual habit (G. M. Hodgson, 2008).

Emotions, habits and our rationalizations thereof interact (G. M. Hodgson, 2008). Habits are the foundation of our deliberations. Our beliefs and reasoning are often the rationalization of emotions and deeply rooted feelings, which originate from the habits captured in our repetitive behaviour. Custom has normative power, due to this interaction of emotions, habits and rationalizations. The normative power of habits plays a fundamental part in people's tendency to abide by the rules.

There are two mechanisms by which habits can be transferred between persons. Firstly, by incentive or constraint. When others are acting in a particular way, there often is a powerful incentive to behave similarly. This applies to abiding by customs and rules, when it is mutual beneficial if everybody complies. Under these circumstances habits are acquired and associated with these behaviours. Hence, with reproducing behaviour habits are reproduced too. The second mechanism by which habits are transferred is by imitation. People have a natural tendency to imitate observed behaviour. This is an unconscious and instinctive method of tacit learning resulting from evolution and natural selection. For imitation to take place, a common behaviour must prevail, which subsequently can be copied. However, an understanding of the underlying rules is required to successfully transfer habits (G. M. Hodgson, 2008).

Routines play a similar role in an organisation as a habit to the individual. Whereas habits relate to individuals, routines are related to organisations (Cohen et al., 1996; Dosi et al., 2000). However, routines are not just the common habits shared among the organisation. Routines are meta-habits as it were. An important aspect of habits is that acquiring both knowledge and skills is the result of gathering related habits (G. M. Hodgson, 2008). Subsequently, the acquired knowledge and skills provide the decision maker with the opportunity to comprehend a complex problem and to rapidly identify a way to tackle it. Here, it is important that experience and intuition are embedded in the acquired patterns of thought and behaviour, to enable the decision maker to identify crucial aspects of the problem and solution methods.

Routines are the organisational equivalent of habits. Whereas habits relate to individuals, routines relate to organisations (Cohen et al., 1996; Dosi et al., 2000). As mentioned, habits are submerged repertoires of potential behaviour; they can be triggered or reinforced by an appropriate stimulus or context (G. M. Hodgson, 2008, p. 16). Similarly, 'a routine is an executable capability for repeated performance in some context that has been learned by an organization in response to selective pressures' (Cohen et al., 1996, p. 683). Levitt & March (1988, p. 320) add that this includes 'the forms, rules, procedures, conventions, strategies, and technologies around which organizations are constructed and through which they operate.'

However, routines are not just the shared habits within an organization. They are conceptualised as 'an ontological layer above' the individual habits in the organisation, which consists of 'organizational meta-habits, existing on a substrate of habituated individuals in a social structure' (G. M. Hodgson, 2008, p. 18). Thus, organisational routines should not be mistaken for organisational behaviours. Instead, routines are conditional, rule-like organisational dispositions; the stored behavioural capacities or capabilities of an organisation (G. M. Hodgson, 2008, p. 19).

To improve comprehension of the functioning of routines, next, attention is given to how knowledge is retained within routines, how learning takes place and how routines are transferred. It is convenient to use a distinction between modes of memory (Cohen & Bacdayan, 1994). Specifically, between procedural memory on the one hand and more cognitive memory forms like semantic, episodic or declarative memory on the other. Behaviour is stored in the procedural memory, whereas cognition or thought relates to semantic and episodic memory (Cohen & Bacdayan, 1994).

The cognitive memories can be utilized to capture items or events and relations among them in order to model the external world. This is not possible with procedural memory (Tulving & Schacter, 1990). Each individual within an organisation brings with them their own particular habits. An individual's habit is triggered or reinforced by a contextual cue, as mentioned in the previous section. In a group setting, the behaviour of other group members can act as a cue to trigger certain individual habits. Within an organization, individual habits are sustained by a structure of interlocking individual behaviours. The interrelated structure of behaviours and habits as a whole, provides groups, teams or departments with collective qualities (G. M. Hodgson, 2008).

Procedural memory contributes to an organisation's ability to retain properties and capabilities that exceed the individuals that make up the group (G. M. Hodgson, 2008). An organisation functions as both the physical and social environment needed, so that subsequently individual habits and memories can be triggered (G. M. Hodgson, 2008). If an employee leaves and another joins the organisation, they again learn the habits required to maintain the organisational routines of the organisation. Thus, routines are retained within the organisation by the interrelated structure of individual behaviours present.

The leading instrument of routines to replicate is an ongoing transfer of employees between organisations, which enables the transferral of knowledge and skills. This process is further enhanced by the involvement of consultants and experts, which stimulate the transferral between different contexts. For routines to be transferred successfully, it is crucial that practices and organisational relationships are replicated at the new organisation. The decisive aspect in this regard is the new organisation's ability to integrate the received knowledge and practices in their existing company culture.

Organisational routines appear to be different depending on the perspective of the observer. From afar a routine appears to have durability and stability (Aldrich, 1999). Closer observation shows that routines endogenously and continuously change (Feldman & Pentland, 2003). This is why some consider organisational routines as generative, dynamic systems (Cohen et al., 1996; Dosi et al., 2000; G. M. Hodgson, 2008).

2.5 Decision model framework

Three decision models are included in a framework, used to analyse the decision-making process to determine the bid amount for large infrastructures at Dutch contractors. These selected models are the bounded rationality model, entrepreneurialism and organisational routines. Below, they are summarized while highlighting their distinctive features. These models are selected because of their distinctiveness and clarity of their indicators in relation to the acquired data.

Bounded rationality decision making

This decision model is selected because it conforms to what theory presumes that contractors do in the tender phase of the literature study. This is described in the acquisition process from an EPC contractor's viewpoint section of the literature study.

There are three key characteristics of the bounded rationality decision model. First, it departs form the fully rational model, where decision makers ought to have complete information. In reality, decision makers do not have complete information nor do they conceive all alternatives first and assess them later. Decision makers assess alternatives sequentially. Second, decision makers rely on heuristics over predetermined criteria to assess alternatives. This is done to reduce the complexity into manageable propositions, which results in faster decision-making. Third, decision makers do not accept the optimum solution only. Instead, people settle for a sufficient solution, once identified.

The bounded rationality decision-making process (Hitt et al., 2012);

1. Define the problem you want to solve and/or set the goal,
2. Establish a minimum performance level,
3. Apply heuristics to narrow the alternatives to a single promising alternative,
4. If this yields an unfeasible solution, lower the aspiration level,
5. After identifying a feasible alternative, evaluate its acceptability,
6. If the individual alternative is unacceptable, search for a different solution (repeat steps 3 to 5). If the alternative is acceptable, implement it,
7. Evaluate to what extent goals are met and raise or lower the level of desired performance accordingly in future decisions.

Entrepreneurialism

Some authors have claimed that mark-up decisions are made based on a mixture of gut feelings, guesses and past experiences (Ahmad, 1990). Entrepreneurialism is a decision model that is in line with this perspective, since it acknowledges that 'most of the important decisions are made on a basis of observation, intuition and experience' (Scherpereel, 2006, p. 1258). Hence, it is included in the framework.

Entrepreneurialism differs from systematic, structured and coordinated decision-making models, such as the rational and bounded rationality models. Instead, it is a model in which decision makers rely greatly on heuristics and their individual beliefs (Mitchell et al., 2002; Wright et al., 2000). In entrepreneurial decision-making, heuristics are combined with individual emotional and attitudinal filters. This enables entrepreneurial decision makers to effectively evaluate and exploit opportunities despite restrictions of limited time and information (Bryant, 2007).

Routines

One can reasonably expect large contractors with the capabilities to design and construct large infrastructure projects to have implemented standardized procedures and to have structured their mark-up determination. Hence, organisational routines are included in the framework. With organizational routines, the decision-making is less of a deliberate decision. Decision-making comes about, almost naturally it seems, through the independent operation of various departments and subdivisions.

Routines can be viewed as patterns of interactions that occur without a deliberate prior decision. The day-to-day operation of an organisation is 'run' by routines. Relying on routines enables common situations to be handled without a deliberate analysis and selection of the best course of action every time they are encountered. Instead, standard operating practice and behavioural patterns are present to deal with the normal operation of the firm, enabling effective operation of the organisation. This almost autonomous functioning of an organisation makes decision moments and decision makers hard to identify.

Model	Bounded rationality	Entrepreneurialism	Routines
Philosophy	Selection of favourable solution among alternatives	Decisions are made on a basis of observation, intuition and experience	Decision making more as output of processes at independently operating subdivision
Identifier	Structured approach	Greatly relying on heuristics	Less of a deliberate decision, hard to identify decision moment and decision maker
	Satisficing; selecting a minimal acceptable solution	Individual believes heavily impact decision making	Independently operating subdivisions
	Alternatives generated until an acceptable solution is conceived	Emotional and attitudinal filters	Decision makers pursue interest of organisation but favour actions that enhance their own role and power position
	Criteria and weights not necessarily explicit, then heuristics used	Process not linear, may be serial, recursive or parallel	Relying on cost-benefit analysis (in political organisation)
			Not in temporary organisation, processes relatively stable over time

Table 4 – Overview of the characteristics of the decision models included in the thesis framework.

3 Methodology

This methodology chapter gives account of the systematics of the thesis. A description is provided of the research approach and the choices made to ensure that the results of the thesis meet the requirements of scientific research.

Research objective

The objective of this thesis is to recommend a method to support contractors in setting their bid amount for large Dutch integrated infrastructure tenders. This is achieved by comparing the applicability of existing price determination methods to the Dutch infrastructure procurement environment. To this end, important aspects are; the procurement procedures used to put large infrastructure tenders to the market, methods that could support the final bid amount decision and finally Dutch contractors' current practice of price determination. Of particular interest is the degree of congruity of currently available bid amount methods and the processes that contractors have in place already.

Research design

Now the choices of the research design are elucidated. First, the type of research is discussed. Followed by a description of the steps in the research approach. Third, the investigated data is covered. The population, sampling and the characteristics of the selection are discussed thereafter. Then, the data collection by means of interviews is covered in detail, including procedures of data collection and processing. Finally, the way the data is analysed is presented.

Research type

The research objective of recommending a method to support contractors in setting their bid amount for large Dutch integrated infrastructure tenders and the knowledge that it is still unknown to what extent competitive bidding models are congruent with the Dutch procurement procedures, point to an empirical study. In particular, to a method to obtain in-depth insight and understanding of the phenomenon of Dutch EPC contractors' tendering processes. The tendering environment of large Dutch infrastructure projects is complex due to variations in clients' procurement procedures, participating tenderers and market environment. The general methodological approach of this thesis is qualitative. This fits the nature of the research problem, since this thesis is interested in decision-making and the reasoning behind it.

Conducting a quantitative study was less feasible. In the first place because it was unclear which data to collect. The literature study concerning the available branches of mark-up models yielded that it is still unclear which type of quantitative mark-up is most suitable to apply in the Dutch tendering environment of large infrastructure projects. In addition, it remains unclear for which variables data is required. In the past, studies in the UK and USA have identified variables that correlate to the tender decision and the subsequent mark-up decision. Yet, such studies are not conducted in the Dutch tendering environment, let alone recently. In the second place, due to the limited data available. Exploratory meetings with a large consultancy firm and a large contractor revealed that there is little historic data gathered among contractors to base a quantitative analysis on. Moreover, the information that is available among contractors is severely restricted due to their economic sensitive nature.

Two types of research are used in this thesis; desk research and interviews. Desk research is applied by means of exploring existing literature regarding decision models and bidding models that may support the decision makers in their bid amount decision. This creates a theoretic framework that is subsequently used in a grounded theory approach. In this approach, the field under observation is confronted with the theoretic framework to '*specify, define and ground these concepts and to formulate a substantive social theory*' (Peters & Wester, 2004, p. 1). More specifically, the characteristics of the Dutch tendering environment are explored with semi-structured interviews. The findings of a study of the bid amount decision making in practice are then compared with theoretical premises, to formulate a theory that, despite of its abstraction, is easily recognized by decision makers (Verschuren & Doorewaard, 2010). How these approaches are applied in this thesis is described in the subsequent section in which each research phase is discussed in detail.

Research phases

This section discusses the qualitative strategy that is followed to conduct the research and to answer the research questions. First, in chapter 2, the context of tendering for large infrastructure projects in the Netherlands was explored. This entails procurement procedures and specific information of how the main client of Dutch infrastructure, Rijkswaterstaat, has arranged its procurement processes. Secondly, a desk study is executed into three models that could support decision makers in determining an optimum bid amount. The characteristics and limitations of each type are highlighted in a theoretical framework (see 2.3). In addition, decision models are studied to compare the characteristics of decision making in practice to the theoretical bidding support models (see 2.5). Thirdly, semi structured interviews are held with key personnel at Dutch infrastructure contractors to uncover how the bid amount is established in practice. Fourthly, the data obtained by the semi-structured interviews is analysed and reflected vis-à-vis the theoretical decision model framework to determine the suitability of the bid amount decision support models.

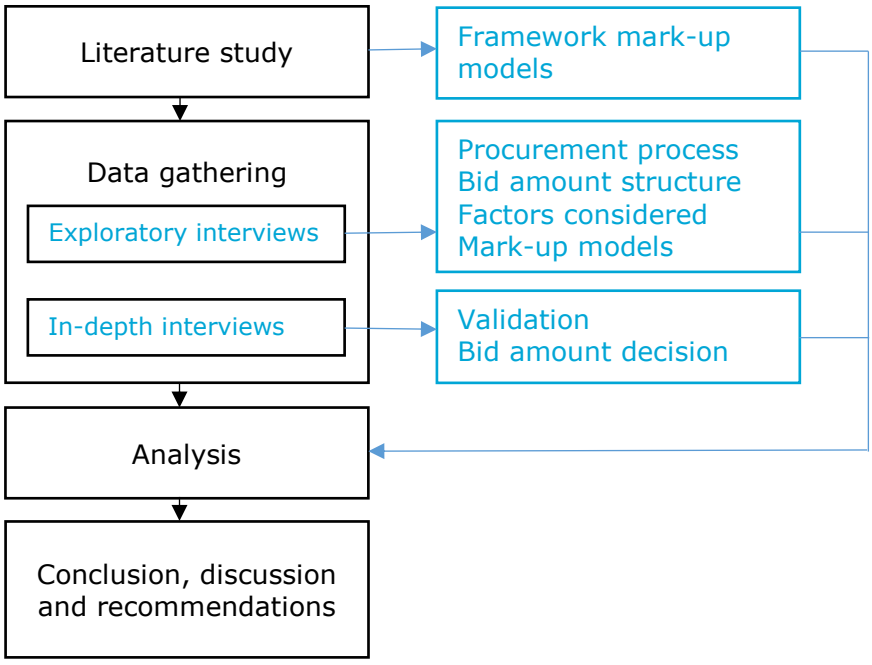


Figure 18 – process diagram of the thesis methodology.

Desk research
Desk research regarding mark-up decision support models is conducted to obtain a picture of the state-of-the-art. Three main streams of mark-up models were identified and studied; statistical, multi-criteria and game theory models. In addition, decision models are studied to compose a framework by which the studied models could be compared to the practice of decision making in the field. At first, basic decision making concepts are investigated; the classical model of rational decision-making, the bounded rationality model, the retrospective decision model and entrepreneurialism. Alternative models are studied too; political decision making, the garbage can model, routines, incrementalism, dual systems and the black stool view on decision-making. For both literature studies, articles and books were selected from the TU Delft library, Scopus, JSTOR and SpringerLink databases. Besides a specific literature search with keywords such as 'mark-up, construction, procurement and decision model', referenced articles, suggestions from Elsevier for relate articles, as well as additional literature recommended by the thesis supervisors was studied. Articles were selected upon the journals they were published in, the number of times they were referenced, the reputation of the author and their fit to this study.

Interviews
The research population consists of Dutch contractors active in large-scale multidisciplinary infrastructure projects. A limited number of contractors have the capability to undertake such projects. These contractors are;BAM, Ballast Nedam, Dura Vermeer, Heijmans, Strukton, TBI, VanGelder and VolkerWessels. These contractors were contacted by phone and in some cases by email to participate in the study. Thereby was aimed to invite experienced and knowledgeable personnel at key positions to be interviewed. One of the aforementioned contractors is excluded since previous experience on that company might result in a biased view. Another contractor was excluded, since the researcher was unable to get in contact with any of the company's decision makers.

Interviews are conducted with six contractors from the population. The selection represents a cross section of the market. Ranging from the largest in the Netherlands to the smallest of the large contractors, from privately owned contractors to companies listed on stock market. The selected contractors are geographically dispersed. In addition, each one has a different specialisation, among them road construction, concrete structures, railways and building in an urban environment, for example.

A total of seven interviews are conducted with six key decision makers. Five interviews focussed on the decision making process and factors considered in it. Two specifically focussed on the information streams, the decision maker's role and to validate the previously gathered data. Top-level personnel with positions such as head of acquisition, managing director and member of the executive board, were questioned about the bid amount decision. Data is collected and analysed by the author.

Data collection
Semi-structured interviews were conducted in Dutch, face-to-face at the company's offices. Though, due to COVID-19, one interview took place online. The interviews took about an hour, with the exception of one, where there were just 45 minutes available. The interview protocols used can be found in Appendices D – F. After an introduction, the interviews started with a brief explanation of the thesis subject and the position of the interview, followed by a description of how the interview would unfold. The respondents were told that their responses could be quoted and in abstracted form used in the thesis report. Next, approval was requested to record the interview for transcription later on. In case a quote would contain information which made it possible to uncover the respondent or their organisation, explicit approval is requested to display the quote. After approval, the interview commenced.

The respondents were asked a series of open questions covering three themes; the bid amount determination process, the factors considered when taking the decision and the use of bidding support models. The respondent was given freedom to drift off topic to emphasize what they thought was worthwhile to mention. Sub questions and cues where used to keep the conversation on topic if needed, while keeping the conversation going and to enable conformity between the interviews so that responses could be compared. At the end a talk sheet was used to introduce the three types of bidding support models; statistical, multi-criteria and game based models. Respondents were asked to assess the applicability of each of the models into the decision-making present at their organisation.

The second round of interviews elapsed slightly differently. The respondents were presented with a picture of a tendering process based on the previous interviews for validation. Then, the decision of the final offer was studied in detail. The questions focussed on the relationship between the preceding processes and the final decision, information that the decision makers assess when determining the bid amount and how a consortium influences decision making. Again, sub questions where used to guide the conversation. Reponses were scanned for similarities to the theoretic framework on the fly. The interviews are recorded with a dictaphone and verbatim transcribed in Dutch. After transcription, the recording was deleted as was agreed with the respondents. The data to be included in the report were subsequently translated into English.

The internal validity is ensured by source triangulation. Data is obtained from and compared to several experts at different levels and at different companies. Combined, the respondents represent the majority of the population of construction companies.

Analysis process

First, the collected data is transcribed into a readable and manageable text. Secondly, individual transcribed interviews are structured and compared to the others. Some main topics were identified; the contractor's bid amount determination process, the factors considered when taking the decision, the bid amount decision itself and bidding support models. Per subject, the data was studied and interpreted, clustered and processed into a story line. The storyline describing the observed bid amount practice is complemented with relevant quotes so that it is anchored in the data and the variance among the studied population is displayed.

There are two types of qualitative data analysis (Coffey & Atkinson, 1996). There is a procedural form of qualitative analysis with emphasis on coding and categorizing data. In addition, there is a more creative form with emphases on interpretation of the data and exploring relationships. In this thesis, a combination of both versions is used. The procedural form is used, as part of deductive analysis based on the theoretical framework. Theory and a priori knowledge are combined with the data of the topics covered by the respondents. Subsequently, the data is further clustered, interpreted and summarized. The creative form is used as well, particular on sensitizing data bits that were not directly related to a code. Here, the interesting sections were gathered, grouped and integrated into the existing data description where relevant. Hereby the focus was mostly on interesting similarities and differences in approaches or viewpoints. For coding, the concepts from the theoretic framework were used. Atlas.TI software was used to assign codes to particular excerpts from the interviews.

Prior to the interviews, the interview protocols were checked by the thesis supervisors. Although it was not feasible to perform the coding of the data several times or with different people, efforts were made throughout the reporting to present the results and subsequent interpretation in a traceable manner and therefore resulting in a reproducible product. Moreover, source and method triangulation with procedural and creative forms of qualitative analysis were applied to confirm findings and display the degree of variation in the population.

4 Data

Decision makers at Dutch construction companies active in large-scale multidisciplinary infrastructure projects with integrated design, construction and maintenance are interviewed to gain an understanding of the Dutch procurement practice of such projects.

Characteristics of sample population

Interviews are conducted with six Dutch contractors active in large-scale infrastructure projects with design and construction integration. Contractor A is listed on the stock market and active in and beyond Europe. They operate in the construction of infrastructure and real estate. Contractor B is a nationally operating, privately owned contractor, active in infrastructure and real estate. Contractor C is a listed contractor, active worldwide in infrastructure and utilitarian construction. Contractor D is a privately owned contractor active in infrastructure, real estate and installations. Contractor E is a listed contractor, active in real estate and infrastructure construction as well as installations. Contractor F is a privately owned contractor, active in national infrastructure.

Among the interviewees, there is one head of acquisition. He has a lot of experience in cost estimation and the tendering activities of a contractor. In addition, he was involved in setting up a planning and control department to take on large integrated projects. Currently, he is responsible for the acquisition of such projects. The majority of respondents are managing directors. As is managing director I, who is someone with years of experience in the construction environment in a wealth of functions, particularly in the tendering and budgeting large infrastructure projects and in setting up tender selection procedures. Managing director II too has years of experience, ranging from project site jobs to management positions. The third managing director has begun his career at the client side, overseeing large infrastructure projects. Concerning his subsequent positions at contractors, he was responsible for large integrated projects previously and is currently managing director. Hence, he is acquainted with both the client's and tenderer's perspective. Managing director IV moved up though positions at [one of the other interviewed contractors] in the past, so he is not only experienced in the tendering of large projects but also has a feeling of the differences between the contractors' approaches. The fifth managing director has experience in managing both projects and contracting organizations. He managed one of the Netherlands' largest infrastructure projects and has been a member of an executive board of a contractor. The final respondent is currently a member of the executive board of a contractor. He has experience with managing projects and as managing director.

The decision makers were questioned regarding the determination process of a bid amount for large-scale, multidisciplinary, integrated infrastructure projects. The conducted interviews were semi-structured, according to protocols which can be found in appendix B and D. The average length of an interview was about an hour and took place during two rounds. The interviews were conducted at the contractor's offices, except one, which took place online due to Covid-19. Some parts of the quotes in this chapter are between brackets. This indicates that these sections are edited to anonymize sensitive information or to increase readability when it was otherwise unclear what was referred to during the interview.

4.1 Mark-up approach

All interviewees described an at first sight simple business accounting method; the mark-up approach. In essence, the bid amount is determined by adding a mark-up to the estimated construction costs.

Construction cost	
Mark-up	+
Bid amount	

Figure 19 - elementary bid amount structure

More specifically, the decision maker receives a cost estimate of the direct costs associated with the contemplated design solution. Next, indirect costs like the construction site amenities, staff and insurance are added. Then, the construction costs are marked up with a risk provision, general overhead and a profit margin.

Construction cost	Direct construction cost	
	Indirect construction cost	
Mark-up	Risk provision	
	General overhead	
+	Profit	+
Bid amount	Bid amount	

Figure 20 - bid amount structure

The interviewed directors summarized the approach in their own words. Some more extensively than others;

> *'The result of such a tendering process is […] a calculation. That calculation basically always consists of the same items; the parties who are tendering, the direct costs, indirect costs […] and a risk provision and 'tail' or mark-up. Thus, general overhead, profit and risk.'*[1]

> *'First, the construction costs. Let us distinguish direct costs and all indirect and associated costs. […]. Then you consider the indirect cost. […] Then, we arrive at the risk budget. […]. That is indeed in the last phase, risks and what kind of surcharges.'*[2]

> *'The structure is always; what are the direct costs; the cost of the cubic meters of concrete, the carpenters, everything you purchase. These are the direct costs. Then, the next major cost item are the indirect costs. The staff that supervises, the cranes not allocated to a section, these are all indirect costs. Those are merely the costs of construction. That must be correct. Then, there is a risk profile, which must provide a particular certainty. What remains is the question of the margin'.*[3]

> *'[...] this ultimately results in a [direct] cost estimate. Of course, this is supplemented with some indirect costs. These are in fact the ongoing construction site costs of the necessities; your site offices, your electricity supply, construction roads, everything that is needed. Actually, also your temporary costs. At a certain moment, you arrive at the PRGO [profit, risk provision and general overhead] percentages. There you make a choice. That is a commercial consideration.'*[4]

[1] Interview with managing director III at contractor D, held May 15, 2019.
[2] Interview with head of acquisition I at contractor E, held May 20, 2019.
[3] Interview with managing director I at contractor A, held June 3, 2019.
[4] Interview with managing director II at contractor C, held May 19, 2019.

Another decision maker provided a more elaborated image of the approach towards the realization of a bid while drawing on a whiteboard;

Well, you could determine your price like this;
Direct cost ← *Assumptions* → *Risk*
Indirect cost
Risk provision ← *RISMAN* ←
General overhead
Profit +
Bid amount

Figure 21 – bid amount structured as sketched by managing director IV at contractor F during an interview held May 23, 2019.

'General overhead is determined from accounting. That is a set percentage. […] The profit is a commercial consideration and the risk provision in case of large projects is more or less a number based on experience. However, that only applies to unforeseen risk. Risk that can be foreseen [is included] in the direct cost. Many assumptions are made to determine the direct costs. Risk analysis is performed to determine to what extent the assumptions represent reality. These [foreseen risks] must simply be included [in the bid amount].'[5]

All respondents reported this mark-up approach to determine the bid price. This rather straightforward response would imply that determining a bid amount is not that hard. However, when the interviewees elaborated on the approach, taken within their companies, of adding a mark-up to the estimated construction costs a more complex image surfaced. Consider the narrative and quotes below, describing the same approach in a more detailed, and comprehensive way.

Direct construction costs

In the Dutch construction environment of large integrated infrastructure projects it is common that a project is divided among multiple business units. Each business unit involved calculates the portion of the project that it will construct. Hence, that company is responsible for the construction of this portion and should be capable to calculate the associated costs.

Within each business unit one or more cost accountants (in Dutch 'kosten calculators') estimate the construction costs of the particular part of the project that his business unit is involved in. The level of detail of the estimate varies with time. At a preliminary stage of a bid process, a rough estimate is made prior to the announcement of the tender. The purpose of this first estimate is to get an idea of the order of magnitude of the project costs. This is a rough estimate, given that most is still unknown at this stage. In general, the level of detail of the cost estimate increases during the tender process. Since the design evolves and becomes more detailed, while simultaneously more and more information becomes available. This enables the cost accountant to move away from rough estimates based on key statistics (in Dutch 'kengetallen') derived from past projects. An example of such a key statistic would be the knowledge that a highway with two lanes in both directions costs approximately €X per meter to construct.

As the project progresses and more detailed information becomes available, the cost account gradually moves away from generic key statistics to a more detailed calculation for a particular context. This entails breaking down the project in detailed but manageable sections. A system breakdown structure is used to dissect a project into all its physical components. Subsequently, the construction costs for each component are determined by calculating the costs of the required materials plus installation costs. To estimate the installation costs, the project is dissected once more but this time in terms of the activities required to construct each component, which is known as a work breakdown structure. This overview of activities is used to estimate, for each individual activity, the number of people required to construct it, the time they will spend on the

[5] Interview with managing director IV at contractor F, held May 23, 2019.

component and their required skill level. From this the calculator compiles a man-hours amount and a monetary amount per hour that is needed to employ an appropriately skilled worker for this task. These numbers are multiplied and supplemented with the costs of any equipment that is required. The material costs and installation costs are added to compile a cost estimate for each component. Summation of the construction costs of all components results in the total estimate of the direct costs of construction.

> *'This ultimately results in the cost estimate. That estimate is simply what the works cost, the costs on its own merits. That are the direct costs; the pile-driving, the sheet piles, the concrete, the steel, the foundation piles.'*[6]

The interviewed contractors claim that the direct costs of construction can be well estimated by cost calculators who make these calculations on a daily basis and have years of experience. They are able to estimate the cost of a cubic meter of concrete or a ton of asphalt accurately to the cent. They constantly seek and acquire information both internally, for example with cost accounting analysis of completed projects, and externally by means of continuous analysis of price levels based on quotations, for example.

Now, we turn to the challenge of accurately estimating the direct construction costs. Among the respondents, there is agreement that in principle the direct construction costs can be estimated accurately. For example, a respondent said; *'direct costs can be estimated fairly well; length x width x unit price or production.'*[7]

Although there is agreement that cost accountants are able to accurately calculate, there are some factors mentioned by the respondents that can reduce that accuracy. One of the contractors who first claimed to be able to estimate accurately continued with the following statement that shows that the estimates contain uncertainties and not just exact numbers.

> *'Still, there are lots of uncertainties. Determining the direct cost for most people is something they have been doing for years and therefore they are pretty good at it. In addition, the calculator is always requested to specify the bandwidths too, on quantities and unit price'.*[7]

This interviewee mentioning some order of bandwidth on quantities and prices, indicates some degree of uncertainty in the estimates. One of the factors that results in uncertainty in estimating the project cost is that it is rare for an activity to be executed without interference from another activity. Consider the anecdote below;

> *'The most important aspect is not the specialist, who is very capable. If I would ask the cost calculator in this office 'how much does a metric ton of asphalt cost on a highway?', then he is able to calculate this to the cent. Yet, if I would add 'but keep in mind that there is also someone who has to construct something on the roadside and someone else has to do some work beside him', than he would react with 'When? Does that hinder me?' These are the items that must be identified. The large projects are particularly about approaching them in an integral way'.*[8]

In other words, interdependencies and interfaces with other (parts) of projects are of key importance and have a large influence on prices.

[6] Interview with managing director II at contractor C, held May 19, 2019.
[7] Interview with head of acquisition I at contractor E, held May 20, 2019.
[8] Interview with managing director IV at contractor F, held May 23, 2019.

A second factor is that projects are estimated years prior to their completion. It can take years before construction of an estimated section starts. In the meantime, all sorts of deviations from the assumptions used by the cost accountant can occur.

> *Especially those cost estimates, that are reasonable estimates. We look back at the developments in the last five years. Alternatively, we try to set fixed prices. If we know exactly what type of asphalt we are going to lay, then we attempt to secure those bitumen. In that case you know that it might be a little more expensive than you otherwise would estimate, but at least you have covered the risk of increasing prices. If projects take more than two years, this is impossible. The bitumen market no longer accepts it. Still, we need an estimate. How will bitumen evolve [pricewise]? It is dependent on the oil price. It is anybody's guess. Anyway, usually we assess seasonal effects. At what level are we now and what kind of market do we expect? People at our acquisition department conduct entire studies and they provide some direction. With some gut feelings, though.*[9]

Owing to the continuous gathering of information by the cost accounts, they have an accurate understanding of current price levels and coupled with their experience are able to estimate to some degree how prices will develop in the short term. Contractors are aware of uncertainties when predicting the future and look for ways to reduce them. If they can, by making agreements in advance and if that is not possible they attempt to estimate the uncertainty and incorporate it in the project's risk, as will be explained in the next section.

A third complicating factor is that during a tender limited time is available. The procurement procedures dictate strict intervals in which a contractor can prepare his offer. Meanwhile, contractors aim to employ personnel to prepare the tender as efficiently as possible. Hence, a contractor consciously chooses to what level sections are analysed.

> *'Very consciously we choose which parts to delve into and which parts not. Where are the critical items located in case of a design and construct project? When you are considering a road project with a substantial number of fairly standard viaducts, then we utilize key statistics. And then we will know that the price is about right. But, if the project includes some sort of complex aqueduct, then that is the one we need to detail out, sometimes to construction level […] depending on how we assess the risk profile. This is a very important issue, what do you detail out and what not.'*[10]

Costs are estimated during the entire tendering process. On one hand in order to determine the costs of a chosen solution and on the other hand as input to choose between solutions. This makes cost estimation a kind of iterative process.
Cost estimation is thus complicated by the complex nature of large infrastructure projects. For example, the many interfaces in such a project introduce new variables that the cost estimator has to deal with. The estimator not only has to estimate the required materials, machines, personnel, the required man-hours and hourly costs, he or she has to determine to what extent productivity is hampered by other activities on the interface. Uncertainty is elaborated on in more detail in the section that describes how the decision makers determine the risk provision.

[9] Interview with head of acquisition I at contractor E, held May 20, 2019.
[10] Interview with managing director I at contractor A, held June 3, 2019.

Indirect construction costs

After the direct construction costs, the contractors turn to the indirect costs. This covers the costs of additional efforts, resources and equipment required to enable the construction of the project. It includes a wide range of costs, though they have in common that they cannot be allocated to a particular section or activity. The calculator estimates indirect costs in much the same way as the direct construction costs.

> *'Next, there is a very substantial cost item of indirect costs. These are the additional staff and cranes which are not allocated to a subsection.'*[11]

> *'Besides, there are simply other costs; for design and all kinds of additional costs like surveying. All of that is more or less part of how many people it takes to execute the work.'*[12]

One respondent elaborated more than the others on the indirect cost, stressing that they are perhaps more important compared to what the other respondents might have indicated in their interviews. Indirect construction costs are an important item of the project's cost estimate, because it consumes a considerable portion of the budget.

'The organizational costs are particularly important, there is a lot of money involved. More and more nowadays.'[12] For reference a rule of thumb was provided by one of the interviewees that is used to estimate the cost of personnel. *'If you have a project of €100 million, then 35% of it, thus €35 million is labour.'*[12] This reference is a clear example of the key statistical figures and heuristics used in cost estimation.

Indirect costs are a cost item that, according to the respondent who provided the rule of thumb, can easily be underestimated, resulting in financial loss.

> *'We noticed that we often 'lose money' on this subject. It turned out that the [project] organisation needed to be strengthened, more or different personnel was required than was anticipated beforehand. Here we touch upon the impact of the client too. Since, it is often clear what we are requested to construct, but how we ought to interact with each other is often more difficult [to predict]. Moreover, it is even more difficult to quantify this.'*[12]

In other words, a large portion of the project's cost are organisational costs. Apparently, it is hard for a contractor to predict what a client expects in terms of cooperation (and its costs) and consequently how large and skilled the project organisation must be to facilitate the desired manner of working.

Another respondent, who had experience as head of acquisition provided some insight in how a contractor attempts to estimate the associated organisational costs.

> *'Well, we do this based on past experience. In this situation, a team is compiled of experienced people to construct this project. We assess the client's request for proposal and specification and we determine what activities are needed besides the technical stuff. What is required in terms of the process? What project organisation is necessary? When we get a client[representative] who is cooperative, we will manage. But more and more often we have to deal with client[representatives], not to play the blame game, who are hired from other consultancies or are freelancers who have other objectives than to swiftly complete the project. […]. It is in their own interest to extend the project's duration, otherwise they have to look for a new job. So, when that dynamic emerges, that client will start to ask lots of questions; demonstrate this, demonstrate that, etc. While we might surmise beforehand that the process would be more efficient. What is the client's attitude in the game? Do we understand each other properly? Do we get along? Those things can have a huge impact. So, this is the cost item with the largest bandwidth.'*[13]

[11] Interview with managing director I at contractor A, held June 3, 2019.
[12] Interview with head of acquisition I at contractor E, held May 20, 2019.
[13] Interview with head of acquisition I at contractor E, held May 20, 2019.

The described approach showed the impact a client has on the project costs. This issue surfaced more often. Later on, in the section covering the factors a contractor considers, a paragraph is dedicated specifically to the relationship between the client and the final bid amount.

Another substantial item in indirect construction costs calculation that might yet be underexposed is a cost item that recently has become more significant. One of the interviews remarked:

> *'[But] a different concern is how to appraise our guarantees. Insurance is an important issue as well. It is generally possible to clarify such items, although there are large differences in the methods used. A few years ago insurance was not an issue, but currently the premiums have become very high, because everyone has claimed bad projects with their insurer. Consequently, those insurers have become more and more critical, which makes sense. If we want to insure a project properly, it requires quite a lot of money. In particular, the guarantees that we provide. There are more frequent claims on our guarantees. So we simply have to budget accordingly. I can easily imagine that this is overlooked by the market, by other parties too'*[14]

This quote shows that the items that need to be considered to accurately determine the indirect costs are dynamic. Given this dynamic, it is easy to overlook which items are currently important and must be budgeted conservatively. While for other items, it might have become obsolete to consider them or it could now be estimated with key statistic figures or heuristics to save time and resources.
Besides relying on a team of experienced people to estimate the indirect costs involved in a project, contractors rely on data of previously constructed projects. This is illustrated by a description of how contractor E deals with another major indirect costs item, indexation;

> *'Indexation is also an issue. Especially lately, with these increasing prices. Usually and certainly with these large projects, there fortunately is always an indexation scheme in the contract. Thus, the client accommodates increasing or decreasing prices in some way. Every year we look back three years. We consider what costs we have had due to our guarantees and translate it to square meters of asphalt top layer or something. All kinds of calculations are possible. For this, we include considerable budgets.'*[14]

The impression was given by the majority of the interviewed contractors that the indirect costs are not really an issue, rather just some additional costs for peripheral matters. However, the indirect costs constitute a large share of the project's total costs and they involve quite a number of uncertainties. Especially since many responsibilities are transferred to the contractor with these large infrastructure projects. Since these projects are procured with both design and construction responsibility for the contractor, additional uncertainties are introduced into the contractor's domain, regarding design and permits for example. Additional uncertainties result from the large design and construction organisations required. The situation is complicated further by EMAT procurement, introducing additional design uncertainties, coupled with uncertainty regarding how a solution will be awarded based on the award criteria.

> *'Nowadays the procurement of almost every tender is not just on costs any more. That used to be EMAT [economically most advantageous tender] and that is nowadays called differently [best quality price ratio (BKPV)].'*[15]

It is interesting to observe that estimating the indirect construction costs encompasses a lot more than assessing the obvious items such as; a site supervisor, surveying, site amenities and utilities. In fact, indirect construction costs consist of a wide range of

[14] Interview with head of acquisition I at contractor E, held May 20, 2019.
[15] Interview with managing director III at contractor D, held May 15, 2019.

items, from man-hours and cost of machinery which cannot be attributed to a particular part of activity to guarantees and insurance.

Likewise, a range of techniques are utilized to best estimate the associated costs. When estimating the required organisation the experience of experts is used. For other aspects, like monetizing guarantees, a retrospective analysis over the last three years is used to be able to work with key statistical numbers (in Dutch 'kengetallen').

Lastly, it can be concluded that the relative importance of certain cost items changes with developments in the industry, as was explained in the example regarding insurance and guarantees.

Risk provision

As mentioned, all respondents described the same mark-up approach of adding a general overhead, a risk provision and some profit to the project's cost estimate. Dealing with risk is a major issue when determining the bid amount of large infrastructure projects. Risks that fire are an important cause of delays and overruns. Due to the massive size of large infrastructure projects, a cost overrun has major implications. One respondent explains:

> *'Those large integrated projects became larger in recent years. There regularly are projects of around one billion euros, like MaVa A15 and Zuidas. The larger the projects become, the larger the range becomes. An overrun of 10% on such a project equates to hundred million euro. With such amounts you make headlines and immediately your company is at risk. An overrun of €8 or 9 million at a smaller project has much less impact.'*[16]

Risk at different levels in the contracting organisation

There is a difference in risk appetite related to the project's size. For larger projects there is a greater necessity to estimate and manage risks properly, since the stakes are greater. Hence, contractors who undertake such large projects not only manage risk at the project level but also at enterprise level. The latter entails choosing deliberately which projects to undertake by looking at all projects in the portfolio and balancing out the risks and returns of each project versus the risks and returns of the entire portfolio. This is risk management applied at a strategic level.

> *'The large integrated projects can have a major impact on the operating result. That is why I prefer to look at the total risk of all projects, the enterprise risk. For this reason we have a maximum of about one third large projects. At contractor [X} it used to be 50%, they have reduced it to about 25% now. The percentage of large projects is reduced, because you can absorb [a failing large project] with lots of smaller projects. Their performance is more consistent. The small projects have a dampening effect. We do at most 12 projects exceeding €50 million a year.'*[17]

At enterprise level participating in a tender is regarded as an investment decision. After all, a team of people will work on a tender for months.

> *'[…] a tender is just like any other investment decision in our opinion. It could be limited if it is a simple one, but usually with large complex projects considered in this thesis it amounts to millions of euros.'*[18]

[16] Interview with managing director II at contractor C, held May 19, 2019.
[17] Interview with member of the executive board I, contractor B, held June 6, 2019.
[18] Interview with managing director I at contractor A, held June 3, 2019.

Just like any other business, contractors try to optimise their investments. This comes down to selecting projects to tender which are likely to be profitable. To do so, contractors attempt to tender for projects that they are familiar with. Considering that they have the technical knowhow, skills and expertise to manage the project properly. Moreover, they are able to estimate costs more accurately. Consequently, the probability of obtaining the project improves while the risk declines. Hence, contractors have become selective in their tenders and have specialised in certain aspects in infrastructure construction to gain a competitive advantage.

> *'We have developed a strategy and a vision of which segment of the market we want to operate in. Which project we want, which projects we do not want. We want a particular segment of the market. In addition, we choose particular clients. Some clients we do not work for, because of a bad reputation for example. So that determines the strategy, linked with your targeted market segment. Annually I want so much turnover, so much return. From there on you [select] your tenders.'*[19]

An important consideration for the selection process is the kind of risk related to the project and the contractor's ability to deal with it.

> *'We are not looking for projects that are technically complicated. A lock, for example, is something we do not do. We could construct a small lock, but we need someone for the installations. Those kind of projects are always performance-oriented. The installation is only about 6% of the contract sum, but determines the availability for 95%. That is a risk I will not take. And the fitter cannot take it. So, we do not do it. […] We want to excel in a complex environment. That is where we can make a difference.'*[20]

Large infrastructure projects are put to market with a performance based contract. The consortium is offering a service. For example, providing a number of motorists with the means to travel from A to B in a certain time. A major requirement is often the availability of the service. As a result, availability is highly rewarded financially. A respondent explained that an important consideration in selecting a tender is the kind of risk and the contractor's ability to manage it. This is especially relevant for large infrastructure projects, given the relationship between the delivered availability and the corresponding financial appreciation.

Consider the quote below, where a contractor describes which projects he prefers, how this has evolved and what the reasoning behind pursuing this kind of projects is.

> *'We are a broad infrastructure contractor. Thus, we and especially within the department of central projects, prefer medium and large integrated contracts. Integrated, not in the sense of both design and construction, but as broad as possible. With multiple disciplines. Bluntly speaking, road-bridge projects we like the most. But the large civil engineering projects are fine too, but our preference is as integrated [read multidisciplinary] as possible. We have a quite strong road business unit in our company. […] But we also like it when there is a considerable portion of structures in the contract. That is what makes us strong, I think. In addition, all the supporting activities that go with it; everything related to traffic measures, guardrails, noise barriers, we have all of that in-house, we do it all ourselves. Therefore, we offer added value in all those areas. When we can offer as much added value as possible, those works have our highest priority.'* [21]

This contractor pursues projects with a large portion of the work related to their core business. Moreover, the preferred projects can be executed largely or completely in-house. Which is essentially a vertical integration of their supply chain. This enables this contractor to effectively adjust processes in order to be cost effective. Moreover, since companies within the group execute all activities, the entire spinoff of the project ends up

[19] Interview with managing director II at contractor C, held May 19, 2019.
[20] Interview with member of the executive board I, contractor B, held June 6, 2019.
[21] Interview with head of acquisition I at contractor E, held May 20, 2019.

at the contractor's organisation opposed to some portion of the profit ending up at subcontractors. In addition, this quote shows that contractors prioritize tenders based on the fit to the contractor's business strategy.

Likewise, another contractor described in a similar way that by specialising in particular projects, they optimised their internal processes to gain a competitive advantage.

> *'Projects which suit us are road projects, large scale asphalt maintenance. […] We have a lot of this kind of work, so apparently we are good at it. Ergo, we have an extensive equipment fleet on that area. So, we can take on many different types of activities. We have a nice spread of our asphalt plants. Thus we are, geographically speaking, truly competitive in a lot of locations. […] So, if there are large quantities of asphalt [in a project] then we are always one of the contenders. Per definition. Simply because we are good at it.'*[22]

That this contractor has a competitive advantage results from both their ability to add value and offer competitive prices.

> *'We have both an equipment fleet with a number of techniques, which nearly no competitors have and I would even venture to say that even if they mastered them we are better anyway in general. That is a distinctive feature. At the moment we have an asphalt mixture which stands out. We are well advanced in circular asphalt mixtures. That is something that works well in the market. Then we can add value. And also in terms of price, we are indeed an efficient company. Our price levels are for sure not higher than the other large contractors.'*[22]

Thus, all contractors have their own business strategy to distinguish themselves from the competition. By specialising, the probability of obtaining the project improves while the risk declines. Contractors aim to improve the likeliness of winning the tender. They do this by specialising, which enables them to better manage and estimate the project. But, they are also able to offer more quality or improve their processes in other ways to add value. In other words, they opt for a best value approach.

Furthermore, they aim to improve their chances more by optimising their bid and tuning their offer to the client's requirements. This aspect is highlighted by contractor A;

> *'In the Netherlands another important question is what promises you are going to make. Because that EMAT or BPQR…What are you going to promise to the client in terms of planning, in terms of risk. What do we think is still responsible? And of course we affect our chances of winning with this. Therefore, we always make trade-off matrices of what does it bring us and what does it costs us. Because especially those EMAT criteria demand money, they increase the risk profile and in return you get a higher probability of winning.'*[23]

So, as a consequence of procurement procedures in the Netherlands with a best value philosophy and project awarding based on EMAT or BPQR, there is a clear relationship between the conceptualized solution and risk provision. Since the risk depends on the solution that the contractor offers and to what extent, a contractor is able and willing to manage risks of the client.

> *'You have to very consciously balance this. […] results [of tenders] can vary that much because of the choices made in this. Those [choices] can turn out quite strangely. Especially if the EMAT value has a large effect. We can make a deliberate choice to go for a low price with a EMAT value of which you think will be sufficient. Or do we invest a lot of money, but also have a high EMAT value and thus a high fictitious discount and have made a good offer that way. We make deliberate choices and as a result you something have very different results than the competitors.'*[23]

[22] Interview with managing director IV at contractor F, held May 23, 2019.

[23] Interview with managing director I at contractor A, held June 3, 2019.

Risk at tender level; dichotomy of foreseen and unforeseen risk

Since all respondents described the same mark-up approach, one might expect uniformity in their risk approach. However, when the contractors explained how they deal with risk and uncertainty during a tender substantial differences in their philosophies emerged.

In general, the contractors distinguish two kinds of risk. '*We always make a dichotomy of identified risk and unidentified risks.'*[24] Firstly, they consider risks that are identified prior to their occurrence; foreseen risks. Secondly, risks are considered that occurred but were not anticipated; called unforeseen risks.

In summary, determining a risk provision starts with the foreseen risks. Risks are firstly identified. A common method to this end is the RISMAN methodology. Identified risks are allocated to the person best able to manage them. These persons quantify each risk; the consequences of the risk occurring are explored and the probability of occurrence is estimated. Further, mitigating measures are devised. Next, the risks and measures are evaluated, usually by means of a Monte Carlo simulation. Based on this analysis a risk provision is chosen. Then, the risk provision is increased to cover unforeseen risks too, whereby contractors rely on their experience.

> *'Lots of assumptions are made to determine the direct costs. Risk analysis is performed to determine to what extent the assumptions represent the truth. These [foreseen risks] must simply be included [in the bid amount]. Techniques are available to judge risks. Basically [we use] the RISMAN methodology to map risks and Monte Carlo analysis can be used to compute an amount. That is a possibility. I am not an advocate of this, but it is a possibility nonetheless.'*[25]

As this contractor explained, the foreseen risks are included in the direct costs. The mitigating measures that must be taken to reduce either the impact of risk if it fires or the probability of occurring itself, cost money to execute. These costs are considered necessary expenses, similar to those of costs of materials or other direct costs. The next section zooms in on how contractors deal with foreseen and unforeseen risk.

Foreseen risk

Cost accountants are asked to specify bandwidths when estimating the direct construction costs. The bandwidth indicates the uncertainty of the estimate. Commonly, the bandwidth consists of a worse and a favourable estimate. These estimates together with a most likely estimate are the input for the Monte Carlo simulations.

> *'Well, these wonderful Monte Carlo simulations can be executed to determine a bandwidth [of the entire project]. Beautiful Gaussian curves can be drawn. We used to spend a lot a time with this, but we wondered: what does it all add up to? We will still do it, but we are not going to look at those Gaussian curves very closely. As far as I am concerned, just use the P85-value to do the calculation. Consequently, we arrive at a direct cost estimate with some bandwidth plus or minus the estimate.'*[26]

Like in this example, it is common for contractors to have set a desired level of certainty. This is the P-value that the respondent referred to. A P85 value relates to a monetary amount for which with a certainty of 85% the project's costs equal amount or are lower. Moreover, this aspired level of certainty, the 85 percentile, is not something that the decision maker determines per project. It is a set value, which is applied to all tenders.

> *'We distinguish a few types of risk. That is the bandwidth analysis already mentioned, that's a risk jar too. We have a jar for unforeseen. Things we did overlook. Those are often*

[24] Interview with managing director I at contractor A, held June 3, 2019.
[25] Interview with managing director IV at contractor F, held May 23, 2019.
[26] Interview with head of acquisition I at contractor E, held May 20, 2019.

numbers that we gathered by looking back in time at the things we have missed. And we do a Monte Carlo analysis on the initiated risks. We see a number of risks, which we rate. We take a number of mitigating measures and calculate those with the direct costs. Those are simply construction costs to us. And then there is some risk left with a probability of occurrence. And the amount that this results in, we simply add. We do the same thing with opportunities, but we no longer take these into account. We do not do it anymore. In the past we have done it too much. Then we ended up somewhere we did not wanted to be.'[27]

So, besides the costs of the mitigating measures, the residual risk is also added to the direct costs of construction.

Decision makers usually focus on the top risks. These are circa five identified risks with the highest impact, which is their potential damage times the probability of occurrence is highest.

'Those top risks differ per project, by the way. So per project a risk analysis must be made. A very good risk inventory, subsequently a risk analysis and we have to appraise it. Either good mitigating measures which we include in your budget so that the risk is reduced and there is only a residual risk left. And that residual rest must be included in your budget or analysed with, for example, Monte Carlo in a way that it results in a realistic risk amount.'[28]

Contractor C described the same approach. Note that he also explains that there is a choice whether to include full residual risk or perform an additional Monte Carlo on the residual risk.

When asked how external factors, like the anticipated working relationship with the client, the project location, etc. influence the final bid amount, it was explained that such issues are incorporated in their risk assessment.

'All of that will be incorporated into the risk profile, in the mark-ups, in the mitigation measures that are required and in scheduling of the additional time required. That is an entire process of how that evolves into a complete package of a bid.'[29]

This contractor uses Monte Carlo simulations to analyse risk, foreseen risk that is, and measures. From the output of the analysis, a certain risk buffer is selected which provides the desired certainty to be covered. '*The risk profile must simply provide a certain level of sureness.'*[29]

A commonly used term in risk management is the risk profile. This refers to the output of the Monte Carlo risk simulation.

'Yes, it is the output of your Monte Carlo simulation. […] The final output is that with a X-percentage certainty know that it can be built for that amount. […] That is what we assess. And we feel that we need a certain percentage of certainty that these construction costs are feasible. Thus, you have a cost amount and you add something as a risk buffer to reach the amount obtained by your Monte Carlo.'[26]

That is what we assess together, that is what gives us the input. In addition, a Monte Carlo with such a risk analysis naturally gives us a lot of guidance when you win such a project. Because you know where your major risks are, what to look out for. If [the main risk] is environmental, then we have to put a team on it, which is environmentally excellent to ensure that those risks are kept within bounds. If it is contractual with the client, we will have to set up a top team for that. If it is financial, etc. That is how we apply the risk analysis as well, in order to form our team, to put the focus of the team on what they have to do.[29]

[27] Interview with head of acquisition I at contractor E, held May 20, 2019.
[28] Interview with managing director II at contractor C, held May 19, 2019.
[29] Interview with managing director I at contractor A, held June 3, 2019.

Unforeseen risk

In the general description of how contractors determine their risk buffer in the previous section it was briefly mentioned that besides a thorough analysis on foreseen risks, contractors include an additional buffer for unforeseen risks. Usually, contractors rely on their experience in past projects to determine the endured exposure due to unforeseen risks.

Contractor D explained that he does not even attempt to quantify the unforeseen risks.

> *'And we often break up that risk percentage into two parts; the calculated risks (i.e. the Monte Carlo) and a bit of mark-up. Well that is basically that black box that you consider. And especially that mark-up … I would say; do not even try to quantify that because that is higher politics.'*[30]

This interviewee described dealing with unforeseen risk as dealing with a black box and as 'higher politics'. By this, he presumably meant that he is unable to grasp indirect risks and that he has no clear way to incorporate it in his decision-making.

The general trend is that contractors increase their risk buffer with a certain percentage based on past experience.

> *'[…] the risk provision, in case of large projects, is more or less a number based on experience, but that only applies to unforeseen risk. Risk that can be foreseen [is included] in the direct cost.'*[31]

Similarly, contractor A confirmed to apply a target value for the additional buffer for unforeseen risks. *'And there are guidelines for this type of projects and contracts, when we target certain percentages. That is basically the standard of how we deal with this.'*[32]

General overhead

General overhead is regarded as one of the simpler items to determine in the mark-up. It is considered as a fixed percentage of mark-up required to cover the expenses of the general organisation, such as housing. Each year the administration determines what percentage is needed to cover the overhead. The interviewed contractors quoted; '*That [general overhead] is in basically simply determined by accounting'*[31], '*We have fixed percentages for general overhead'*[33] and '*We make an inventory of the overhead percentage that we need. That is fixed.'*[34] Contractor A added that general overhead is barely discussed by decision makers when setting the final bid amount. '*[…] with us general overhead is basically a predetermined amount, so it is hardly something to linger over.'*[32]

However, other contractors claimed that although general overhead is general is fixed, there could be consideration to relax this.

> *'As a contractor, we play with [the mark-up]. That is the philosophy of a traditional contractor as well, to keep the expenses low. We have a commercial edge, if we have cheap housing.'*[30]

> *'If, in the end, we have less work, I could say for once I settle for less regarding the general overhead. Which are still costs [that have to be paid]. That used to be far more than nowadays. […] In the early 2000s, the large projects were regularly tendered with null general overhead or even minus. Just to be present, to have a large project to create revenue'.*[31]

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[30] Interview with managing director III at contractor D, held May 15, 2019.
[31] Interview with managing director IV at contractor F, held May 23, 2019.
[32] Interview with managing director I at contractor A, held June 3, 2019.
[33] Interview with member of the executive board I, contractor B, held June 6, 2019.
[34] Interview with managing director II at contractor C, held May 19, 2019.

Profit

The profit, or discount, is the last thing to consider when the final bid amount is determined with the mark-up approach. Since the profit margin is directly related to the probability of acquiring the tender, one might expect that determining the profit margin is a challenge. After all, when a decent profit is charged there is likely a competitor with a more competitive bid who will win the tender. On the other hand, when a contractor offers a bid with no profit, he is likely to get the project but is unable to make a profit. Determining the profit is not regarded a thorny issue though. For the majority of contractors there is not much to discuss. One reason for this is that a set percentage for the profit margin is used.

> *'Profit is in principle a predetermined amount, so we never really think about it for too long. […] A baseline has been formulated consisting of minimal requirements for a tender, including a minimum amount of profit. […] there is the company's aspiration to make a profit. We stated in our annual report that we pursue an after tax profit of 2 to 4 percent. Which means that you easily need a pre-tax profit margin of somewhere round 5 percent. It is that simple.'*[35]

Other contractors have a predetermined minimum as well. *'Yes, and there is a minimum percentage that we always include. Which we believe is in line with the prevailing market. In any case, we believe that everyone should include it.'*[36] Surprisingly, some clients have stepped into the shoes of the contractor and predetermined the profit margin. A topsy-turvy situation. *'For example, for integrated contracts (UAV-GC) of ProRail the margins [staartkosten] are laid down. Thus, general overhead, profit, risk and indirect costs are all prescribed.'*[37]

Another reason is of quite a different nature. Contractor E expressed that they do not attach much importance to the profit consideration.

> *'Whole considerations can be made about it, but in the end it is nothing more than just wrapping up the offer. Its effect is not that great on your bid amount. It lies in what we did well upfront. Do we have the right solution, a smart solution? We also see that when we score well on our qualitative documents, our EMAT documents, then we often score well in price too. That means low. Then we have found a good solution. We just struck the right chord. […] And if we have not found [the right] solution, it does not matter if you charge 5% more or less. […] We have made the calculation; presume we had charged 5% more, how many projects did we pass by? Often it does not make much of a difference.'*[36]

This finding was backed up by contractor A, who made a similar analysis.

> *'You know, I once looked at quite a number of projects from a few years ago […]. If we look back afterwards and you take 100 projects and consider if we had charged 2 percent more profit, I think we would have missed 1 or 2 of the 100. An additional 2% profit is a huge leap in our industry.'*[35]

It is interesting that these contractors acknowledge that a few percent profit more or less does not really matter. This could be the reason why other contractors do not put a lot of effort in determining the profit margin and stick to fixed percentages.

Besides, when one assumes that the top decision makers determine the profit margin for a tender, one sets himself up for disappointment. Curiously, it is not uncommon for a tender team to suggest a profit margin to the board of directors who merely authorize the submission of the offer. *'Our board of directors does not say 'we want this [profit]', they say 'what do you want to submit?'. They just ask us what we think and why.'*[37] They view the profit decision as a commercial consideration. Hence, if this is the case there is

[35] Interview with managing director I at contractor A, held June 3, 2019.
[36] Interview with head of acquisition I at contractor E, held May 20, 2019.
[37] Interview with member of the executive board I, contractor B, held June 6, 2019.

some fluctuation in the profit margin. *'The profit is debatable. But there is also a commercial consideration of what you think the others will do.'*[38] Thus, this contractor adjusts the profit margin in accordance with expected competiveness of competitors. Another contractor has a similar view, although their focus is inwards, to their own organisation.

> *'The profit is a commercial consideration. […] The board members who are present [at the final bid decision] are aware of the cover ratios of; asphalt, equipment and people. They know how our departments are doing and based on that we can determine for which general overhead percentage and profit percentage we settle for.'*[39]

4.2 Bid amount determination process

The process followed by a contractor to determine the final bid amount depends on the type of procurement procedure prescribed by the client. Nevertheless, there are clear and structured processes to make sure that all the requirements are met when an offer is submitted at the end of the process.

> *'In itself [this is a] fixed process. Nevertheless, there are tenders that run differently. When a client inquires differently, if they want a technical design prior to a price, then we adjust to it. Alternatively, if they procure in a totally different manner where you select a contract based on rough sketches and work out the design later in consultation. There are a lot of variants; the design team, two phase tenders, you name it.'*[40]

That being said, most large infrastructure projects abide by a general structure. These projects are commonly put to market as tenders with design, construction and maintenance integration and are awarded based on performance, not just on the lowest price.

The general tendering process can be described based on three distinct phases. First, a reconnaissance phase where upcoming projects are identified and selected. Secondly, the prequalification or selection phase where interested contractors apply to tender and the number of contractors is reduced to at least three who enter into the tender. The third phase is the actual tender phase, in which the selected parties formulate their offer based on a solution concept. Finally, the last challenge is to finalize the offer and determining what to charge for it.

Reconnaissance

Although one would expect the contractor's tender process to start when a contract notice is published, this is not the case. A contractor starts well in advance to prepare a tender, initially with a reconnaissance in which an upcoming tender is thoroughly explored.

Reconnaissance – market exploration

The exploration phase starts with identifying future projects. Contractors have employees dedicated to searching for potential projects. A respondent explained how they are able to identify potential projects years in advance of the contract notice.

> *'In any case, we have the marketing researchers for projects exceeding €10 million. When you consider these large projects […] you could know, over a year in advance, that they are approaching. […] for Rijkswaterstaat on the MIRT (Multi-year program Infrastructure, Spatial development and Transport), for ProRail via Tenderned and they can be found for the Provinces as well.'*[41]

[38] Interview with member of the executive board I, contractor B, held June 6, 2019.
[39] Interview with managing director IV at contractor F, held May 23, 2019.
[40] Interview with managing director I at contractor A, held June 3, 2019.
[41] Interview with member of the executive board I, contractor B, held June 6, 2019.

Identified upcoming projects are preliminary assessed on whether they could become an interesting project for the contractor. '*Then we assess in advance if they appear to be interesting for us.*'[42], '*Do we have the feeling that we can build this project?*'[43] are common considerations in this phase.

Once a future project has been identified as a potential tender for the contractor, the project's development is tracked while more information is gathered.

> '*At that moment, we already assigned someone to it, most often someone from the area, to perform preliminary work. That entails, among other things, who the stakeholders are? Then we consider if the project fits us. Thus, if it is a busy environment, difficult, many objections lodged, that is interesting for us. This means that it has been eventful and that they really need us.*'[42]

This is an example of how contractors identify and start analysing projects well in advance of their announcement. After a project is labelled as interesting, an employee who is familiar with the project's location explores the project further. The project location, context, developments and the chance of obtaining the project are researched. At this stage, the main consideration is whether the upcoming project fits the contractor's business case. As in the provided example, in which the contractor mentioned some aspects, like a busy environment with a fierce opposition to the project, as indicators that this project conforms to their strengths.

Several aspects are explored, when they all seem positive or promising, the future project is included in an information system to keep track of current and upcoming tenders. This usually is a file containing future and upcoming tenders with their key characteristics.

> '*We have a large list of submitted tenders that we are awaiting results on, current tenders, tenders in the selection phase and there are projects to follow too. […] When all lights turn green [the project is added to the list].*'[42]

To conclude, the first phase of the market reconnaissance is exactly that, searching and researching potential tenders.

Reconnaissance – partners and supply chain

The second step is where the first tangible preparations take place. This phase is all about committing the right partners and suppliers to you as a contractor and the project.

> '*In the first few weeks, we make a quick scan. Of course, we made the choice prior to the type of project, whether there are activities we cannot do in house , whether we need to commit to a partnership or if we need a consortium partner to share risks with and with whom we can divide the works with, do I need a specialist subcontractor with exclusive commitment. Those are the strategic choices in the preliminary stage.*'[44]

> '*Then we start with searching for partners, prior to the tender.*'[42]

Note that the first steps in partnering and setting up a consortium to undertake the project takes place in this early stage of the tender process. Efforts are made to connect with potential partners well prior to the contract notice and before the details of the project are published.

[42] Interview with member of the executive board I, contractor B, held June 6, 2019.
[43] Interview with managing director III at contractor D, held May 15, 2019.
[44] Interview with managing director II at contractor C, held May 19, 2019.

Many things are still unclear at this stage. In spite of the uncertainty, partners are sought who can supplement the contractor.

> *'Prior to the start of the tender we already have an agreement. That is too non-binding to the extent that there are all kinds of excuses to get rid of each other if thing go wrong, but in principle this is a binding agreement. […] Then we wait for the tender documents to arrive and that could take a year or two, but the agreement is in place.'*[45]

> *'At the beginning, we set up a so-called pre-bid agreement, thus a tender agreement. Part of that agreement is, as far as I am concerned, always a discussion of the return, the profit margin that you aspire, our average overhead percentage. Often, we discuss margins because there are no exact agreements yet, but it cannot be the case that you go through an entire tender and spend a lot of money only to figure out at the end that one wants to charge 12% and you are not able to come to an agreement. It is better to find out that you think so differently about this in the beginning, then you can either look for a solution or otherwise conclude that you are not the right partner.'*[44]

Thus, about a year before a tender is officially announced, contractors have already identified the upcoming project, assessed whether it will be an interesting project for them based on the strategic fit and have made agreements with partners to undertake the project with. Noteworthy is that at this stage in which a lot is still uncertain, as the project is not even announced yet, there already are far reaching partnering agreements in place. Mark-up percentages are already being discussed. Now we will investigate the partnering further.

There are two main reasons to partner. The first reason is to fill the lacunas of the own organisation. This could be, for example, lacunas in experience required to qualify for the tender or inadequate technical knowledge regarding a sub process of the project. For example, a contractor whose sphere of activities only consists of road construction needs a partner experienced in structures to tender for a multidisciplinary project that consists of a new highway with a bridge in the route. A respondent explained that when contemplating on potential partners they ask themselves: *'With whom can we fill our lacunas? Is there a steel bridge included? We do not do that. In terms of technology, who could we need? '*[45]

The second reason to partner is to spread risks and resources, given the massive size of infrastructure projects these days. Even the largest contractors would not take on a present day infrastructure project by themselves. One of the largest contractors mentioned:

> *'For a while we thought that [we could take on a project singlehandedly], but we have had a rude awakening. There are a number of projects that are so complex and large that you should not aspire to do it by yourself.'*[46]

When inquiring whether the reason behind taking on projects with multiple companies, had to do with the ability to share risk, the responded replied;

> *'In terms of risk, indeed. We can do projects until a certain level, but there is no way we can do projects exceeding that level on our own. There are just many large projects exceeding that level. Then you simply want to share capabilities, resources, but also spread risks. Therefore, we always do so in a joint venture. Occasionally, because of special techniques too.'*[46]

[45] Interview with member of the executive board I, contractor B, held June 6, 2019.

[46] Interview with managing director I at contractor A, held June 3, 2019.

Partnering is not only favourable to divide the risks and acquire the expertise needed, but there are also competitive advantages that come with partnering. Contractor C explained;

> *'Up front, you make a cost estimate to identify the largest cost units. Where are the distinctive features? How can we optimise our probability of winning? From there you examine; what if I tender with another party, then I spread my risk and increase my chances. As if you do not tender, the market becomes smaller. The competition becomes less, but above all, we complement each other in these kind of areas; they are very capable design wise and we are capable constructors, or the other way around. In that case you complement each other, while your risk reduces'.*[47]

Thus, there is another incentive to partner; by collaborating the number of competitors decreases. This has led to strategic partnerships as this respondent continued:

> *'Then you could also say to this party, in this case we also take on the next project. Then you enter into a strategic partnership. However, all of this is done up front. If this is the right market for you, is considered up front'*[47]

Likewise, other contractors have similar strategic partnerships.

> *'We have, that is no secret, long-term agreements with a traffic management provider, Y, for example. Every couple of weeks this provider joins the meeting to discuss new tenders. Then we discuss the projects we want to take on to see if our schedules align. And often, this is the case, because they are aware of the same projects. For example, for steel bridges we always cooperate with Z. […] In addition, we also have binding agreements with engineering firms. In advance, with the engineering firm we believe is most suited. That is the same at contractor X. Moreover, there are specific engineering firms for concrete, lock doors, etc. But as far as normal project are concerned, you are covered with [a large engineering firm]'*[48]

Reconnaissance – decision to tender

The third step is deciding whether to tender. The decision to tender is important, since committing to a tender equals investing millions of euros, as was already mentioned. This has resulted in reticent and very selective contractors who go to great lengths to tender only for favourable tenders. '*Because we want to improve our hit rate […] we want to be even more selective in formulating why we have a chance of winning here.'*[49]
Deciding to tender is quite detailed and structured, often with regular intervals and based on predetermined criteria.

> *'Once every two weeks there is a meeting with the director of national projects, the director of regional projects, the director of rail, etc. and they discuss which projects to undertake based on a number of clear-cut criteria.'*[48]

Other respondents explained that the same approach is followed at different contractors.

> *'Then we decide internally by means of a consultative structure in which all tenders pass in a review whether a project is interesting for us or not. […] We have a number of assessment frameworks upon we may or may not select a tender.'*[50]

> *'Already prior to the selection phase, a pre-bid consideration is made; do we think that this project will be interesting to us? Will we apply as a candidate? […] There are many criteria.'*[47]

[47] Interview with managing director II at contractor C, held May 19, 2019.
[48] Interview with member of the executive board I, contractor B, held June 6, 2019.
[49] Interview with managing director I at contractor A, held June 3, 2019.
[50] Interview with head of acquisition I at contractor E, held May 20, 2019.

'We make a pre-bid consideration; will we find this project interesting? Will we sign up as a potential candidate? When [granting the project] is too much [based] on price, too little on EMAT or if there are too many unfamiliar activities, then we would not do it. There are plenty criteria.'[51]

'Well, there are many questions to ask yourself in advance and those must be followed up precisely. That is quite structured. That [the answers of the questions] ends up at the stage gate procedure. The first one is; do we want to prequalify for this tender? Considering that for these tenders you must prequalify, you must be invited. Thus, you must hand in prequalification documentation. Then you must have thought about all those questions, about all the reasons why you want to undertake the project, what your strategy is, why you will win, such things must be considered. In the end, a decision is made whether we invest money in this tender.'[52]

Common considerations when deciding whether participating in a tender is worthwhile are;

- How well does the tender fit the contractor's strategy?
  'Does it fit our business?'[53]
- Is the contractor able to distinguish himself from competitors?
  'What is our distinctive ability?'[52]
  'Can we add value?'[53]
  'If there is too much [focus] on price, too little on EMAT.'[54]
  'When we are not able to distinguish ourselves, we do not tender.'[51]
- Are the right partners committed?
  'Do we have the right partners?'[53]
  'Are there unknown partners involved?'[52]
- Are all the requirements to qualify for the tender met?
  'Do we have the references?'[53]
  'Do you have the skills and knowhow?'[52]
  'Or if it contains too much unfamiliar works, then we would not do it.'[54]
- Does the contractor expect to have a considerable chance of winning the tender?
  'Of course you consider the probability of winning.'[52]

Although contractors have a well thought out and structured process implemented to ensure proper decision-making on whether to tender or not, this does not include data. Only one respondent, managing director I, said to consult a database in this process. To be precise, they do rely on records of past projects to some degree in their decision-making, to predict future developments and to learn from and compare to past projects.

'We make an analysis of the market, which looks both forward and backward. We have an enormous database with past projects for clients with the results [grouped] in areas and techniques. We can make all sorts of cross sections from that database. We can simply see, when a client proposes a project, why we should want to work for them. Did we make a profit in the past with this client? How well was the cooperation? Does this project require familiar techniques, are we capable? Or the geographic area, do we perform well in such areas, do we have the people and means at the location? Thus, beforehand we think strategically whether we want to participate in the tender based on a risk profile.'[52]

Thus, to the contractor the first important decision in the process is whether to tender, that is whether to apply for the prequalification and invest money. At this decision moment, several aspects are considered; the strategic fit, likelihood of winning, right partners and strategy. At this moment, arrangements with partners are already made.

[51] Interview with managing director III at contractor D, held May 15, 2019.
[52] Interview with managing director I at contractor A, held June 3, 2019.
[53] Interview head of acquisition I at contractor E, held May 20, 2019.
[54] Interview with managing director II at contractor C, held May 19, 2019.

Qualifying and selection to tender

When the decision is made to participate in the tender, the consortium as a whole applies for the tender. However, it is common for Dutch large infrastructure projects to tender with a limited numbers of tenderers. So, from all the applications of parties, at least three are selected by the client to actually tender for the project. Upon selection, they receive the tender documents that prescribe how the tender will advance.

> *'Then the documents arrive and the selection phase begins. Subsequently, the tendering really starts.'*[55]

> *'When you have prequalified, the tender guideline, contracts and EMAT criteria arrive. Then, we check those documents. With the documents at hand we verify that what we thought beforehand, because you made some assumptions, is still valid*.'[56]

Tender team

This is also the moment that a team is assembled, which is charged with the day-to-day management of the tender. *'During the selection phase we put together the tender team. To us that is always important.'*[55] Amongst the different contractors, the composition of the tender team is similar, yet different. The tender team always consists of a leader, a design manager and a construction manager, although, there are different team members added to bring particular expertise depending on the characteristics of the tender or contractor's operating strategy. Depending on the project characteristics, additional expertise is also brought into the tender team when it is of importance, or has a major contribution to project. In addition, there is someone especially appointed to BPQR.

> *'[A team] with a leader who may intervene, who has a mandate, who has a steering committee.'*[57]

> *'Of course the tender manager, the technical manager, someone to look at the construction itself, the design manager and in addition to this there is always someone who is responsible for EMAT. The tender manager is of course overall responsible, but one person carefully monitors EMAT.'*[55]

> *'Then putting together the tender team is next. […] At the start you put together a tender team with people with technical knowledge, logistical knowledge, who write the tender documents and who schedule. […] The tender team must be put together carefully. The right person must be in charge. They must complement each other's competences. If they are caught up in a running competition, you do not have the right tender team. Neither if it is a situation of pretend and extend. In the end, there must be an offer.'*[58]

The tender

When a tender team is assembled, the tender documents are received and the stipulated conditions are to be found acceptable, the actual tendering commences. During this phase, the tender is elaborated, more and more detailed designs are made, plans and schedules are drawn up, cost estimates are made and an offer is conceptualised.

Structure

To a contractor a tender is a project. Not a common construction project that results in a structure or building, but results in an offer instead.

> *'Those [tenders] are actually projects in themselves. Tendering is in fact carrying out a project with a different result, a commercial purpose.'*[57]

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[55] Interview with member of the executive board I, contractor B, held June 6, 2019.
[56] Interview with managing director I at contractor A, held June 3, 2019.
[57] Interview with managing director III at contractor D, held May 15, 2019.
[58] Interview with managing director II at contractor C, held May 19, 2019.

Accordingly, distinct project management characteristics can be observed in the tender process as it takes place at a contractor. As proper project management dictates, a project is divided into manageable phases. At the end of each phase there is a formal go/no go decision when results are assessed and the decision is made whether to or not to proceed to the next phase. This project management arrangement is present in a tender too.

> '*We have very deliberately structured our tendering process with a number of go/no-go moments.'*[59]

> *'Every company defines such processes. We have defined them too. That is a good thing, because towards the end there are many things that have to be arranged. Moreover, tendering is a knock-out system, so if you forgot something, too bad. That is very formal, so it must be done very carefully. Our process systems provide this. Basically, we always use certain standards, a kind of template to make sure we supply the information similarly every time. This way information is comparable with similar tenders. That is important, so that comparisons can be made.'*[60]

> *For a number of years we have deliberately pinned down a number of go / no go moments in our tender process, which we take very seriously. We have set up our meetings accordingly. We have four go / no go moments. The first is when the work is put to the market, either as a public tender or as pre-qualification. […] Then we first determine internally, through a consultation structure where all tenders pass in review, whether this tender is interesting to us or not. […] Then we receive the documents and thus are part of the selected parties. Then we proceed to a phase we call the strategy phase. With a small team we start working on; how could we win this tender? Based on that strategy, in a purposely-scheduled meeting, we determine whether we all believe that this could be the winning one. […] This is in the tender the first formal go / no moment, the strategy is the first. The second we call elaboration. So, we have a strategy, on that basis we get to work with many things; design, cost calculation, schedules, all sorts of work. In addition, we will ask [the client] questions, upon which we receive information notices. It could happen that we do not fancy the answer, which makes us decide to drop the tender when we are about halfway there. That is painful, still it is supported by the team. […] Basically, they are the initiators at the moment […] they have lost confidence. Then we have the last [go / no go decision], just prior to submitting the offer. An overall risk profile. With the large projects the board of directors is involved. They joined earlier, they are the ones that have to make the decision. That concerns mostly the risk profile is still acceptable in relation to the price, the room within the risk buffer that we apply.'*[59]

A clear and detailed description is provided by contractor E of how they have arranged their tender process into phases, which are concluded with a go / no go decision moment. It also shows that the different gate decisions are made by different sets of people. For example, at the second gate there is a strong input from the tender team on the decision whether it is worth to continue with a particular strategy. Note that the decision is made mostly unfounded, based on the level of confidence they have in the change of winning.

> *'The tender we do in a number of phases. First, we inventory all kinds of things. We try to keep this a short as possible. Then, we narrow down to solutions. A few basic choices are made. With that, the elaboration is continued. Then the documents are worked out further. […] They are checked with all kinds of reviews, from design reviews to costing reviews and so on. This is in the end what the construction costs are based on.'* [61]

> *'At a large company like X it is a challenge to get everyone to join and in line, so that they look at a tender with equal enthusiasm. Because that is what we need in the end to be successful on all levels. It takes countless meetings. Generally speaking, we work with a*

[59] Interview with head of acquisition I at contractor E, held May 20, 2019.
[60] Interview with member of the executive board I, contractor B, held June 6, 2019.
[61] Interview with managing director I at contractor A, held June 3, 2019.

core team of 5, 6 people who pull the strings. They give account to a steering committee, which consists of the management of, in this case, department X and the board of directors of X, but it could be a different department.'[59]

'Speaking about the large projects, projects exceeding €50 million and up to €1 billion. Fortunately, those [projects of close to €1 billion] are uncommon. Then the board of directors has joined. Dependent on the risk profile we meet two or three times to involve them. The first time, to inform what the project is about. The second time regarding the risks. And the third time, for what amount we will tender in the end.'[62]

'There are periodic meetings with both the steering committee [stuurgroep] and tender board. Generally speaking with a tender with an order of magnitude of €100 million takes 3 till 6 months. Within those 3 till 6 months there could be up to 2 or three tender boards. Those are with the directors of the group. Steering committee meetings take place every 4 weeks. Then [the director of the civil engineering company within the group] will be informed about how the tender proceeds; in terms of progress, quality, abnormalities, tender costs and budget.'[63]

Conceptualizing a tender offer

The tender phase is geared towards developing an optimum solution for the client's request, in order to obtain the project on favourable terms.

'The tender trajectory is about creating ideas and putting plans to paper. […] In essence, the result of such a tender process is, depending on how long it takes, a plan of how to construct it technically, a schedule, a capacity budget, how much it will cost, the people assigned to it, the parties that you will construct it with. […] Sometimes you already have a quotation and sometimes you leave it until a later moment. There is a philosophy behind it too. A risk assessment; contractual and technical. That determines your Monte Carlo. Based on all of that a calculation is made. That is the rational side, which you take as something for gospel truth.'[64]

Crucial in this process of conceptualizing a solution and detailing it out to the required level is the tender strategy.

'*Up front, during our strategy sessions we make different scenarios. With our strategy we aspire a particular result; we want to score high on EMAT with a solid price, for example. We score high because of certain aspects. Now imagine that there is someone who just goes for a low price and disregards the EMAT. Likewise, you can sketch a number of scenarios. We do it, but briefly. What are the different scores compared to different levels of cost? What makes great strides? In particular, we review which EMAT criteria and what to adjust, to fine-tune our own strategy.'*[62]

To summarize, the starting point of the tender process is the strategy. Scenarios are built to get a picture of what the possibilities are. To get a notion of the playing field. Moreover, this indicates also, what to expect that the competitors could do. The different scenarios are assessed on how they will score to the award criteria and the associated costs are estimated. The ratio between score and cost determines which scenario is favourable. This is basically reverse analysing the client's request. Contractors look for the criteria that result in most return and adjust their strategy to a level in which they can deliver optimum value; optimising the delivered value and additional investment (BPQR). The optimum depends on the procurement characteristics and to some extent on contractor's strengths. Once a strategy is chosen, is serves as a reference for all future decisions in the tender phase. It is an assessment framework for all choices that the design teams make when elaborating the strategy into a fully conceptualised solution.

[62] Interview with head of acquisition I at contractor E, held May 20, 2019.
[63] Interview with managing director II at contractor C, held May 19, 2019.
[64] Interview with managing director III at contractor D, held May 15, 2019.

'Depending on the size of the project a team sets to work. In case of a very large project dozens of people, up to 80 or so in the tender phase. At the largest projects even more, in the order of magnitude of 120.'[64]

The afore mentioned careful consideration of whether to tender results from the large opportunity costs endured during the tendering process, due to the large teams required to perform proper due diligence in the limited time available. The size of the tender team is also an important consideration, since this is the only variable that the decision makers can adjust to ensure that an adequate offer will be submitted.

'We have common processes for the tendering process itself. To my mind, there has been a time where at these large projects some people almost prioritised the process over the result. That is changing now. You can work according to a process, but if you do not win, it is of no use. With regard to the substance, we always struggle with the degree of detail we need with respect to time and costs.'[65]

The issue of determining the required detail is of key importance due to the size of the team required to obtain that level of detail during the limited time in the tender phase. Moreover, the degree of detail is related to the accuracy and reliability of the offer and thus to the risk that a contractor bears.

'A tender team also puts the assumptions on paper. If a company is organized in a way that employees are awarded with bonuses for the projects that they seize, then they get perverse incentives. Then the team will have just one thing on its mind; we will get this tender! The question then becomes what they write down [as their assumptions which result in the direct cost amount]. Actually, I do not really care so much about the stuff that is written down. To me it is much more interesting what is not written down. If one does not have expert knowledge of the business, one will never find out.'[66]

Consequently, it is hard for decision makers to judge the information that they receive from their tender team. Particularly, whether all the necessary things are considered and checked. In addition, judging whether the choices made were made overly optimistic, too conservative or somewhere in between. Therefore, it is hard to steer the team to be more or less conservative. Subsequently the decision maker is unsure whether the estimated direct costs of construction are an optimistic or conservative estimate and to what extent there is playing room in the margins. There is a relation between how reliable the cost estimate is and what the risk buffer needs to be.

All kinds of procedures and checks are put in place to make sure no mistakes are made. Managing directors C and D explain;

'As standard we scan the project. That is a requirement prior to meeting with the tender board. We have an contract assessment sheet (CAS) for this. Presently, there is a TAS too, a technical assessment sheet. That describes where the technical risks are. You can go on like this; CAS, TAS, RAS (risk assessment sheet), you name it. […] But in the end, with such a contract assessment you consider responsibilities, odd payment or financing agreements. Is it necessary to complete 100% to get payed 25% or something like that. Or payed 75% with the rest retained. In other words, does your pre-financing work out. How is responsibility divided? What is the penalty clause? What are the completion dates, does it fit in your schedule? If you have to work 24/7 from day one or with double shifts, including Saturdays, Sundays and holidays, then you know that you will never meet that schedule.'[67]

'I think that you bring up an interesting issue. Because, I am convinced that, no matter how small a tender is, by definition you can never oversee everything. Especially the projects we do. […] So, that means that indeed the required budget, of which you know that not everything was elaborated is assessed. At the end of the tender, at the moment

[65] Interview with member of the executive board I, contractor B, held June 6, 2019.
[66] Interview with managing director IV at contractor F, held May 23, 2019.
[67] Interview with managing director II at contractor C, held May 19, 2019.

you sign, we collectively and so do I in the end, evaluate whether we dare to take on construction for that amount, because that is the amount I have to do it for. One thing we know for sure; that the next day the project will commence, sometimes it lasts three months but usually three years. For sure, we cannot foresee everything that will happen during those three years. That is what it is all about, did we estimate that correctly?'[68]

4.3 Bid amount decision

The final decision is one of how much to charge for the thought up solution. At this stage this comes down to laying down the final risk provision and a profit mark-up or a discount as the case may be. Contractors perceive this challenge differently. Some say the profit determination is not even a challenge. Recall the quotes from the profit section in the beginning of this chapter in which the mark-up approach is discussed. Usually this view is present at contractors when the mark-up is either fixed or practically predetermined in the reconnaissance phase.

> *'The price is the output. I assume that if we buy a cubic meter of concrete, that someone else buying it too, ends up with the same output. Because when I go to a supermarket and you go to a supermarket, that should result in the same price for a carton of milk.'*[69]

While for others this is still an important consideration, as this quote from a member of the executive board I shows '*The profit is debatable. Partly, it is a commercial consideration.'*[70] Generally, this is the case with contractors with less emphasis on procedures and more room for entrepreneurialism. The observation is that this happens more in privately owned businesses. There, decision makers follow procedures but they have a bigger presence, more input in the final decision.

Consider the approaches below, highlighting both ends of the spectrum. The first is a quote from contractor E, who apply a predetermined minimal percentage that they believe is in line with the prevailing market. In addition, they claimed that it is not an important decision. Given that a few percent more or less does not make a difference in the probability of obtaining the project.

> '*That is indeed in the last phase, risks and what kind of surcharges. Whole considerations can be made, but in the end that is nothing more than a round off'.*[71]

While contractor C makes a commercial consideration for each tender;

> *'At a certain moment we consider the PRGO [in Dutch; WRAK] percentages [profit, risk buffer and general overhead]. There a choice is made. That is a commercial consideration. Sometimes the percentages are fixed. The tender is considered in its entirety. We assess the competition. That is something we have done beforehand. What is our chance of winning? We have optimised your chance by involving the right partners and specialists, made the right design, interpreted the client's whished properly and have the winning strategy. Our policy is not to make modifications to the price. The only consideration we are willing to make is to possibly subtract the tender costs. But, even that, especially with a large tender, we do not want to do because it involves millions. We believe that the tender costs should be paid from the won tender. The profit percentage has been determined in consultation with concern management. Like, this is our proposal, we want this much return. It gets authorized. The risk provision is the output of the Monte Carlo. Some questions come up and it gets adjusted upwards or downwards. That is it. Sometimes if we end up at an odd number we round of to €102 million or something. That is how we do it currently.'*[69]

[68] Interview with managing director III at contractor D, held May 15, 2019.
[69] Interview with managing director II at contractor C, held May 19, 2019.
[70] Interview with member of the executive board I, contractor B, held June 6, 2019.
[71] Interview with head of acquisition I at contractor E, held May 20, 2019.

Considered factors when determining the mark-up

Now the considerations made by the decision makers when discussing the final bid amount are investigated. During the discussion, the decision makers cover a number of aspects:

> *'[Determining a mark-up] deals with a number of aspects. In essence, always the same aspects. However, upon closer inspection, it is different each time but it is always the same corners of the playing field that are covered.'*[72]

Although details change depending on the tender and environmental characteristics, the main factors that are considered with decision-making are fixed. These are now investigated in detail, in which a distinction is made between factors that concern the position of the own organisation and environmental factors.

Internally

The first and perhaps most important factor for contractors is the situation of their own organisation's position. Particularly, the contractor's future workload, as the next quotes show. Besides the own organisation, the entire chain of participating companies and suppliers have a major impact.

Project portfolio

The first thing a contractor considers is his own position. Contractor D explained:

> *'The first is the company itself. How many projects are already in the portfolio? The project types [too]. If we already have six water treatment plants under construction, when we get a 7th, there is no skilled personnel left. Alternatively, [we tender for this 7th] if we still need more projects. Then, we start to drift towards the social psychological side of things.'*[72]

From this response two things can be inferred. First, the workload is important in this respect. It is the first thing contractors consider. Second, not only the number of projects in the portfolio are of importance, but also the types of projects in the portfolio matter. Both have a particular influence on the capabilities of the contractor. In addition, this quote also gives a clue that setting the final amount is not strictly rational. There is a social psychological side to it.

The impact of the project portfolio and the psychological side of decision making are present at different contractors. Respondents working for different contractors provided the quotes below. The next quote highlights how the current portfolio affects decision-making, but this time viewed from an opposite situation, one where the workload is (too) small.

> *'When we would have a few thousand men on the payroll and no projects, then we surely consider projects differently then when we have many projects to choose from. That is absolutely the case.'*[73]

> *'Indeed, that has everything to do with it. It also has to do with whether we live in times of economic growth or a recession. That relates heavily to how the people at the top look at a tender. Because they are ordinary people, not robots. They are not people who only make considerations rationally, based on technology. That is not the case. Fortunately, those people all have their own point of view, are working with their own emotions. Actually, many smaller decisions are made irrationally. If one has a lot of work, then one interprets a contract requirement very differently from when he has few projects. Then one would think 'well that is not so important, I will sweep it under the rug'. When one has enough work, then one will think 'well I will include it [in the risk provision] or I will be sorry in case I run into it'. Will they tell me all of this, no.'*[74]

[72] Interview with managing director III at contractor D, held May 15, 2019.
[73] Interview with managing director I at contractor A, held June 3, 2019.
[74] Interview with managing director IV at contractor F, held May 23, 2019.

Respondents shared their approach of assessing the company's current workload and how they incorporate that in their decision making of current tenders.

> *'The tender schedule is as such that you never exactly know when a project will start. At this moment, all Rijkswaterstaat's projects are postponed [due to legislative issues with nitrogen and PFAS]. All of a sudden we are in a situation where all our anticipated tenders are called off and we have to make new plans. Thus, we keep everything double or triple occupied, so we can reschedule if one is called off. It becomes more difficult to keep our complement of staff up. In that case, we increase our checkmarks [marking more tenders as preferable]. The project that comes next, we take.'*[75]

Hence, not only does the portfolio of projects affects the final offer (workload and types of project), the way it influences varies depending on the economic situation. Criteria, or at least the relative importance of them, change depending on the economic situation.

Supply chain

Not just the own organisation is an important factor in the bid amount discussion. The whole contractor's supply chain determines to some extent the final bid amount. This has to do with the large degree of work bought in from specialized subcontractors and other suppliers.

> *'To get some feeling; about 75% of the work is acquired. Subcontracted work we acquire from subcontractors and suppliers.'*[76]

> *'The supply chain has an influence, depending on the contractor. Keep in mind that as main contractor we purchase between 70 and 80%. So, the influence of supply chain partners on both the price level and construction is huge.'*[77]

Still, some subcontractors are more important in some projects. Hence, some projects require highly specialized work. Therefore, it essential for a consortium to acquire that particular skill, material or equipment.

> *'The fourth is the bottom of the supply chain, the suppliers and subcontractors. For example, when we know that there are five competitors and we have to acquire a particular technology that only two parties in the Netherlands have mastered. Then we are dependent on short supply. When we are aware that the labour market is terribly tight, as it currently is, then we deal with specialized knowhow differently.'*[76]

> *'And there is another aspect. The car industry did it a hundred years ago, but more and more we work with regular partners […] to take away risk. All large contractors would happily accept the next project if all expenses were covered and 3% profit is guaranteed. Which is quite strange actually, that everyone would be happy with 3% after all that effort.'*[77]

Externally

Generally, contractors consider two external areas: the client and the companies they are competing against.

Client

Generally, the client is a factor when a tender is selected. To some, the client is a consideration when setting the bid amount as well, as the following quotes will show. Particularly, if the contractor has a premonition that the relationship with the client will be far from ideal later on, but decide to tender anyway. '*In the past, we let a client know*

[75] Interview with managing director II at contractor C, held May 19, 2019.
[76] Interview with managing director III at contractor D, held May 15, 2019.
[77] Interview with member of the executive board I, contractor B, held June 6, 2019.

that we expected a certain project manager. […] So, we marked up with 10% because we knew it would cost us that much.'[78]

> *'A third aspect is the client. This is an important area since every client is different. [That the client is an important aspect] has to deal with the organisation, but also with the people. Why is that of importance? Because managing your risk profile greatly depends on the client's representative that we are dealing with. Whether he accepts taking certain measures. Whether he opens the door for some additional revenue.'*[79]

To contractor A, the client is less important in the bid amount decision. *'Although there are differences between Rijkswaterstaat, ProRail, Provinces or large municipalities, the people at those organisations know how to deal with issues. We do not deliberately research who the project manager is.*[80]*'* Contractor A feels that it is not necessary to account for a specific client's representative, since all clients have standardized their operation to a large degree. As a result, they do not presume any abnormalities that have to be taken into account.

Competition

To all contractors, the competition is an important external factor to assess.

> *'The second aspect is the competitive field, which always plays a part. We always say 'we do not consider it', but it does play a role of course. […] one has no idea what a competitor does, so it is pointless to form an opinion about it. Yet it still plays a part. Therefore, we estimate how much work your competitor has and whether he desires [the tender]. If our competitor has a lot of work, then we contemplate that he would not be a fierce competitor, so we stand more chance.'*[79]

It is interesting that, although this respondent said 'we do not consider [competition]', he is aware that unconsciously they still consider it. All contractors claimed 'not to consider competition' and 'to believe in their own strength'. However, during the interviews, multiple examples were provided of occasions in which they did consider their competition.

> *'We consider competition particularly in the smaller projects. Competition is a big thing in the market of traditional building contracts, in which the contractor constructs a provided design whilst being supervised by the client's agent [RAW systematiek]. What do we think others will tender for? With the large projects, we do not really look at it that way. We do consider which parties participate in the tender and how much work hunger we expect them to have. But, it does not change our solution. So, we will not consciously mark down 5 or 10% because we expect contractor X to go low. Then, contractor X should do that. It has become that rational.'*[81]

> *'What do we think that the others will do? That is where it goes wrong often, because we think that the direct costs, upon which everything is based, are the same for everyone. Which is not the case of course. Consider the ingenious lock concept of competitor X. There they should have taken into account at least half of the mark-down in the direct costs. We encountered this at a certain project. […] We had an inventive and sustainable method to improve the soil, instead of having to take it all out and backfill and compact it in layers, which resulted in a cost saving of €X million. We discounted the full €X million. Well, the client laughed themselves silly. What we should have done, risk wise, is to discount roughly half the amount. We did not do that, because we were convinced that someone else had the same solution.'*[82]

[78] Interview with head of acquisition I at contractor E, held May 20, 2019.
[79] Interview with managing director III at contractor D, held May 15, 2019.
[80] Interview with managing director I at contractor A, held June 3, 2019.
[81] Interview with head of acquisition I at contractor E, held May 20, 2019.
[82] Interview with member of the executive board I, contractor B, held June 6, 2019.

> *'There are very different views held on [competition]. Personally, I do not bother about what competitors can or want to do. I believe you should start form your own strengths and power. From there you must determine your own construction costs and together commercially weigh up what to do with it. I think in the past we considered too much what others might do and that led to stupid decisions. Like that we think a competitor of ours will make a low offer because they need the work. We have completely moved away from that. We do not do that anymore. We only want projects with a certain internal sureness, that if we win it is under such conditions and price that it will be a good project. […] Competition is looked at beforehand and less so afterwards at the completion of the tender.'*[83]

Despite claims of disregarding completion, it could be observed that competition is an important factor in the mark-up decision making. Contractors consider their competitors not only rationally and objectively, by the number of capable competitors available for example, but also irrationally based on hunches and expectations of what their competitors might do.

Contractor A elaborated on why they attach so much value on sticking to your own strategy and believing in your own strengths.

> *'Particularly if one influences the sentiment, things accelerate. When one starts a tender by telling everyone 'we need this tender, because for example we do not have any work, or it is in front of our headquarters, etc. everyone's thinking switches. The designers and cost calculators all optimise their plans once more. A little less rebar, this beam could be a little bit thinner and the cost estimate can be a few euros less. Everybody starts doing it. And in the end you even commercially cut the amount, because 'we really need the project'. In that case one could know in advance that it will turn into a horrible project. So our target is now: the cost estimate must be right. Our estimators and planners must feel comfortable that the plans are executable; they are constructible in a proper manner, there are some reserves, the price is right. It will take hard work, but it is possible.'*[83]

To conclude, in the contractors' mark-up decision-making, internal and external factors are considered. Internal factors like projects currently in the portfolio and the contractor's supply chain and external factors like the client and competition play a role. These factors remain, while more detailed considerations per factor vary depending on the circumstances. This was clearly displayed with examples on how the current workload affects the mark-up decision differently depending on the economic state.

Commercial considerations

Besides assessing the aforementioned factors taken account in contractors' decision-making, there could be a commercial consideration too. A common example is to discount the offer in order to increase the probability of winning a tender, as Contractors A and C mentioned;

> *'It is disastrous when we do not win the tender. [A large tender] costs millions. It is disastrous when we only get 20% refunded. So, when we tender, we simply want to get it. That is a mechanism in itself.'*[84]

> *'Yet, someone else in the board could make a commercial consideration and decide to mark-up or discount. At least we know that in advance. Then we are in control. […] A number of directors is responsible for the decision, which has to be discussed and approved.'*[83]

Contractor E has a completely different approach to bid amount decision making. One in which the price is not put together with a bottom up approach, based on costs and the minimum required amount to cover costs such as overhead. Instead, a more commercial philosophy is followed by assessing how much you could charge for the project.

[83] Interview with managing director I at contractor A, held June 3, 2019.

[84] Interview with managing director II at contractor C, held May 19, 2019.

'I think that it is also important; what do we think we should charge if we want to get the project is a substantially different question than what would you like to get yourself? It is particularly our board of directors who hold this mirror up to our faces. If we make an offer with 3% profit, are we pleased? Does this make us want to work that hard work for it. It is bit of an insinuating question.'[85]

Contractors also make commercial considerations on other levels. This is most easily noticeable in road projects. Managing director V provided some insight in the business economics of asphalt road projects.

'As an asphalt road constructor, we are aware of the locations of asphalt plants nationwide. It is most profitable to construct roads in the vicinity of our plant. Then we are always cheaper [than your competition].'[86]

However, despite this simple concept of increasing costs with increasing transportation, a contractor's business case is not as clear.

Things become blurry when one considers that contractors are not only service providers by offering the service to complete a project or to provide the means of transport for motorists from A to B in a certain timespan, but that they are producers and traders too. Many large contractors have their own asphalt, concrete or timber plants. Moreover, contractors buy materials and services from suppliers and subcontractors and sell this to the client. Hence, contractors make their profit not only by the profit margin they put on a project, but also from their production and trading. As a result, contractors are partly revenue oriented. This heavily affects the decision-making;

'[…] they need the revenue to facilitate production. It becomes almost impossible to decide [not to tender] for a project in province X, if we need a [certain] revenue [to be able to cover the cost]'.[86]

This indicates that the decision makers are dealing with a production mind-set. Running a production company is about focusing on unit costs of production. This is contrary to a project organisation mind-set, with a mark-up approach and the aspiration to optimise the profit of the project.

When infrastructure contractors with own asphalt plants do not have a project, they cannot make a profit on a project since there is not one. Moreover, their machines are not running and more importantly, their plant is not running. This results in losses on many levels. This could explain why contractors are often eager to take on a large project despite the large risks involved. A large project results in substantial revenue. This revenue provides them with the opportunity to cover their fixed costs.

'When we have a few very large road projects, then our plants already have the required production to be cost effective. Therefore our plant is profitable and we are able to take on additional work more easily'[86]

Managing director V elaborated why it becomes easier to take on additional work, highlighting the decision maker's thought processes that take place.

'A plant has to produce 200,000 ton to be profitable, for example. When we have produced that, the next ton is a lot cheaper than the first 200,000 tons.'[86]

Contractors determine the price level of a ton of asphalt on the estimated annual production. The fixed costs of the plant are divided by the expected production to determine the variable costs per ton. When the expected production is reached, enough money has been made to cover the fixed costs of the plant. Additional production is then

[85] Interview with head of acquisition I at contractor E, held May 20, 2019.

[86] Interview with managing director V at contractor F, held August 19, 2020.

offered for the fixed costs only, so for only the material costs. This makes additional production mathematically much cheaper.

Although contractors are businesses and hence profit driven, they opt not to keep the same price levels and make a profit on the additional production as an ordinary production company would do. Instead, they choose to lower their price levels to increase the probability of acquiring another project. This mechanism was recognized by managing director III, who anticipated this kind of behaviour when assessing the competition.

> *'Others have dredging, asphalt or companies […] that is something we deliberately take into account in the final bid consideration. When it concerns a competitor who will take on the project with his own plant, which does not need to make a profit now because they have reached their production level, then we know that they will discount. So, we have to make up for that somewhere else.'*[87]

4.4 Mark-up models

Statistical analysis

Many contractors believe that it is currently not possible to apply statistical mark-up models or even to perform sound statistical analysis. Contractors A,B,D, E and F have all tried to apply similar statistical approaches to support their decision making. However, the amount of data required to perform sound statistical analysis proved to be a challenge.

Contractor F has tried to apply a statistical approach to its mark-up decision making for regional projects. Unsuccessfully however, as they were limited by the amount of data they had. Contractor A drew a similar conclusion; *'That is only possible if there is a pretty high degree of repetition involved in the work.'*[88] A high degree of repetition is required to gather enough data on the competitors to infer statistically valid conclusions.

Current databases are not sufficient to perform such statistical analysis. Databases are often set up for different purposes and therefore not usable. Managing director I explained that their company has an extensive database with all their completed projects, projects under construction, projects in tendering and potential upcoming projects. Although such an extensive database is useful in the decision to tender and to derive heuristics and key figures from, it not suited for statistical analysis.

> *'It is project oriented, which complicated things. There are a lot of road projects in it, still they are all different. One could include a bridge, while another has a tunnel and the next could have several railway crossings. We could not derive anything useful from it.'*[88]

Even when one considers projects that appear to have a lot of repetition, it is still hard to infer meaningful information. Consider maintenance work of asphalt highways for example;

> *'In that case we know that the scope is comparable. Well, actually we do not know that. In asphalt maintenance projects often the top layer from kilometre X till Y is replaced. However, there is also some correction of the profile required. That is the case with almost all of those large asphalt projects.'*[89]

Although projects may seem comparable at first sight, there is a lot of variation resulting from different environmental contexts. This makes it hard to gather enough comparable data and thus to infer findings accurately. Estimating the competition is even harder, even for the less complex projects like asphalt maintenance. *As head of*

[87] Interview with managing director III at contractor D, held May 15, 2019.
[88] Interview with managing director I at contractor A, held June 3, 2019.
[89] Interview with head of acquisition I at contractor E, held May 20, 2019.

acquisition I elaborated on the questions they face when trying to assess competitor behaviour; 'How much will your competitors charge for it? […] Do they calculate the execution of the work in just one weekend or will they spread it over several smaller nights?'[90] It proves difficult to infer accurate insights, since many of the competitors' potential motives are hidden. Hence, contractors have focussed on the big picture first. '*We have tried to extract a common thread. We could say that we were X percent more expensive on average. However, would you subtract that at the end? No, that is undesirable.'*[90]

Another reason why statistical mark-up approaches are not considerd useful is related to the procurement characteristics of large Dutch infrastructure projects. Contractors are challenged to design their own solution, subsequently different solutions are offered. Moreover, awarding a project is not just based on price. This restricts the applicability of the statistical mark-up models.

Head of acquisition I commented; '*I do not have much faith in [statistical mark-up models]. That would mean that this works if everyone comes up with the same solution. Thus, it might work for projects with just a construction contract [in Dutch: RAW bestekken]'*[90]*.* This is consistent with the response of contractor F, who replied that statistical approaches are more useful for regional projects, since these are more often procured as a construct only project.

In addition, procurement procedures are tuned in such a way that offering the right solution is very beneficial in terms of the rewarded BPQR value. So much so, that a few percent difference in the mark-up does make enough of difference to compensate for a suboptimal solution.

> *'It does not yield enough. What is lacking here is that the technical component in the direct costs of a smart solution is that large that it does not matter anymore. However, we ignore that, because we think that everyone has that [smart and innovative] solution.'*[91]

The next managing director does not think that is the result of the limited data, but that it does not model the decision making appropriately. The mark-up decision is not taken based on data only, whilst statistical mark-up models are.

> '*It is applicable for sure, but I do not think that you come close to reality. You oversimplify to such a degree that the output looks more exact than that reality is. […] It is about soft criteria. It are estimates, judgements, feelings. It is more social psychological.'*[92]

'One could try to capture that.'[107] However, this managing director III is afraid that decision makers would not consider it in their decision-making. '*There is a mentality of; what does this [output] figure tell me? That [an analysis] results in a mark-up suggestion of X percent.'*[92] Managing director B point out that decision makers have a tendency to disregard information when it does not conform to their expectation. *'I still think it is a shitty customer.'*[92]

The same behaviour occurs when the output of other analyses are considered by the decision makers. This is illustrated with an anecdote regarding risk analysis;

> *'After a complete Monte Carlo simulation which results in a output of a risk provision of 1,96%. Then someone will say 'However, we always charge at least 3% with this kind of projects. Thus, I do not believe the 1,96%. So, use 3% or more.' That is how it goes.'*[92]

[90] Interview with head of acquisition I at contractor E, held May 20, 2019.
[91] Interview with member of the executive board I, contractor B, held June 6, 2019.
[92] Interview with managing director III at contractor D, held May 15, 2019.

Decision makers have the tendency not to adopt the output of an analysis. Instead, they judge the outcome by their expectations based on their experience. They rely so strongly on their heuristics and feelings that they disregard new information if it does not align with their expectation.
Contractor F thinks that statistical methods could be useful to support decision makers. Not so much by suggesting a mark-up as output, but more so by providing insights into competitors' decision making by uncovering trends in their past behaviour which could help to predict future tendencies.

> *'One could generate the price. Because that is the behaviour of certain parties in terms of their price level. One could discover patterns. That could be seasonal patterns, but also patterns such as competitor A has lost the previous three tenders, so he will do anything in his power to win this time, like he has done in the past. This could also be done on BPQR. You should be careful though because BPQR criteria can be used in a variety of manners. So you should carefully assess whether you can make a statistical analysis. […] That requires very precise data gathering and not every client is that open with sharing how our competitors performed. There are clients who announce only the sequence from best to worst performing contractor. I cannot put that into my statistical methods.'*[93]

One contractor objected to the use of statistical mark-up decision models. His disapproval has to do with estimating the bidding behaviour of competitors. Contractor C claims that he does not know who its competitors are, let alone the bid amount they will submit. '*That is my biggest concern. Because, we think that we can do that. Resulting in offering too little. That is precisely what not to do.'*[94] This again displays the restraint to consider competitors. Since this has led to unhealthy low price levels in the past. Now they preach not to be guided by what competitors might be doing, but to rely on their own processes. Believing in your own strength is an often-heard mantra. *I do not want to make a loss. I cannot emphasize that enough.'*[94] Yet, as with other contractors who preach to consider competitors and to stick to their own approach, contractor C still considers competition anyway.

> '*Of course, we look at who the competition is and what they will offer; then we look at the amount of work they have. […] We do not assess statistically what another party does. Above all, I want to know what we do.'*[94]

Interesting though, Dutch contractors lag behind in this respect of data gathering. Some of the interviewed contractors have collaborated with foreign contractors. Therefore, they are aware of their state-of-the-art. In comparison to other contractors capable of executing large infrastructure projects, the Dutch contractors have little information.

> *The larger foreign contractors have more detailed databases. They are able to produce a detailed cost estimate at subsection level based on past data.*[95] *There are parties that use massive databases of projects, including risks based on the project's characteristics.*[96]

[93] Interview with managing director IV at contractor F, held May 23, 2019.
[94] Interview with managing director II at contractor C, held May 19, 2019.
[95] Interview with managing director I at contractor A, held June 3, 2019.
[96] Interview with managing director I at contractor A, held August 12, 2020.

Game theory

Game theory is a technique that all decision makers have heard off. The following quote by contractor E is representative for the general mind-set towards game theory radiated by the interviewed contractors; *'I know of it, but we have never applied it'.*[97] Most contractors do not realize the potential of game theory to support bid amount decision making, as does contractor F; *'I understand game theory, but I question the benefits it offers me'.*[98]

In general, a strong hesitation was felt to consider and take into account external factors, like the competition. *You should ask yourself if you should let yourself be guided by the competition with this type of projects. I think that it is unwise.*[98] Contractors only allow themselves to consider the competition at the start of a tender, to assess whether it is worthwhile to make the investment to tender. *'We focus less and less [on competition]. At the start we do; if it is a tender with ten competing contractors then we have no business being there.'*[99] Contractors stay away from assessing competition at later stages to prevent overestimating competitors' strengths, which could lead to an urge to make an even more competitive bid.

> *'You determine what you will do, based on what you think others will do. Then, I think, you let yourself be guided a lot by what others are going to do. I wonder if that is healthy, because others can make mistakes too.'*[98]

Still, contractors do consider their competition, subconsciously or not. *Competition is always a factor*[100], as was touched upon in the section covering the considered factors when determining the mark-up. The next quote highlights how and what type of information contractors can gather regarding their competitors.

> *'Through the grapevine we hear from suppliers what others have requested to quote. That gives us some notion [of what a competitor might offer]. However, we disregard this information, because it is too late. It is pointless [to make changes to the design]. We made the choices in the beginning. Now we must elaborate and optimize it. There is no action-reaction.'*[99]

Contractor C previously said that not knowing his completion was his biggest concern. Later on in the interview he elaborated;

> *'Often, we know our competitors. There are not that many parties. Moreover, occasionally we run into each other at information rounds. It happens that we estimate which choices or strategies potential competitors will take.'*[101]

Contractor B explained how they get a "feeling" for the margins on risk and profit that a competitor might apply;

> *For example, what would competitor X do now? We see that competitor X invests heavily in the urban environment […] What is their risk appetite then? Well, that will be always be less than competitor Y or Z. Especially competitor Z, because they have too little projects. […] So we say; they will make an offer with less profit. […] That is how we go down the list [of potential competitors].*[102]

Although contractors can determine whom their likely competitors are and get some insight in what they might offer, they are still critical on their ability to make predications on their competitor's behaviour.

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[97] Interview with head of acquisition I at contractor E, held May 20, 2019.
[98] Interview with managing director IV at contractor F, held May 23, 2019.
[99] Interview with managing director I at contractor A, held June 3, 2019.
[100] Interview with managing director III at contractor D, held May 15, 2019
[101] Interview with managing director II at contractor C, held May 19, 2019.
[102] Interview with member of the executive board I, contractor B, held June 6, 2019.

'We just do not know what our competitor is doing. So, we must consider his previous tenders. A project like the Afsluitdijk happens once in 80 years. So, you cannot predict how it will unfold. Hence, we do not really believe in analysing a specific moment and what the competitor may do. We do look at competitors. When there is a tender with a lot of dredging for example and we do not have a strong dredging partner, then we should not tender. Because we do not have the right competencies.'[103]

Contractor C elaborated by discussing a past tender;

'Subconsciously we are consistently engaged with [our competition]. Recently we had a tender with only two tenderers. That tender had a large design BPQR component. […] In such a situation, we consider what the competitor might do, of course. That goes through our head. We had an [architect] and [architects] are not concerned with that at all. They have their own vision. It is about steering based on our vision. Being enthusiastic about it, about our strategy. […] That is a choice made in the beginning. Then we follow [the chosen strategy]. But when one is constantly considering what the other does, then one constantly goes back [on your plans] […] However, [changing strategy] has an impact in terms of money. That is undesirable. We want consistency, believing in our own strength. It is most important to deal with that at the beginning, then we have most influence, we make the least costs. In the end, our only option is to spend more money. The further we get with the design, the more things become fixed. So we have to utilize the front end by making the right choices then and checking it a few times along the way.'[104]

These responses show that contractors are able to gather some information concerning against whom they are tendering. In addition, they consider which courses of actions to take in terms of what solution a competitor might offer. However, they emphasize to not let this information affect the internal processes that were set in motion, separating this information from the mark-up decision.

Managing director III shed some light on his considerations during the endgame of a recent tender. The reasoning he followed depicts that he used game theory, even though he was not aware of it. Conveniently, the tender in his example was the same tender as C elaborated on. In this tender there were only two parties tendering. There had been some communication between the parties and the client regarding the price ceiling and the limited competition. Hence, both contractors were aware that they had only one competitor in this tender.

'I estimated that my competitor would make a nice but austere design. Therefore, I thought that he would have a cost price of X + 15%. I thought that we could make a more beautiful design, with more added value. So, I gave my tender team the freedom to devise scenarios and make an offer of X+15%+15%. I did that because I expected to recover 20% [due to the added value an additional investment of 15% would yield.] So, I spent 10% more and assume that I get a fictitious discount of 20% and still win. Although I am the most expensive one, I win. That was my strategy.'[105]

The managing director considered several incremental options for the offers that his company and the competitor could opt for and adjusted his strategy accordingly. Without realizing it, he applied game theoretic reasoning in his decision-making.
When another tender was discussed, it showed that elements of game theory are sometimes present in the endgame that the final offer is decided on.

'During a tender the prices oscillate to a value. What remains are the final assumptions that we make in the last week. Note that when we win a tender, we are not done yet. Not all sections are detailed out, quotations have not yet been received for everything yet, and agreements with other subcontractors may not be finalized, so there still is some margin for improvement or deterioration. […] In this tender we had to make four plans, each plan

[103] Interview with managing director I at contractor A, held June 3, 2019.
[104] Interview with managing director II at contractor C, held May 19, 2019.
[105] Interview with managing director III at contractor D, held May 15, 2019.

is scored with increments of a fictitious discount €X on a four point scale. However, if a certain bid amount level is exceeded, we only got half the discount. So the client stimulated to remain under that price ceiling level. So, I said; I want to stay below that level if it is sensible. And I said, I want to be competitive, with a reduction of (X + €50.000).'[106]

Deciding on a reduction that just exceeds X is strategic behaviour on which the managing director elaborated;

'If we would both make an offer at the price ceiling and my competitor scores one step better on one of the plans, then he wins. I do not want that, so I discounted €50.000 so that I win arithmetically.'[106]

Decision makers are mostly focussed on their own tendering process. They aim to produce the best offer, based on their own strengths. Still, there is some game theory involved. This takes place at the beginning and at the end of the tendering process, at those moments their view broadens. When deciding whether to tender, contractors consider their own position, their supply chain, the client and briefly the expected competition to determine if tendering is feasible. When deciding on the final offer, these same items pass under review. Every tender has its unique aspects, which can be used by a contractor for strategic behaviour. This behaviour can sometimes be anticipated and taken into account, as the provided examples showed.

Multi-criteria mark-up models

As became apparent throughout this chapter, contractors consider a wide range of factors in their bid amount decision making. The interviewed decision makers mentioned assessing the workload, contract conditions, risks, the client, partners and supply chain and competitors. As one might expect, this mark-up model is recognized by the contractors in their decision-making. *'We use it to get a general picture of a tender.'*[107] *'I think we use this subconsciously.'*[108]

However, it took the respondents some effort to identify this approach in their decision making. On one hand because it is not used consciously. On the other hand, it is not specifically used to determine the mark-up, but more generally to determine the best course of action during a tender.

'[…] differently from [in theory] and not with just a mark-up suggestion as output.'[107]

'Honestly, I think we do this. In fact, but not consciously with a checklist or a measurable system. […] It is to nourish our gut feeling, 'we have to go this way'. That is why we do it. This will become clear in our substantiation of why we want to offer a certain price. We want to offer this amount because this is our strategy and we think to distinguish ourselves in this way, we have a solution of which we think that the others do not have it, resulting in this much advantage. That is what it results to in the end. So I think you can say that based on proper arguments we determine what we want for it.'[108]

How this respondent started his response points towards a difficulty felt to determine whether a contractor was using a multi-criteria approach in their bid amount decision making. This was observed during other interviews too; *'I am contemplating whether we use multi-criteria decision making.'*[107]

In Dutch contractor's procurement practice multi-criteria decision takes place mostly subconsciously, it is not structured in a process or procedure. In addition, multi-criteria

[106] Interview with managing director III at contractor D, held May 15, 2019.
[107] Interview with managing director I at contractor A, held June 3, 2019.
[108] Interview with head of acquisition I at contractor E, held May 20, 2019.

decision-making is not used just to determine the bid amount in a final meeting. It is more commonly used in the preceding stages, to get a feeling or general picture of a project. This occurs most noticeably and deliberately during the decision whether to participate in the tender or not. Consider the multiple criteria that contractor A mentioned to consider at that early decision moment; *'It is always the big picture. The cost price; how much is it, where are the largest chunks? The risk analyses; where are the general risks, the large risks? And many more criteria.'*[109]

Other contractors made similar comments. Contractor E uses '*many lists of items that they try to rank relative to each other. Every trade-off matrix does the same, right. We try, as early as in the strategy phase, to sketch scenarios regarding how we can score BPQR value and what the price level will be on a number of aspects.'*[110]

While contractor A elaborated on additional factors that they consider;

> *'The entire sentiment [of how satisfied we are with each of the factors] and the yardstick, that is what we are dealing with during a tender. That concerns the contract conditions, the technology, the location and the client. These kind of issues play a part.'*[109]

Contractor E acknowledged considering multiple criteria in his decision making, while stressing that this is not always used consciously.

> *'Perhaps multi-criteria mark-up models are similar to what we do in our heads. […] [In the models] it is very deliberate; we do it a bit more subconsciously. Still, I think that we take the same steps in our decision process*.'[110]

Similarly, contractor B too recognized subconscious use of multi-criteria decision-making in their processes. *'This reasonably corresponds to what is happening, be it less explicit. [The scoring of factors] does not happen objectively, often, it is based on feelings.'* The process of tuning the offer's BPQR corresponds better to deliberate multi-criteria decision-making, *'then we really consider how much money we utilize in which area to get result X. However, we do not in the final decision. Than we fall back to our feelings.'*[111]

Multi-criteria mark-up models could serve as a mirror for tender teams, as managing director III pointed out. As a check whether all necessary items are considered. *'Therefore I think that multi-criteria models are very meaningful in the process of determining a bid amount based on a cost estimate.'*[112] At contractor E potential was seen in multi-criteria support models as a way to reflect and compare their mark-up decision making.
'Perhaps it is a good idea to make it very explicit for once and see what happens. To see whether your own thought process matches with what you can actually conclude from your considerations.'[110]

Managing director III further suggested using a financially oriented multi-criteria analysis. He provided an example concerning a certain environmental aspect.

> '*When we are constructing in the city centre of [a large Dutch city], the question is whether the troublesome neighbouring people will make us lose money or make us profit as a result of additional works. Rated on a scale ranging from -5 till +5 for example. Do we think that the client will be pleasant or thwart, so that we make or lose money?'*[112]

[109] Interview with managing director I at contractor A, held June 3, 2019.
[110] Interview with head of acquisition I at contractor E, held May 20, 2019.
[111] Interview with member of the executive board I, contractor B, held June 6, 2019.
[112] Interview with managing director III at contractor D, held May 15, 2019.

'I have no desire for a number as output. I can do that myself. It comes down to identifying the aspects that can affect the outcome of the project.'[113] Managing director III elaborated how a multi-criteria analysis can be incorporated into his decision-making by indicating which factors could make a positive or negative contribution to the outcome of the project:

> '*In essence, the bid amount consists of the direct costs, indirect costs and a mark-up; general overhead, profit and risk. We distinguish calculated risks [foreseen risk analysis with a Monte Carlo simulation] and some provision [to cover unforeseen risk]. Considering that provision in particular […] when all signs of your multi-criteria analysis are red, indicating that we could lose money on all kinds of aspects, then that is a good indication for me to increase that provision.'*[113]

Also, contractor E hinted in this direction, of a tool that can provide an overview of the uncertainties in a tender so that decision makers can adjust their decision making accordingly.

> *'I think it should be an overview of all uncertainties that you have, when you consider a tender. That determines what your [price]level becomes in the end. You do not have to consider the things that you know for sure. Risk profile, have we taken everything into account, the complexity of the project, can we oversee everything already, the degree of design detail, uncertainties regarding the people in the team. They are all human, some are better in certain things than others. Worse still, I know that for some I have to curb their enthusiasm and goad others. These are the factors that should be included, they always play in the back of our minds in the endgame.'*[114]

Member of the executive board I suggests that different mark-up models can be used in conjunction, to enhance each other. For example, assessing your competition and concluding that most likely a low offer will be made, is in line with game theory. This information can then be brought in a multi-criteria model to incorporate it into the decision-making. Alternatively, vice versa, to better estimate a competitor's position, a multi-criteria analysis can be scored as if you are that competitor. Similar as to how contractors now estimate how others will score on BPQR criteria.

Multi-criteria decision models could also serve as a tool to measure the sentiment of key personnel which makes it useful for other decisions too. *'I would like to use it for the tender decision instead of the mark-up. Maybe everyone is enthusiastic about the project, but the objective analysis shows that perhaps we should not participate.'*[115] In addition, the multi-criteria model could be scored again when the tender is completed. This could be a way to see *'whether your feelings were correct. Were we able to identify the items which we could exploit?'*[115] Discussing the differences may produce valuable insights, such as aspects that might be overlooked or not assessed objectively.

Still, some criticism was expressed towards using multi-criteria decision models in support of the mark-up decision. This has to do with scoring the alternatives. Contractor IV uses multi-criteria analysis in their decision making of alternatives and other technical considerations. '*Technical criteria can be scored rationally. By calculating the reliability or vehicle lost hours.'*[116] However, he is concerned that applying multi-criteria analysis to aspects that are hard to quantify, makes the analysis very subjective.

[113] Interview with managing director III at contractor D, held May 15, 2019.
[114] Interview with head of acquisition I at contractor E, held May 20, 2019.
[115] Interview with managing director II at contractor C, held May 19, 2019.
[116] Interview with managing director IV at contractor F, held May 23, 2019.

5 Analysis

In this chapter the obtained picture of processes that Dutch contractors follow to determine the bid amount are compared with the findings of the literature study.

The bid amount structure

In literature, the 'cost plus mark-up pricing model' is a widely accepted concept to determine the bid amount. According to this model, a bid is composed of the project's cost, subdivided into direct and indirect costs, supplemented with a mark-up. Broadly speaking, this approach is confirmed based on the observations and data obtained from Dutch infrastructure contractors. They first estimate the construction costs, which they mark-up subsequently. Dutch contractors distinguish direct and indirect costs in this process, which is in line with mark-up theory.

Furthermore, the theory presumes that construction costs are marked-up with contingencies, overhead and a profit as return on the investment (Shash, 1993). This too is in line with the contractors' approach, who regard the mark-up as the total of a risk provision, general overhead and a (pre-tax) profit margin. This means that the cost plus mark-up pricing model, introduced in chapter 2, can be applied to model the Dutch tendering process of large integrated infrastructure projects.

Nevertheless, there are slight differences between theory and practice. Some mark-up models, such as the one described by Yuan (2011), have a different view of what the indirect cost ought to be. Yuan considers that indirect cost consist of overheads; a project overhead and a general overhead.

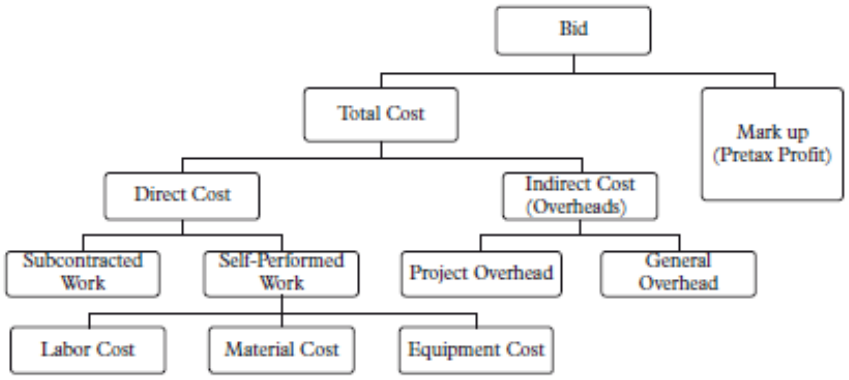

Figure 22 - Bid amount structure by Yuan (2011)

Dutch contractors typically include foreseen risks in the direct construction costs and unforeseen risks in the mark-up by means of a risk buffer. While the mark-up model's project overhead may be similar as what Dutch contractors regard as indirect construction costs, general overhead is not included in the indirect cost, but in the mark-up. This implies that in some theoretical models, the mark-up only consists of pre-tax profit. In these models, risks, if considered at all, are included in the project overhead and thus in the indirect construction costs, instead of in the mark-up as generally is assumed.

Therefore, although the cost plus mark-up models generally are applicable to the Dutch tendering environment of large integrated infrastructure projects, one should be careful and verify that this is indeed the case for the specific model under consideration. If not, a risk provision might be overlooked by some models.

Bid amount determination process

It is challenging to determine the optimum bid amount. A complicating factor is that there are a multiplicity of procurement procedures for large infrastructure projects. A variety of multitude of project delivery models exists and in addition different procurement procedures are available to contracting authorities. Although public procurement law is becoming more uniform due to increasing European legislation, there are still differences among national legislations. Within the Dutch legislative framework, different building contract models exist; the traditional model, the early contractor involvement model, the integrated model and the alliance model (Bruggeman et al., 2010, p. 25). In addition, there are different procurement procedures that a contracting authority can select. Besides this multitude of building contract models and procurement procedures, there are several award and selection criteria used.

This makes the tendering process itself highly dependent on the client and the specific project. For large integrated infrastructure projects in the Netherlands, the pre-eminent contracting authority is Rijkswaterstaat; the executive agency of the Ministry of Infrastructure and Water Management. Rijkswaterstaat uses integrated contracts (UAC-IC conditions) for large integrated infrastructure projects. Rijkswaterstaat applies open and restricted procurement procedures and bases awarding on Best Price Quality Ratio (BPQR), Lowest lifecycle cost (LLC), and lowest price. Of these procedures, BPQR is currently mostly preferred (Rijkswaterstaat, n.d.-b). Moreover, depending on the project's objectives and characteristics, different BPQR criteria and restrictions like a set price ceiling are used.

Mark-up models have traditionally been developed for situations with the traditional project delivery model. Situations where the client provides a detailed specifications of the object to be constructed and where the contractor is in only charged with the construction the object according to the provided specifications. Moreover, projects procured with the traditional project delivery model generally are awarded based on lowest price. As a result, most mark-up models do not conform to the complexity of the procurement process of large infrastructure in the Netherlands, since these are procured with an integrated project delivery model and not awarded on lowest price.

Furthermore, tendering is a knockout system, in which the offer is not considered if it does not meet the requirements of procurement process as set by the client in the tender guideline. Since Rijkswaterstaat dictates how the tendering process takes place and what type of contract is being sought, the contractors must strictly abide by these procedures. Hence, the generic tender procedure with similar phases is visible in all of the contractors' procedures too, particularly concerning the decision moments. However, contractors go through additional steps during and in between the specified and mandatory phases.

From a client's perspective a tender consists of three main stages; preparing of a tender, tendering itself and awarding. The tendering phase in turn consists of; a publication of a contact notice, information rounds, applications to the tender, a bid submission and finally the awarding of the project.

In procurement literature little attention is paid to the bid amount determination process by contractors. More common are descriptions and discussions of the tendering process itself. Such processes are, in general, descriptions of the procedural steps from the perspective of contracting authority. Meanwhile, the steps that a contractor takes are less well-known.

The limited literature available that describes contractor's processes presumes that contractors take four steps in their bid amount determination process (Wilson & Hillebrandt, 2006);

1. Considering whether to participate in this tender,

2. Estimating the construction costs,
3. Assessing the lowest price worthwhile to undertake the project,
4. Determining the mark-up.

Interviews with key contractor's personnel who are involved on a daily basis in the tendering process of large infrastructure projects, shed some light on the current practice of Dutch contractors. An approach with distinct phases, subdivided by go/no go decision moments has been observed at all of the interviewed contractors. Such a process with distinct phases and clear decision moments is typical for a project management approach.

To make sure contractor's offers meet all the requirements and conform to the timeline of the tender, contractors defined their own processes, checklists and templates. Although contractors defined their organizational procedures, they ended up with similar phases; reconnaissance, prequalifying and selection, tendering and submission of the tender offer. Note that these steps differ from the steps presumed in literature.

Contractors start with a reconnaissance phase. During the reconnaissance, contractors continuously scan for potential upcoming projects. Once a potential project is identified, it is tracked. When the potential project is likely to evolve into a tender in the foreseeable future, contractors start to make arrangements with partners. Pre-bid agreements can range from just expressing the intention to tender together once the tender starts, to detailed agreements where the mark-up percentages for risk, general overhead and profit are outlined.

In this initial reconnaissance phase, the first go/no go decision is made. Managing directors assess the potential project. Based on preliminary information and multiple criteria they decide whether the project is interesting. That is, does the project fit the contractor's capabilities and business strategy and is there confidence that they have a chance of winning the tender. When this is the case, a consortium as a whole enters the tender.

The next phase is the first tender phase, the qualification and selection phase. In this phase, the number consortia that applied to tender is reduced to five or three. The selected consortia receive the tender documents; a description of the project, a tender guideline, contracts and BPQR criteria. Upon receipt, the documents are scanned to check that the contractor's assumption made in the reconnaissance phase still hold. When this is the case, the next phase begins.

The following phase is the tender phase. This phase starts with the formation of a tender team, which is charged with the day-to-day management of the tender. In the tender phase a design is elaborated based on a predetermined strategy. This strategy ensures that the contractor optimized his BPQR of the offered solution. Multi-criteria matrixes are used to guide the decision making during this phase. During the tender process the consortium's solutions become more detailed. Simultaneously, the costs of the devised solution are estimated. This is an iterative process, in which design and costs are optimized.

Generally, as time passes and designs become more detailed, so becomes the associated cost estimate. This is in line with what project management theory presumes. Cost estimating moves away from key statistic figures towards detailed considerations of the materials, equipment and personnel used and their costs. Yet, the assumption that the design and cost estimate becomes increasingly accurate does not always hold. Contractors choose carefully which items to detail out, to save time and money. When the design and costs are sufficiently determined, usually to the point that the uncertainty is 5 till 10%, a risk analysis has been performed and the tender documents are written, the last phase commences.

The last aspect for the decision makers is to determine whether to submit the tender documents and to determine their final offer. The decision makers gather and discuss the tender. They have received the tender documents and condensed assessments of risk, contract conditions and technical issues. The decision makers consider this information, supplemented with their experience and additional information such as the project portfolio and the degree of capacity utilization. In general, four aspects are considered; the project portfolio, the consortium and its suppliers, the client and the competition. Discussing these four aspects leads to adjustments in the mark-up items of a risk provision, general overhead and profit to determine the final bid amount that is submitted.

Literature states that contractors first consider whether to apply for the tender, then go through the selection phase, elaborate their tender proposal and estimate the associated costs. Then they assess the lowest acceptable worthwhile price (or lowest mark-up) at which the work should be taken on and finally they set the final mark-up (Hillebrandt, 2000; Wilson & Hillebrandt, 2006). The obtained picture of the tender processes at Dutch contractors involved in large multi-disciplinary infrastructure projects differs from what the limited theory on contractors tendering process presumes. These discrepancies are now discussed.

First, the interviews with Dutch contractors uncovered that they do not simply start with the decision whether to participate in the tender. Instead, they have appointed someone to track the project as early as possible. Commonly a project is tracked years prior to the invitation to tender. From the first indications of an upcoming project in government's multi-year infrastructure programs or when it is discussed in local and province councils. From this early on contractors sound out potential partners about participating in a consortium to undertake the projects. Well before the project is officially announced and contractors are invited to tender, contractors have partnered up and signed declarations of intent. It is in this early stage that the mark-ups are discussed and roughly agreed on. That contractor's processes start earlier and that important agreements are already made this early is not yet taken into account in literature.

Secondly, another interesting discrepancy is that none of the contractors in the population reported to determine a minimum acceptable bid amount. In other words, an important step in the selection process for the bid appears not to be present. In spite of the protection this could offer against offering a bid amount that is too low.

Thirdly, estimating the project costs is not a one-time activity, as literature leads to expect. Cost estimation happens throughout the contractor's tender process. Starting with rough estimates based on key numbers prior to the contract notice. During the tender phase, the costs associate with different alternatives are estimated to provide input for the selection of a final design solution. This final design solution, once elaborated, is subsequently estimated in more detail. Hence, estimating the project's costs is more of an iterative process than presumed or displayed in literature.

This is related to the integrated project delivery model that Rijkswaterstaat requests for large infrastructure projects. Once again literature assumed a traditional model, in which Rijkswaterstaat as the client would provide the design and specifications. However, this is not the case for these projects in the Netherlands. The contractor has to design and construct the solution. Since, at the early stages of the tender, the design is not finalized, a contractor cannot simply determine the project's construction costs by multiplying the items that make up the design with a monetary amount required to build it, based on a list of unit prices.

Fourthly, with mark-up models in literature, the final bid amount decision is a clearly defined decision moment. In practice, respondents sketched a process that is much

fuzzier. At first glance, there is a clear decision moment to pinpoint. However, upon closer inspection, this decision moment is often a formal one, authorizing the submission of the final offer rather than an extensive contemplation process regarding the bid amount. In fact, the final decision concerns either the application of predetermined percentages for the mark-up, or authorizing a mark-up suggestion made by the tender team, or marginal adjustments upon mark-up agreements made with consortium partners well in advance of the tender.

The foundations for the bid amount decision seem to be in place long before the final decision. If one assumes to make a difference in the outcome of the tender just by setting a mark-up at the end, they will have a rude awakening. It is simply too late. Not only are contractors bound by prior agreements with consortium members regarding the mark-up, the entire elaboration of the offer has been according to a certain strategy. For example, to provide an innovative, high quality solution for a fair price, or a basic solution for a competitive price. When the designs and plans are complete, it is too late to change your pricing strategy. The costs and value of the offer are already set. Thus, the bid amount decision is not one decision moment at the end of a tender, but evolves gradually over time. This aspect, of prior agreements that dictate the final bid amount decision to a large extent has not been incorporated in a mark-up model yet.

Factors in decision making

The decision makers consider multiple aspects in their bid amount decision making. To contractors, the most important aspect seems to be their own position. The portfolio of projects has been mentioned multiple times as being the first aspect a contractor considers. The project portfolio impacts a contractor's business in two ways.

First, the projects in the portfolio are directly related to a contractor's revenue. This affects decision-making depending on the contractor's ability to cover their costs. When their revenue is low, meaning there are few projects in their portfolio, their main objective becomes to increase revenue. This gives them an opportunity to cover the costs. To do so, they are willing to lower their mark-up. Reasoning that improving the probability to obtain a project with no profit mark-up is always better than to have a smaller chance to obtain a project with a profit. In the first case, at least they are able to pay their personnel and equipment. In the latter, there is a greater risk of not obtaining the project, having too little income whilst having thousands of men on the payroll. While in a situation with already sufficient projects in the portfolio to cover their costs, contractors allow themselves to be more risk averse, by increasing their margins and risk provision.

Second, the type of projects in the portfolio matters. When a contractor has a number of similar projects in its portfolio, it becomes increasingly difficult to mobilize the required skilled workforce for additional projects. As a result, decision makers become hesitant and increase their mark-up. Their reasoning could be that it does not harm them much if they do not obtain the project, since they have other projects that cover their costs and if they do get it at least they make a decent profit. Perhaps the increased mark-ups are a kind of reserve to be able to subcontract more of the work if needed. Yet, having more of the same kind of projects in the portfolio improves the contractor's continuity and provides the opportunity to optimize processes. This would result in better profitability and might be a consideration to allow smaller mark-ups.

The contractors said to consider external factors too. The client and the competition are often mentioned. Regarding the client there are different viewpoints. Some contractors have claimed that the client can heavily affect the mark-up. A case is mentioned in which the mark-up was increased with 10% because of the expected impact that a client would have on their cooperation. When cooperation is not smooth, additional resources must be invested to mitigate this. When this is foreseen, the mark-up is increased accordingly. Others stated that the client is not a factor, due to a high level of standardisation present

at contracting authorities. Therefore, they are able to estimate what is required to have a fruitful cooperation and can do without the additional mark-up.

The client can be a commercial consideration though, especially when it is in relation to competition. If a competitor has a strong market position at a particular client, a consideration could be to submit a low offer in order to establish a working relationship. In the hope that if this project is won and the cooperation is successful, there will be improved opportunities for further work.

To contractors the most important external factor is their competition, although all contractors stated 'we do not consider competition, we believe in our own strengths'. That is an interesting finding in itself. Most contractors try very hard to stay away from letting the competition influence their own decision making. This is a result from past tenders where the tendency was to discount the offer based on hunches that there would be a very competitive competitor. Whether or not this was the case, they were unable to make a profit by offering low bids anyway. This in turn influenced others, which resulted in a bad market environment. Therefore, the 'market vision' was introduced, whereby contractors agreed not to submit discounted offers any longer.

Subconsciously, the competition always plays a part. Subconsciously with all and consciously with a few of the interviewed contractors. Although most contractors said not to consider competition, they were aware that subconsciously it has an influence. They still consider which parties are likely to be their competitors. This on itself can be considered a rational thing to do. On one hand, this could make participating in the tender not worthwhile and save the contractors the opportunity costs. However, then competition must be considered in relation to the decision to tender, rather than the mark-up decision. On the other hand, it will give an indication of the position of the contractors compared to the competition. Which could be used to improve the tender strategy, potentially resulting in a stronger offer. Yet, the contractors seem not willing to share this viewpoint.

There are differences observed in the extent in which internal aspects are important to a contractor depending on how a contractor operates. Larger contractors, who have more in-house capabilities, attach more importance to workload, probably to keep all sub companies going. Smaller contractor rely more on supply chain partners, hence they mentioned their supply chain is an important consideration. So, the contractor's structure and business model affects which factors are considered in the mark-up decision.

The main factors that Dutch contractors assess in their mark-up decision for large integrated infrastructure projects therefore are; their project portfolio, their supply chain, the client and the competition. When this finding is compared to the study by Shash (1993) into the factors considered by UK based contractors when deciding on the mark-up, significant differences surface. In Shash's study the degree of difficulty and the risk involved owing to the nature of the work were ranked higher than the current workload, the highest scoring factor from Dutch contractors. The client was ranked 7th, competition (number of competitors tendering) 28th and subcontractors 38th. UK and Dutch contractors attach quite a difference of importance to the factors they consider in their mark-up decision-making. It appears that the tendering environment between NL now and UK three decades ago is quite different. At least based on the differences in the considered factors.

Comparison with the study of mark-up factors considered by contractors in the USA by Ahmad & Minkarah (1988) paints a similar story. Again, other factors ranked higher, the degree of hazard and difficulty. Workload came 6th, the client 9th, subcontractors 12th and competition 16th.

The claim of not taking competition into account whilst simultaneously acknowledging that it influences them subconsciously anyway was not the only interesting discrepancy encountered. Some believe that other contractors will submit a similar bid. They reason that this is the case since they all have similar costs of building materials. It might be true that a there is little to no difference between the cost price of cubic meter of concrete. However, this does not mean that the construction costs are automatically similar. Each contractor has different transporting costs depending on their distance to the site location, different levels of efficiency and indirect cost, they even offer different solutions all together. The same phenomenon occurs when contractors conceptualize solutions. Just because they conceived a smart solution is enough to make them believe others could and therefore did the same. Simultaneously through acknowledging that this, in fact, never happened. So, contractors have perceptions of their competitors that are incorrect and they are to some degree aware of this as well.

With a worldview that is skewed, it is difficult to make sound decisions. Perhaps this is also a reason why contractors try so hard to disregard competition. Anyhow, fear is and always will be a bad counsellor. By restraining themselves not to consider competitors, contractors might have given themselves the idea to be safer. Yet, they restrain themselves from spotting opportunities too. Recently, there were two projects put to market where only two parties tendered. By not considering competition, opportunities for improved probabilities of winning a tender and for higher mark-ups in situations with less competition are missed.

Disunion between structured processes and unstructured processes.

The transition from quantitative, tangible information obtained during the elaboration of tender, to relying on heuristics and gut feelings in the mark-up decision points to another interesting phenomenon. Which is a disunion between structured and unstructured processes. This occurs on multiple levels.

Firstly, there is a disunion in respect to processes. For the tender detailed and standardised processes are laid down. All contractors defined their own tender processes, from the reconnaissance phase all the way through selection and elaboration of the tender offer. A contractor's tender process has become standardized and has become highly structured by distinct stages, review moments and stage gates. In addition, protocols are in place, describing what items must be researched and taken into account in the decision-making at each stage. Even the way of reporting is standardised with templates. These highly structured phases are in sharp contrast to the subsequent mark-up decision. It seems that all the structured processes stop at the mark-up decision moment. Not a word was said by the respondents about a laid down process or guideline regarding the mark-up decision. It appears that the decision makers have freedom in this regard.

Secondly, there is a disunion in respect to the content upon which decisions are made. There is departure from tangible, quantitative data obtained by extensive research and analysis by the own organisation's tender team, to other sorts of information from different sources gathered by the decision makers themselves.

Thirdly, there is a disunion between the decision-making itself. Decision-making shifts from being data driven, to a more intangible way of decision-making. It becomes unclear to outsiders how the actual decision-making takes place.

Decision models

Elements of multiple decision models surfaced from the responses from the interviewed decision makers when describing their mark-up decision-making approach. One could argue that the way the mark-up decision comes about, indicates incremental decision-making. The mark-up decision seems to come about gradually during the process, starting with a discussion of the expected mark-ups for risk, overhead and profit with new partners at the formation of the consortium in the reconnaissance phase. The agreed mark-up percentages are mostly based on past performance, since there is hardly any information to go by at this early moment in the process. During the next phases in which the tender offer is elaborated and gradually more information becomes available, decision makers may come to new insights and subsequently to slightly adjusted mark-ups. Relying on past performance, particular relying on proven solutions, combined with small deviations from the status quo, are characteristics of incrementalism. However, in situations with incremental decision-making the decision-makers are likely to repeat the decision making ad infinitum (Lindblom, 1959), which is when the incrementalism stops being a reasonable explanation of the decision making process.

Despite the discrepancies mentioned previously, one might argue that the bid amount determination process conforms on a high level with rational decision-making, since the same basic steps are present (Hitt et al., 2012). The first step in decision-making is recognizing a problem or opportunity and defining it. Contractors have dedicated marketing researchers who actively scout upcoming tenders. However, defining the project is something that Rijkswaterstaat does in their preparative stage of the tender process. Contractors set the first step in the tender process and define their approach by selecting partners. The next step is identifying and analysing courses of action. Contractors start their tender stage by defining a tender strategy. They analyse the client's request and their own competitive advantages to determine a course of action. The third step is selecting a preferred course of action or in the case of tendering, setting the bid amount. Given these differences, bid amount decision making does not conform with classical decision making.

Furthermore, one could infer that mark-up decision making within Dutch contractors resembles retrospective decision making, given the numerous analyses that are made, but not taken directly taken into account in the decision-making. Perhaps the analyses were preformed to legitimize the intuitively made mark-up decision. However, such a line of reasoning might be farfetched. It shows that elements of several models were picked up in the data, implying that there is not a model that perfectly described the decision-making. In this thesis, the analysis of the data is confined to the decision models of the decision model framework, consisting of the bounded rationality model, entrepreneurialism and organisational routines. These models align with tendering theory, as is discussed in section 2.5 that describes the decision model framework.

Decision makers have not formalised alternatives to analyse and to select from, they have not defined a minimal acceptable result and perhaps, most important have limited information opposed to the complete information presumed in the classical rational decision making model. In fact, each decision maker has his/her own information, his/her own point of view, as was discovered during the interviews. Alternatives are conceptualized one at a time. This process is stopped when the contractor has the impression that sufficient alternatives are considered to make a sound choice. There is simply not enough time to continue. Subsequently the conceptualized alternatives are assessed. This approach fits the bounded rationality model.

In addition, establishing a minimum performance level instead of the optimum solution is clearly present. The minimum performance level is complying with the client's requirements and thus always established. Moreover, the decision makers rely on the feeling of sureness and heuristics when setting the mark-up. Again, something that is in

line with bounded rationality decision-making, making the bounded rationality a plausible approximation of the mark-up the decision-making.

Entrepreneurialism is another plausible depiction of the mark-up process. It is in line with the last part of the tender phase, where there is no longer a systematic, structural approach, as was discussed in the section describing the disunion between the structured processes and unstructured processes. Instead, the mark-up decision is unstructured and there is a departure of decision-making based on data to decision-making based on decision makers' individual beliefs and heuristics. Examples are; applying a heuristic risk provision rather than considering the output of the Monte Carlo analysis based on personal beliefs that adopting the output is unfeasible or simply wrong. This conforms to the notion of the entrepreneurial decision model in which decision makers rely greatly on heuristics and their individual believes (Mitchell et al., 2002; Wright et al., 2000).

For an outsider it is difficult to pinpoint the actual mark-up decision moment. Is it at the formation of the consortium, when mark-up percentages are roughly established? Or is it at the end of the tender when the offer is authorized? Or is it at the moment that the tender team comes up with a mark-up suggestion? This ambiguity is an indicator of organisational routines. Another indicator is the presence of more or less independently operating departments and subdivisions. This conforms to how within a consortium the project is divided between contractors and subdivisions. Each subdivision estimates the costs of the portion of the project for which it is responsible. Relying on routines for the day-to-day operation of the contractor's firm empowers an almost autonomous functioning of the firm, without deliberate decision making throughout the process. One could argue that this is the case with these large tenders, since the key decision makers are only sporadically involved.

We have seen that the decision makers consider both internal and external factors. Decision makers have different inputs in their mark-up decision-making process. On one hand, there they rely on quantitative information, for example, the extensive risk analysis made. However, the output of such analysis is not directly incorporated into the decision-making. The output is first interpreted, judged and discussed by the decision makers. At this moment, heuristics and gut feelings take over the decision making. Although effort was invested in careful analysis, output is disregarded when it is not in line with expectation. An example was given of an output of a Monte Carlo analysis that was too high in the opinion of the decision makers, so they halved it without investigating why the output was twice their expectation. By doing so valuable information was lost.

This points to a noteworthy phenomenon. Decision makers consider aspects inconsistently. On one hand, they try hard to keep away from intangible inputs such as hunches regarding the competition and on the other hand they disregard tangible inputs like a Monte Carlo analysis and rely on intangible inputs. The difference is that the heuristics and gut feelings that they do value and take into account in their decision-making are their own.

To conclude; the decision-making during the tender process correspond to bounded rationality, while entrepreneurialism fits the subsequent mark-up decision. When taken a step back and regarding the entire process, routines are a good description.

Mark-up models

Statistical mark-up models are not suitable to model the mark-up of large infrastructure projects due a self-defeating prophecy in the assumption used. The first precarious assumption is that the contractor knows his competitors; the competing contractors and past bidding behaviour. Although the market is small, to a contractor it is unclear which competitors will participate and in which consortium they unite. Secondly, given the few large integrated infrastructure projects put to market in the Netherlands it is practically impossible to gather enough data for sound statistical analysis of bidding behaviours. Thirdly, the model assumes rational bidders, contractors that are pursuing profit maximisation. Although this is the target of contractors in times of economic boom, in economic downturn this changes into maintaining a particular level of revenue as was discussed in the section covering the factors decision makers consider in their mark-up decision making. Finally, the models are only suited for tenders with awarding based on lowest price, while large infrastructure projects are generally procured with a quality aspect as well. The mismatch on the fundamental assumptions of statistical models makes them not suitable for the Dutch tendering environment of large infrastructure projects

Game theoretic models are less well known among contractors. Game theory is a technique to determine an optimum strategy based on estimates regarding competitors' options. This approach clashes with an observed philosophy present at contractors of 'believing in your own strengths'; basing their strategy on internal factors and disregarding any hunches regarding the competition. This combined with the limited awareness of the potential value that game theory can generate for the decision-making makes this an underexposed and underestimated mark-up support model. Still, one contractor provided a description of his decision-making at a recent tender that shows he implicitly used game theory to fine-tune his offer to his competitors. So, there is potential for game theory to assist decision makers.

Multi-criteria mark-up models are the only type of mark-up models under consideration that are able to consider a wide range of variables. Moreover, the inputs for a variable can be both numerical and qualitative or a ranking. This aligns with the variety of factors that the Dutch contractors said to consider. These ranged from internal factors such as the portfolio of projects to external factors such as competition and the client in some cases. The potential of this type of model is to enable decision makers to incorporate qualitative inputs, which makes it useful during the tendering period when limited information is available. In addition, this type is flexible enough to adapt to the specific circumstances of a particular project, contract or procurement method. However, it is still unclear which variables should be included to accurately model the Dutch tendering environment of large integrated infrastructure projects. Likewise, a method to transform the inputs into a reliable output also needs to be determined. Nevertheless, a multi-criteria model could be the pre-eminent means to reduce the disunion between the structured and unstructured processes, by proving a means to take the plural analysis and gathered data into account in the mark-up mark-decision.

However, in case of mark-up decision-making for Dutch tenders of large infrastructure projects it currently remains unclear which technique is most used to transform the various input variables into an output. Numerous techniques have been suggested, such as utility, fuzzy logic, neural networks and analytical hierarchy processes (Cagno et al., 2001; Cheng et al., 2011; Christodoulou, 2004; Dozzi et al., 1996; Hegazy & Moselhi, 1994; Liu & Ling, 2005). Still, multi-criteria mark-up models can support decision makers without consensus on the underlying transformation technique. Since multi-criteria analysis is also a tool to provide an overview of the uncertainties that remain in tender at the moment of the mark-up decision. A multi-criteria analysis can show graphically whether the remaining uncertainties are likely to result in a deterioration or improvement of the contractor's position. This is precisely the information that is used by the decision makers to fine-tune the components of the mark-up; the risk provision, general overhead

and profit margins. Currently, contractors do this based on feelings and hunches. A multi-criteria analysis can be the first step to rationalise this process.

6 Conclusions

The aspiration of this thesis was to investigate how Dutch Engineering, Procurement and Construction contractors could improve their bid amount determination process for large infrastructure projects with design and construction integration. In conclusion, this can be achieved by reducing the disunion between the contractor's tender process and subsequent mark-up decision.

A prescriptive model of the tendering practice of the Dutch procurement process from a contractor's viewpoint is lacking for large-scale, multi-disciplinary infrastructure projects with design and construction integrated into one contract. Instead, contractors devised individual processes. These processes conform to each other and go through distinct phases of; a market reconnaissance, a qualification and selection phase, a tender phase and finally the formulation and submission of the tender bid.

In the contractor's tender process a solution to a client's problem is elaborated according to a strategy, that the contractor believes will result in the winning offer. The decision of how much to charge for this solution is called the mark-up decision. Decision makers determine the bid amount by marking-up the construction costs of the contemplated solution to accommodate for risks, general overhead and pre-tax profit. This approach is identical to what is known in literature as the mark-up approach. Hence, in general terms, mark-up models are applicable to Dutch procurement practice.

Three types of mark-up models are identified among the current body of knowledge; statistical, game theory and multi-criteria mark-up models. The statistical models are not applicable to the Dutch procurement process, since the underlying assumptions do not correspond with the tendering environment of large-scale infrastructure projects.
Game theory models are less well known among contractors. Consequently, they remain incognizant to the potential use of game theoretic models to analyse and to a certain degree predict the behaviour of competitors. Dutch contractors are extremely hesitant to base their mark-up decision on the expected behaviour of competitors. Instead, the final mark-up decision is about fine-tuning a mark-up, based on an informal and unstructured discussion of four areas; the contractor's current portfolio of projects, the partners and suppliers committed to the project, the client and their competition. Multi-criteria mark-up models can accommodate the multitude of factors, and their quantitative and qualitative nature, considered by the decision makers. Hence, multi-criteria mark-up models are most congruent to Dutch contractors' practice of bid amount decision-making.

Upon investigation of contractors' procurement processes, a disunion between the tender and mark-up processes was found on several levels;

- At process level.
  The tender process of a contractor is a highly structured process wherein in distinct phases the client's request is analysed, a strategy to win the tender formulated, a solution contemplated, elaborated and compiled into an offer. This is in sharp contrast to the mark-up determination, which appears to be unstructured and left to the discretion of the decision makers.
- At content level.
  The tender phase is very much data driven. During the course of the tender, the tender team gathers lots of data. In addition, many analyses are conducted to produce valuable information to optimise the offer. This information is provided to the decision makers in abstracted form. Although decision makers consider this information, they gather their own information independently from the contractor's organization. The whole of the information considered by the decision makers is of a more intangible nature.

- At decision level.
  Whereas decisions made during the tender phase are based on the gathered data and conducted analyses, the mark-up decision is more intangible, founded more on heuristics and gut feelings.

This disunion is also present in the way in which the mark-up determination process can be portrayed. Decision-making during the tender process is in line with the bounded rationality model, while the subsequent mark-up decision itself corresponds with entrepreneurial decision-making. When the bid amount determination process is viewed as a whole it can be characterized as an organisational routine.

Multi-criteria mark-up models could provide the opportunity to reduce the disunion between the tender and the mark-up decision processes. It provides the means to incorporate the gathered data and analyses into the decision-making as variables, whilst leaving room for decision makers to add other factors that are important to them. There is also an opportunity to better assess competition by applying game theory and incorporating the output of this analysis in the multi-criteria model as well.

7 Discussion

This thesis covers the bid determination process for largescale infrastructure projects by Dutch EPC contractors. In the Netherlands, such projects are publicly procured by Rijkswaterstaat, the executive agency of the Ministry of Infrastructure and Water Management. Procurement procedures are prescribed dictating the tendering process. Within these processes, contractors independently make a proposal for at least the design and the construction of a piece of infrastructure. This proposal, supplemented with a bid amount are submitted as an offer to Rijkswaterstaat. Generally, among the received offers a winner is chosen based on the best price-quality ratio.

Setting the bid amount is challenging for the decision makers at EPC contractors. With a higher bid amount the contractor's profit increases, but the probability of winning the project declines. A difficult adjudication. Especially when you consider that the decision makers are confronted with limited information, large uncertainties and little time to make sound decisions. Fortunately, through the years several methods have been proposed to assist decision makers in setting the bid amount. Yet, it remains unclear whether there is a suitable method for the Dutch tendering environment of large infrastructure projects among them. This thesis set out to answer; *How could the bidding price determination process for large infrastructure projects by Dutch EPC contractors be improved?*

Dutch EPC contractors use a mark-up approach to determine the bid amount. The estimated costs of construction are marked-up to cover risk, overhead and profit. Senior management fine-tunes this mark-up by balancing the profit with the probability of acquiring the project. In their decision making, senior management assesses the project portfolio, the supply chain, the competitors and the client.

Discrepancy between tendering phase and bid determination phase.

Studying the way that Dutch EPC contractors determine their bid amount for large infrastructure projects by interviewing key decision makers uncovered that contractors have structured their processes over the recent years. The processes in which an offer is established are divided in distinct phases of; market reconnaissance, qualification and selection, conceptualizing and developing a solution and setting the accompanying bid price. Each stage has been demarcated by a decision moment at the end, called a stage gate, where decision makers assess the completed work and decide whether to continue to the next phase. During a phase, the tender team gathers and analyses information to reduce the enormous uncertainty that is present initially. This takes place in a routine-like way, according to standardized organisational processes and procedures that have been implemented. Decisions are made on predetermined criteria by means of trade-offs with multi-criteria matrixes.

However, there are no indications that there are any procedures or standardized process implemented in bid amount decision-making. It seems that decision makers have complete freedom in their operations during the final stage. Whereas the preceding phases are highly structured, the bid amount determination phase is not. Closer inspection revealed that there is a misalignment between the phase in which a contractor conceptualises the content of the offer and the subsequent phase of determining how much to charge for it.

The found misalignment between Dutch contractors' tender phases and subsequent bid amount decision is not only present in terms of the structure or lack thereof, but also in the decision-making philosophy. The decision-making in the first tender phases is very rational. It is data driven, with a focus on objectively gathered information and on

reducing uncertainty. On the contrary, in the last phase, the focus on data diminishes and becomes more subjective. Decision makers' individual belief and experience prevail.

In their bid amount decision making, the decision makers take note of the objectively, internally gathered information supplied by the tender team. Yet, the tender team generally does not provide the decision makers with complete information. Instead, the gathered information is summarized according to standardized formats. In addition, the highlights are communicated to the decision makers by means of a presentation by the tender management. In addition, decision makers personally gather additional information that they take into account in their decision-making. The exact information that the decision makers consider and the criteria they apply remain fuzzy though. The interviewed decision makers described that the bid amount decision takes place in an informal setting. In which the decision makers, the directors from the contractors involved, discuss the project vis-à-vis their expectations and experience. Typically, four areas are considered by the decision makers; the contractors' project portfolio, their supply chain, their competitors and the client. Based on this discussion, the mark-up is fine-tuned. In the final stage, when the final bid amount is set, decision-making moves from rational, data driven, routine like to a more subjective decision-making, driven by individual beliefs, heuristics, past experience and emotional pressures.

The fact that contractors have attempted to structure their process can be viewed as an attempt to standardize and rationalise their processes, which point to a desire to reduce variation (Farrell & Saloner, 1992). This aligns with the general viewpoint in literature that when bid amount decision making moves away from subjective consideration to consider more objective information, decision making would improve (Abotaleb & El-adaway, 2017; Mochtar & Arditi, 2001; Perng & Chang, 2004). Dividing a project, such as developing a tender offer into distinct phases is a distinctive feature of project management. Projects that are complex, either due to their technical difficulty, organizational complexity or due to the requirements imposed on it, are undertaken in a stepwise fashion. At the end of each phase, the project objectives, costs and outcomes are evaluated and a decision is made to either continue, suspend or cancel the project. This is called a phased project planning or is known as project gating. This reduces the complexity and increases the manageability (Nicholas & Steyn, 2012). Still, the contractors managed only to structure the preceding phases, but not the bid amount determination phase. The actual bid amount decision-making remains unstructured and left to the discretion of the decision makers. Some explanations for this are discussed in this section.

In the course of a tender contractors invest a lot of resources to obtain more information and subsequently reduce the uncertainty. However, the majority of this information is disregarded in the decision-making of the final offer. There are a few reasons for this. To start with, as mentioned previously, the decision makers receive condensed information. In addition, information is disregarded when there is ambiguity regarding how it ought to be included in the bid amount decision-making.

To illustrate, consider how foreseen risks are incorporated in the bid amount decision. The tender team performs extensive risk analysis on these risks. They are identified, quantified in terms of both effect and probability of occurring, mitigation measures are devised, their costs and effects quantified and the residual risk is determined. It is standard practice to perform extensive Monte Carlo simulations to analyse the risk and the impact on the project. However, when the interviewed decision makers elaborated on how they determine the risk buffer in the mark-up, it became clear that the output of such a Monte Carlo analysis is largely disregarded. A figure is included in the appendix H to illustrate the outputs of a Monte Carlo simulation. For example, among the outputs of such a simulation is a curve displaying the project's cost and the corresponding probability. In general, just the monetary value that corresponds to the buffer needed to

cover the risks with X% certainty is used in the decision-making. This amount is added to the direct costs of construction.

The shape of the output probability density function contains useful information too, but is disregarded as well. Its tail represents how likely it is that the project turns into a bleeder, a project with major overruns. However, this matter cannot be incorporated in the decision-making in the usual way, since the probabilities of the occurrence of such a bleeder are calculated as extreme unlikely. This means that due to the very small probability of occurrence, a small buffer should be added to account for this event. It is too small, given the few large projects executed to accumulate a sufficient buffer to cover a bleeder when it occurs. Anyhow, in all decency decision makers cannot simply add a buffer equal to the costs of a typical bleeder divided by the number of executed large projects. That would easily result in a buffer of tens of millions. Such a buffer severely reduces the competitiveness of a contractor. Still, the decision makers face this dilemma. Since, adding a conservative buffer would result in a situation in which they would not acquire any new projects and will go bankrupt anyway. Thus, market pressures influence the decision-making too.

This example of dealing with foreseen risk illustrated the difficulty to incorporate the output of the tender team into the decision. This leads to the belief that decision makers disregard information that is hard to incorporate into the bid, because they do not know how to incorporate it. It seems reasonable to assume that for other pieces of information, similar problems occur. That would explain why decision makers are currently unable to include all the information and uncertainties into the decision-making in a substantiated way. This would also explain why the last part of the process is still unstructured.

In addition, this could also explain why some decision makers expressed that they desire freedom in their decision-making. They are perfectly happy to be in charge of setting the bid price, they feel competent and see it as their duty as director. In this sense, they feel like they do not need a model to support them in determine the bid amount, yet simultaneously they recognize that decision-making would improve if it would be more structured and less susceptible to emotional pressures.

The misalignment between the structured tender phases and unstructured bid determination phase has some implications. Decision makers attempt to improve decision-making by personally gathering additional information and utilizing their experience when there is not enough data, but in this process, they inadvertently increase the uncertainty they so badly want to reduce. With information on a wide variety of aspects, but still with large uncertainties and no proven way to process this into a sound decision, some information is neglected. Furthermore, the decision-making becomes more susceptible to biases due to the reliance on believes and heuristics. Both issues reduce the quality of the decision-making. In addition, the tender teams might notice this phenomenon and reduce the accuracy of their analyses, since they know the additional output is disregarded. In any case, it is a waste of resources to make accurate analyses. Moreover, when the decision makers rely only on their feelings and use the received information from the tender team only to legitimize their decision-making, the tender team will feel unappreciated, which could lead to internal friction.

Impact of the market environment and contractor's business models on contractors' operation.

The Dutch tendering environment of large infrastructure projects with design and construction integration is small. Just eight large contractors operate in the market with projects exceeding €250 million. Rijkswaterstaat is the only client of these projects (McKinsey & Company, 2019). This market is categorized by the high level of competition, high failure costs and limited improvements in productivity and innovation (McKinsey & Company, 2019). This resulted in poor operating margins of contractors, compared to other sectors (Deloitte, 2018). The average operating result during 2008-2017 of the eight largest contractors was just 0.3% (McKinsey & Company, 2019, p. 10). In particular, contractors have been unable to cover the estimated profit and risk margins, thus the mark-up, for these large projects. With as a result occasional bleeders, projects with major financial losses, that put the financial positions of contractors under stress (McKinsey & Company, 2019).

Since there is severe competition in the market, the price levels of infrastructure are low. Hence, Rijkswaterstaat and in turn the public, obtain infrastructure against low costs. As a society, it is favourable to economically efficiently obtain infrastructure. However, due to the low profit margins, the sector struggles, hampering the sector's progress on challenges that the Netherlands face, such as becoming more sustainable and catching up on overdue maintenance. Furthermore, the relationship between Rijkswaterstaat and a contractor quickly deteriorates when things go wrong. Contractors do not have the buffers to absorb a bad project. Hence, such a situation quickly results in acrimonious battle, which hampers economic efficiency and the sector's image.

This situation is aggravated by the procurement procedures that Rijkswaterstaat utilizes. Large infrastructure projects are awarded based on the best price – quality ratio. The interviews showed that currently consortia heavily optimise the BPQR ratio of their offer. In other words, they offer high quality solutions for low prices. This is a desirable situation for the client and the taxpayers, who receive excellent value for the money spend. Yet, this is not sustainable for contractors, since they do not make enough profit to build the buffers required to be resilient in case of a bad project. The procurement procedures with project awarding based on BPQR contravene the economic principle. By the economic principle, we mean the aim to achieve the greatest possible result with a certain scarcity of resources (Himmelweit, Simonetti, & Trigg, 2001). It is possible to get high quality infrastructure for a decent price, or low quality solution cheap, but not high quality solutions for low prices, which is exactly what BPQR incentivizes.
Contractors' business models can explain the contractors' behaviour of offering the best solution for the lowest price, instead of a fair price. Contractors operate by two business models. On one hand, they employ a project organisation's business model, where each successful project yields a profit the size of the profit margin, in line with the mark-up approach. On the other hand, contractors employ a manufacturer or production business model, which is revenue and unit cost driven, in which with increased production the production cost decrease, resulting in an increasing profit with increasing production. However, in their decision-making objective, generating revenue dominates profit optimisation. The two conflicting business models complicate the decision-making and cause injudicious incentives.

Being focussed on revenue, contractors prefer to optimize the BPQR instead of maximising the project's profit. A side effect of this is that most mark-up models were designed for situations with rational behaving contractors that pursue profit maximisation. However, this is not the dominant business objective of contractors when tendering. Hence, this restrict the usefulness of most mark-up models. Yet, since the first mark-up model by Friedman in 1956, other objectives besides profit optimisation were identified. Yet, during the literature study, no mark-up models for any of the other objectives were found.

From a microeconomic viewpoint, the Dutch market of large infrastructures is upset. It is an imperfect market. However, instead of a single firm that controls price levels and potential competition, in case of infrastructure projects, the client controls the market. Since the government is the sole buyer, through its executive agency Rijkswaterstaat, it has a monopoly position. The government uses its position and regulatory power to regulate the market by implementing procurement procedures that pursue equal treatment, proportionality and transparency (European parliament, 2014), in an effort to create a sustainable market environment. However, as explained, this introduced new barriers to a healthy functioning of the market.

Rijkswaterstaat and the large contractors have tried to restore this imperfect market. In the past, by illegal price agreements among contractors. The participating contractors were heavily punished. This could explain why all contractors are currently extremely hesitant to consider their competitors in their decision-making. Over the years, their collective focus has shifted inwards from an outward focus on their competitors, by focussing on the own organisation and utilizing its strengths. Currently, contractors still try to restore the functioning of the market; currently, they utilize specialisation, to obtain a market of few suppliers, in which a few firms have some power over the market price but no single contractor or client exercises the complete market. This market resembles a more oligopolistic market.

This specialisation results in contractors having a competitive advantage in certain projects. Their specialisation yields the supply of higher quality solutions, combined with improved efficiency results in superior BPQR that they can offer. By doing so, contractors divided the market of large-scale infrastructure projects into niches among the contractors. Currently, the market is divided in a legal way. This specialisation is also beneficial to the client, who obtains high quality solutions for a competitive price. The downside is however, that the specialisation can result in few contractors bidding for a type of project. Consequently, the client has trouble guaranteeing that the offer is competitive, since there is limited competition. In addition, contractors have become more reluctant to undertake large construction projects. This is affected by the economic situation at the times of the interviews. The interviews were conducted in the summer of 2019 and 2020, times at which there was economic growth. Contractors reached their capabilities. Consequently, contractors only took on projects with little risk and good potential for profits.

Also, Rijkswaterstaat made efforts to restore the market. It has stopped procurement with design, build, finance and maintain projects, since contractors were reluctant to tender for them, due to losses. And due to economic boom, they had sufficient other projects to generate the required revenue. A major contributor to the unsustainable tendering environment is that some risks are not taken into account properly. Only quantified risk can be taken into account in the bid amount with proven methods, while uncertainty cannot. An analysis of the Dutch tendering environment by consultancy McKinsey & Company in 2019 came to a similar conclusion. Hence, they advised Rijkswaterstaat to lower the risk that contractors face by determining the bid amount at a later moment. This is called the two-stage procurement process; first a contractor is selected and only when the project is elaborated and more uncertainty is transformed into risk, the final bid amount is set. This should allow for more time to perform risk analysis, which they believe will result in less overruns.

Barriers to improvement

A literature study yielded that the performance and competitiveness of contractors would improve if the bid amount decision-making were more rationally. Currently, bid amount decision-making is subjective to individual beliefs and emotional pressures. The general viewpoint is that decision makers should more rationally consider a wider variety of aspects when determining the bid amount (Abotaleb & El-adaway, 2017; Mochtar & Arditi, 2001; Perng & Chang, 2004).

The bid amount decision-making at Dutch contractors regarding large projects is becoming more structured, more rational and well considered. Nevertheless, there is still room for improvement. Despites contractors' efforts, bid determination processes remain unaligned and environmental pressures hamper sound decision-making. Due to the complexity of the tendering process and the tendering environment, the bid amount decision making cannot be optimized with a quick fix. There is a variety of issues that constitute barriers for improvement. These barriers are discussed in this section.

The first area with barriers to improvement is the individual decision making by the people involved, such as the tender team, and particularly the directors of the contractors involved. These decision makers have a large influence on the decision-making process. They rely heavily on gut feelings, heuristics and individual beliefs in their decision-making. However, this kind of decision-making is prone to biases. To illustrate, a common bias is to be overly optimistic regarding the topic that one finds interesting. Architects like to design, engineers like to calculate and directors like to manage a flourishing company. According to this bias, called appraisal optimism by Flyvbjerg, Holm, & Buhl (2002), decision makers are held to be overly optimistic regarding the tender during the tendering phase (Fouracre, Allport, & Thomson, 1990; Mackie & Preston, 1998; Walmsley & Pickett Crown, 1992). Another common bias concerns the information that decision makers take into account. Given the decision makers' enthusiasm for the tender opportunity and the desire for additional information, their urge for information might be accelerated. This can lead to a focus on a subject that is particularly interesting to the decision makers, while other areas are overlooked. This bias is known as tunnelling of attention (Pech & Cameron, 2006). When this bias occurs, rationality is reduced, since part of the relevant information is neglected (Bryant, 2007). These two common biases show how the decision-making could be inadequate.

Although, one could argue that since the decision makers have a wealth of experience, they should have adjusted their emotional pressures and individual beliefs over the years. Ideally, they should have learned to account for their individual biases. However, this appears not to have happened. During the interviews, it became apparent that some decision makers tried to improve their decision-making by implementing a support model. When this was the case, they tried to apply statistics. Nevertheless, this did not result in useful information. So, some of the decision makers showed to aspire personal improvement. Yet, this has not materialized. Moreover, the interviews showed that the decision makers remained largely unaware of developments in literature of models or techniques that could support their mark-up decision. Even though contractors have tried to rationalise and structure their tendering processes in order to reduce uncertainty, no efforts have been made to eliminate individual biases.

This could be explained by the lack of incentives to actively improve. The decision makers are often selected for the position of director, because of their ability to effectively evaluate and exploit opportunities, despite restrictions of limited time and information. Hence, on their application of their individual belief, gut feelings. As such, there is no incentive to structure their decision-making and implement standard operating procedures. Because they reduce the ability to distinguish themselves.

The second area of barriers to improvement concerns personal and organisational self-interest. The decision maker is in charge of the company, which is a construction

business. When the decision maker does not acquire any new projects, the company runs out of work and goes bankrupt. Therefor there is an incentive for the decision maker to acquire the project, so he remains to have a job. Therefore, there is an economic self-interest to acquire the tender. Hence, this is an incentive to optimise the price-quality ratio. In addition, contractors participate in a tender with the objective to acquire the project. It appears that when a project goes bad, tender teams and decision makers are hardly ever held accountable for their part, for example unreliable estimation or overlooking an issue. Since there are always other issues that will have arisen that have contributed to the overruns. And they can fall back on the fact that there is limited information and a lot of uncertainty, hence decision making is not perfect. And they are held accountable more when the workload is low. Hence, individual and organisational incentives to investigate and improve the decision making are limited.

Thirdly, the decision makers currently overlook developments and sources of improvement. Decision makers remain unaware of developments in their and other domains, that could support the decision-making. The interviews uncovered that the decision makers were not familiar with the state of the art of mark-up decision support models. Incentives to improve individual decision-making are not strong enough, as was discussed on the previous page.

In addition, the decision makers are very hesitant to consider competition. In a highly competitive market with contractors driven by revenue, there is a tendency to overestimate a competitor's position. In response, contractors over-optimized their own price-quality ratio, which led to severe losses. Currently, the contractors are reluctant to consider competition. However, by doing so, external opportunities are missed. For example, if only two consortia participate in a tender, the competition is weaker. When one considers the economic principle of supply and demand, this should be an incentive to offer a higher price. This does not happen, since contractors are predominantly revenue driven.

Fourthly, there are barriers to improvement originating from contractors' dependability on Rijkswaterstaat and the procurement processes employed. Generally, Rijkswaterstaat puts each project to the market individually. Hence, contractors have no long prospects for large construction projects. Consequently, contractors do not have a long-term focus, instead their focus moves from project to project. Due to the procurement procedures there is little continuity and stability. This makes contractors hesitant to innovate, since it is uncertain whether the investment costs can be recovered. Reduced learning and innovation is the result. Improvement is further restricted by the small budgets available for innovation, due to the sector's low operating results (McKinsey & Company, 2019).

Fifthly, there are barriers hampering the implementation of a decision support model. Of the three mark-up models in the theoretic framework, the multi-criteria model is identified as the most suitable model to support the mark-up decision-making of large infrastructure tenders in the Netherlands. However, a barrier to its application is identified. Decision makers expressed that they desire freedom in their decision-making. Presumably, because they need the freedom to apply their individual decision making to deal with uncertainties. A support model should not restrict their freedom. Their authority to decide remains. In fact, they obtain a tool in support of their individual decision making. A multi-criteria model increases their situational awareness by serving as a checklists to consider all relevant aspects. Moreover, it enforces each aspect to be well-considered consciously. In this way, the negative influence of biases is reduced, rationalizing the process.

Validity

This thesis is the first substantial study into the bid amount decision-making by Dutch EPC contractors for large infrastructure tenders. Not only is the process mapped, but it also gives a better comprehension of the process. The study provides insight on; the structure of the bid amount, the processes that are followed, the factors that are considered and the types of decision-making employed in contractor's bid amount decision-making. In addition, motives behind contractors' reasoning are uncovered and a misalignment relating to dealing with risk and uncertainty was found. This section discusses the validity of the research that yielded these results.

In this thesis, data was collected by means of interviews with six Dutch contractors with the capability to take on large multidisciplinary infrastructure projects with integration of design and construction in one contract. In the Netherlands, eight contractors have these capabilities. Although the sample population is small with six interviewed companies, this represents 75% of the research population. The selected contractors are a cross-section of the population and thus representative thereof. To sum up, among the interviewed companies are; contractors which are privately owned and contractors that are listed on the stock market, contractors who own production plants and contractors that subcontract the majority of the works, contractors that operate in the Netherlands only and contractors that operate beyond. In addition, they are dispersed geographically over the Netherlands.

One, and on one occasion two, decision makers within each company were interviewed. These are individuals with years of experience in the field and at the companies they work at. Hence, they were able to provide information representative of the operating of their companies. The interviewees have different positions within the companies. Among the interviewees are a head of acquisition, managing directors and a member of the executive board. These individuals are involved in bid amount decision-making on a regular basis. Hence, they are knowledgeable on the subject and capable of providing a complete picture of the procurement practice at Dutch infrastructure contractors. As a result, the findings of this study are applicable to all Dutch contractors active in large-scale multidisciplinary infrastructure projects.

The interviews were of a semi-structured nature. This enabled in-depth information gathering. The degree of structure enabled comparisons to be made between the responses of the interviewees, while offering the interviewees the freedom to deviate, in order to provide additional information or emphasize aspects in their responses when deemed relevant. In addition, the interviewees could clarify their responses if needed. The interviews took place at contractors' offices. Due to the familiarity of the setting, decision makers were more likely to provide information regarding the operations at the companies they work at. To ensure the quality and consistency between the interviews, they were conducted according to a protocol founded on the theoretic frameworks in this study. In addition, TU Delft supervisors checked the protocols. During the first interview, a TU Delft professor was present to ensure the proper functioning of the protocol and conducting of the interviews. Furthermore, two interviews in the second round were used to validate the findings of the first round of interviews.

The obtained data was transcribed in Dutch and analysed subsequently. Initial coding took place based on key concepts identified in literature and incorporated in the interview protocol. Subsequently, open coding took place on sections that contained interesting information that was not yet incorporated. Hereby, the sections of interest were gathered, grouped and integrated in the data analysis. The sections of the transcript that were coded by either of the two methods were translated into English. Unfortunately, it was not feasible to perform the coding multiple times nor by multiple persons. Nonetheless, attention was given to theoretic triangulation. The data is analysed from procurement theory, mark-up theory, decision-making and business economics perspectives.

8 Recommendations

This thesis researched the processes that Dutch EPC contractors employ to determine the bid amount for large infrastructure tenders. A literature study yielded that the performance and competitiveness of contractors would improve if the bid amount decision would become more rational and less sensitive to subjective considerations.

The main recommendation is to structure the mark-up decision. This will reduce the sensitivity to biases and emotional pressures, hence improving decision-making. However, a barrier to structuring the bid decision was identified. In the contractor's tendering process, there is a misalignment between the phases in which an offer is conceptualized and the final phase in which the bid amount is determined. Reducing this misalignment will lessen the barrier to improvement of bid amount decision-making.

In order to reduce the misalignment, the implementation a multi-criteria decision support model is recommended. This mark-up model is most suitable to support decision makers in their bid amount decision. Implementing a multi-criteria decision support model yields several benefits. Firstly, it will support decision makers, as a checklist, to consider all relevant aspects in their decision-making. Secondly, it promotes conscious consideration of each relevant aspect. Thirdly, the model provides the decision makers with a dashboard; an overview of tender situation by displaying all the aspects and how they are assessed. This will result in a more conscious and rational decision-making and make it less susceptible to individual biases.

Decision-making can be improved further by creating more awareness of the type of decision-making that is used. When sufficient reliable information is available, decision makers are dealing with risk. Hence, a rational and quantitative approach to decision-making can be utilized. If reliable information is not sufficiently available, decision makers are dealing with uncertainty. Hence, they rely on their individual beliefs, experience and heuristics to be able to deal with the ambiguity. Each type of decision-making has its strengths and weaknesses, which decision makers should take into account.

Likewise, the decision-maker should be aware of the objective that they aim to achieve by participating in a tender. This could be either to make a profit on the project or to obtain the project as a means to increase turnover. Each objective corresponds to a different business model. These business models can easily be entangled, reducing the reliability of the decision-making. In addition, the decision makers are encouraged to utilize their entrepreneurial senses to be more perceptive to external opportunities that might arise.

Lastly, the contractors are advised to gather additional data regarding their decision-making. This can be used to improve the accuracy of the heuristics used and uncover biases in the individual decision-making.

Recommendations for further research

In addition, this thesis yields recommendations for further research.
Firstly, although, it is clear that contractors in their tendering pursue other objectives apart from profit maximisation, these objectives have not been incorporated in mark-up models, yet. Therefore, research regarding mark-up models should focus on incorporating these objectives in order to increase the applicability of the models.
Secondly, additional work on the factors that influence the mark-up of large infrastructure projects would help to facilitate the applicability of a multi-criteria decision support model. Studies in the UK and USA have identified which factors affect the mark-up and to what extent. A similar study in the Netherlands would accelerate the

implementation of multi-criteria decision support models in Dutch practice and enable cross comparisons to be made.
Thirdly, an interesting issue for future studies is to investigate which method is most suitable to transform the input variables of a multi-criteria mark-up model into an output, in light of the large uncertainties present and limited data available.

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10 Appendices

10.1 Appendix A – Additional decision-making models

10.1.1 Political decision-making

Although organisations, and especially governments, are often generalised as unitary, rational decision makers, ones that are centrally controlled, completely informed and in pursuit of value maximisation. Just like a government is more than a prime minister, an organisation is more than the CEO. Also instead of 'well oiled machines' organizations more often than not seem less than efficient and of singular purpose. An organisation is in fact a conglomerate of sub divisions and departments, each with their own viewpoints and interests, with responsibilities for particular tasks divided among the departments. Organisations perceive information concerning issues through organisational sensors dispersed among its departments (Allison & Zelikow, 1999).

An organisation deals with a specific domain. Within this domain an organisation acts quasi-independent, however hardly any issues are confined within their specific domain. When faced with a problem, organisations define alternatives and estimate consequences as part of their standard patterns of behaviour of the organisation. The processes and outputs of the organisation are only partially coordinated by the leaders, they can substantially disturb, but seldom precisely control the organisation's routines. Given this viewpoint, an organisation's decision making should be viewed less as deliberate decision making and more as an output of the organisational routines that are in place at independently operating subdivisions (Allison & Zelikow, 1999).

The behaviour of the individuals within the organisation must be coordinated in order to accomplish complex tasks, like designing and executing large infrastructure projects. Coordination calls for standard operating practices. All subsidiaries that make up the organisation have their own sets of standard operating practices. How an organisation as a whole responds to external pressures is therefore predominately determined by the routines. Hence, an organisation's behaviour can be described and explained based on the routines, while noting deviations (Allison & Zelikow, 1999).

This understanding of how an organisation functions resulted in a number of models aimed to clarify and predict political organisational behaviour (Allison & Zelikow, 1999). The first model is the rational actor model. In this model the organisation is modelled as one centrally controlled rational behaving actor. The organisation shares common goals and decisions are made by selecting optimal solutions on the basis of cost-benefit analysis. The second model portrays the organisation's behaviour as the result of the organisation's structure and its practices. Here, the options available to the organisation's leader are framed by the previous leader's decision making path. The third model, the governmental or the bureaucratic politics model, explains organisational behaviour through concepts of the organisation's mission and the bureaucratic roles and positions within the organisation. The model is based on the presumption that decision makers pursue the interests of their organisation, but will also favour actions and policies that enhance their own bureaucratic role and power position.

Later, the second and third model are fused to form the bureaucratic politics paradigm (Allison & Halperin, 1972). A crucial element of bureaucratic politics is political competition, a process of bargaining between actors about propositions with different preferences and power levels. Power originates from individual advantages in the bargaining processes, the extent to which these advantages can be used and how these are perceived by the other actors. The level of power an actor has is related to his bureaucratic position and dictates an actor's actions to an large extent.

Furthermore, although the actors are still considered to behave rationally, this assumption is relaxed a bit. Actors are no longer presumed to decide based on cost-benefit analysis. Rather 'each player pulls and hauls with the power at his discretion for

outcomes that will advance his conception of national, organisational, group, and personal interests' (Allison & Zelikow, 1999, p. 171). Despite the different parties involved, with each their own viewpoints and power, the decision making will progress due to this 'pull and haul' bargaining process as well as the emergence of coalitions and compromises. The final decision will reflect a compromise as a result of the bargaining between a small group of leaders who represent their organisations (Allison & Zelikow, 1999).

Pre-conditions

- Multi actor problems
  The political decision models are all designed for situations in which multiple actors are involved in the decision-making. These situations are characterised by interdependence among actors with different viewpoints.
- No temporary organisation (Allison & Zelikow, 1999, p. 145)
  Organisations are presumed to be arranged to act harmoniously. Structures and procedures should be clearly established. There should be an appropriate division of labour and specialisation. Employee's behaviour is constrained by programs and routines into a desired direction, with only limited room to deviate. And there should be a company culture which shapes the behaviour of the employees in ways (alignment) with the informal and formal norms to create a distinctive entity with its own identity and momentum. These models do not apply to temporal project organisations.

Bureaucratic politics models have been critiqued by scholars for being too complex, too broad to yield testable hypotheses. Furthermore they believe that the models overstates the bureaucrats' power and influence (Blomdahl, 2016). Some go further and reject the model because it attaches too little importance to the role of leader of the organisation (Krasner, 1972; Rosati, 1981). They argue that leaders set the rules of the game and that leaders are directly involved in the decision-making process of crucial decisions.

10.1.2 Incrementalism

Incrementalism was established when Lindblom (1959) investigated how public administrators' decision making processes where actually used. He raised awareness for the need to consider a different approach of decision-making concerning policy changes. He identified two approaches that a decision maker could follow to decide on a policy.

The first approach entails beginning with identifying all objectives related to the decision and ordering them in importance. Then all possible policy outcomes are envisioned and rated in their effectiveness of attaining a maximum policy value. For this, the decision maker must inventory the public for the values they hold. And even more cumbersome, he must establish how much each value can be compromised for each other value. Then, he can outline all alternative policies. Subsequently, he can compare all alternatives systematically to derive at which alternatives are valued the most. When comparing policies, the decision maker utilizes and takes advantage of any available theory which can be generalised over the affected areas. Ultimately, the decision maker chooses an alternative which maximises the objectives (Lindblom, 1959).

Decision making in the public domain is generally described as if it were in alignment with this approach (Lindblom, 1959, 1979). The approach resonates with public desires like transparency, fairness and equality. For example, by means of clarity of the objectives and comprehensive evaluation of alternatives. However, the first approach is impossible to apply to complex problems (Lindblom, 1959), since this approach presumes full rationality. In the sense that the decision maker would be able to identify all objectives, all alternatives, all possible outcomes and has an exact understanding of the values that the public holds and how these values can be substituted or interchanged. However, no one has access to this amount of information, nor the intellectual capacity

to process it. This becomes even more problematic when the decision maker is constrained by time and resources, as is always the case with procurement of infrastructure projects. Furthermore, there are different objectives desired among the public and they even change per time and circumstance. Establishing to what extent objectives can be interchanged, for example to obtain value functions.

The second approach works around issues such as identifying objectives beforehand and establishing clear value functions. This approach is less systematic. It starts with delineating the alternatives that came to mind. Most of the generated alternatives will be based on previously applied solutions. The alternatives display indirectly which objectives are aimed for and the considerations that have been made. Next, the generated alternatives are compared. The comparison, too, is based on the past performance of similar alternatives. Generally, the decision maker does not consult the body of knowledge for any relevant theories to substantiate his judgement. Next, he recognizes that each alternative merges multiple objectives in different ways. Accordingly, he will arrive at a final decision by combining the various objectives and means.

With this approach decision makers focus on small deviations from the status quo, hereby reducing the complexity. This enables decision makers to envision practicable alternatives, of which the impact can be extrapolated from the present and past policies. The decision maker expects to achieve multiple objectives partially, instead of fully achieving one. As a consequence, the decision maker is likely to repeat this approach ad infinitum, since ambitions and conditions change over time (Lindblom, 1959).

Pre-conditions

Incrementalism has its origin in public administration decision making, in particular for complex social policy problems. Hence, it is suited for situations in which there is relative stability, although a desire to change the current policy. With the incremental steps of this approach the pace of change is slow to avoid revolt to changes. It is not suited for situations where immediate change is required, such as a crisis (Lindblom, 1959).

Although incrementalism is said to be a better option for decision making on complex issues than rational synopsis, it has some drawbacks;

- Adapting to new circumstances by incrementalism provides the decision maker with the opportunity to evaluate and adjust his course of action. However, this approach may not be as effective as when a larger change is implemented in a more direct and perhaps dictatorial way (Lindblom, 1979)
- Within the incrementalism approach there is not a safeguard integrated to capture all relevant objectives (Lindblom, 1959). Instead the method relies on adjustments of objectives at the final stage, in which there are opportunities for interest groups and watchdogs to raise awareness on overlooked objectives (Lindblom, 1979).
- Focussing on alternatives that differ slightly from the status quo is a method to reduce the complexity to a manageable level. But it bears the risk that the decision maker overlooks excellent alternatives, in case they are substantially innovative (Lindblom, 1959, 1979).

10.1.3 Garbage can model

Decision making in practice can be quite different from the belief that alternatives are generated, their outcomes are evaluated and finally a decision is made. Instead, the garbage can model perceives an organisation (process) as *'a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work'* (Cohen, March, & Olsen, 1972, p. 2). A solution emerges when the content and timing of the garbage can match.

10.1.4 Dual systems

Heuristics and intuition are also a part of another decision-making concept, 'dual systems'. Dual system theories propose that human cognition is composed by two reasoning systems, each corresponding with a distinct mode of information processing (Frankish, 2010). The first type of mental processing is dubbed as fast, intuitive and high capacity (Jonathan Evans, 2010) and also characterized as automatic, non-conscious and heuristic (Frankish, 2010). Whereas the second type is slow, reflective and low capacity (Jonathan Evans, 2010) and rule-based, analytical or reflective (Frankish, 2010). Rational decision making requires both systems (Stanovich, 2011).

Particularly interesting is the way the two modes of information processing interact. Consider for example the default-interventionist model, a common dual systems concept (Johathan Evans, 1989, 2006; Daniel Kahneman & Frederick, 2002; Stanovich, 2011). When a problem arises, the first type of information processing systems quickly supplies a general solution. The second system checks the initial solution and may reject it if deems it unsatisfactory. Thus, the first system can be considered to be intuitive, while the second is reflective or supervisory (Jonathan Evans, 2010).

The two systems are both related to instrumental rationality, both aim to achieve objectives. However, the desired objectives and means differ (Jonathan Evans, 2010). The first system's objectives are short-term objectives to satisfy immediate needs based on past experiences. Whereas the second system's objectives are motivated by anticipating the consequences of the decision making.

Another concept distinguishes intuitive and analytical processing (Reyna, 2004). Here intuitive processes entail gist memories. These are not accurate but do capture the essence of an experience. The analytical processes involve reciting past memories. These are precise, but more superficial. Unlike most dual system theorists, Reyna (2004) claims that intuitive judgements are often better than analytical judgements.

Pre-conditions

For system two, to fulfill its supervisory role there must be sufficient time available, a degree of confidence in the proposed solution, an incentive to behave rational and there cannot be competing demands (V. A. Thompson, 2009).

Conceptualising the cognitive processes in humans in two simple systems has been critiqued. Oversimplification to assume that intuitive judgement and implicit learning is accomplished by a single simple system, system 1. Moreover, the other system, system 2, is single-handedly responsible for checking intuitive judgement, deductive reasoning, hyphothesing consequences and a wealth of other cognitive functions. Neural imaging studies have shown that indeed multiple cognitive systems are engaged in duductive reasoning tasks (Goel, 2008). In response, Evans (2010) states that a wider view should be adopted and instead considered as two families of systems with both characteristics.

10.1.5 Decision making viewed from the black stool

The black stool is not really a decision model, more a view on organisational decision making which got its name from an anecdote about the issue of buying a housewarming present (Langley, Mintzberg, Pitcher, Posada, & Saint-Macary, 1995). When asked what the colour scheme of the new apartment was, the answer was; black. In a department store a black stool was spotted, which would fit the white countertop. This led to a swift selection of a wide array of other items with white, grey and black colours. Interestingly though, this decision could not be explained with conventional literature.

One conventional organisational decision making model is one of structured sequences. Here decision making is modelled as three sequential steps (Mintzberg, Raisinghani, & Theoret, 1976; H. Simon, 1960). First, diverse environmental inputs are reduced with an intelligent diagnosis of the problem. Next, the diagnosis initiates design, in which alternative solutions are generated. Finally, the alternatives are analysed to determine one definitive choice. Although it is bounded by the decision maker's limited rationality, this sequential process driven by diagnostics steadily progresses to one solution.

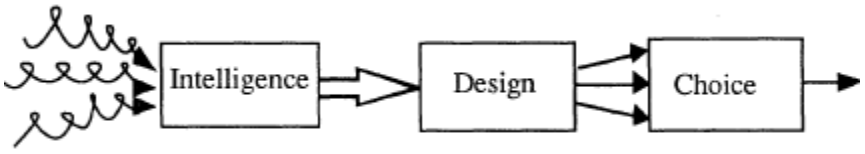


Figure 23 - Sequential organisational decision making (Langley et al., 1995, p. 263)

A second conventional model has quite a contradictory view of decision-making. With this view, decision-making is seen as a social interaction. The focus is on not structured activities like diagnoses and conceptualizing alternatives. Instead, it concentrates on ways in which problems and solutions emerging from different departments within the organisation meet and can be combined into a decision. This view of apparent random emersion of decisions, without any apparent structure or preceding process, can be visualised as a vortex, producing arbitrary solutions. The garbage can political decision making model (Cohen et al., 1972) is a well-known example of these types of models. Similar models are known as anarchical decision models, since one could argue that rationally bounded decision makers, in some situations, are confronted with so much complexity and ambiguity that anarchy takes over.

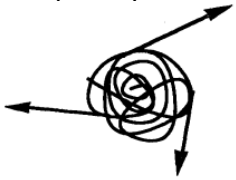


Figure 24 – Anarchical decision making displayed as a vortex generating arbitrary solutions (Hickson, Butler, Cray, Mallory, & Wilson, 1986)

A third model is positioned between the two previous models. It is based on sequential decision making, but includes anarchical elements (Mintzberg et al., 1976). These are dynamic factors that reflect the chaotic nature of the anarchical viewpoint, for example internal politics or some degree of external interference. The decision making process starts with a tangible problem, similar to the one in the sequential model. During the process the decision makers attempt to progress through the sequences, whilst their progress is hampered by unexpected external events and conflicts. The degree of impact that these events have determines how the decision making process mutates. Either towards a structured sequential process if the impact is small, or towards a more anarchical process when it becomes impossible to restore order (Langley et al., 1995).

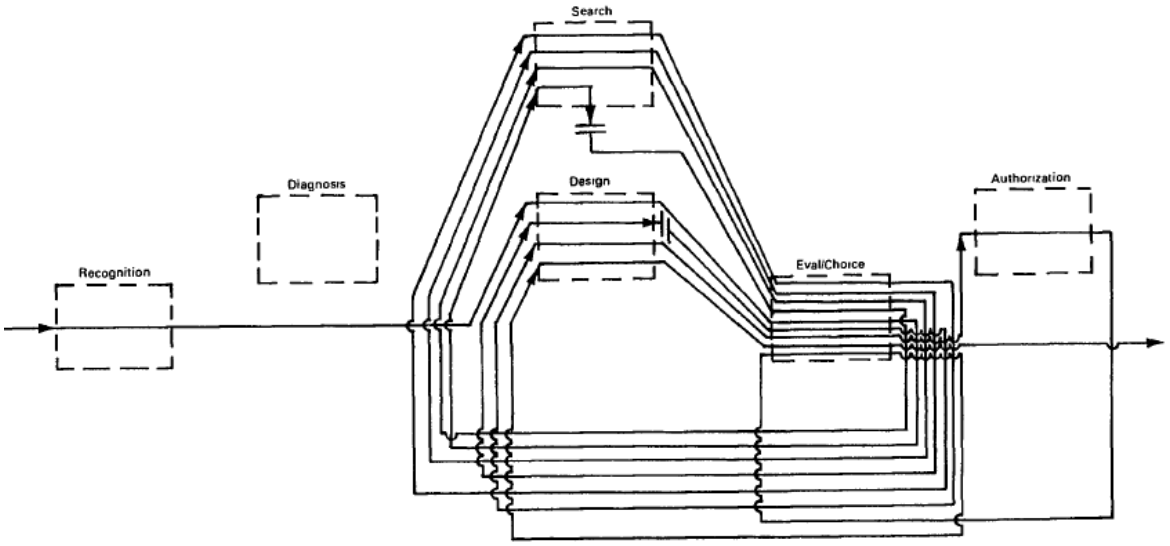


Figure 25 - (Mintzberg et al., 1976, p. 273)

Langley et al. (1995) explain that important aspects are underexposed in conventional decision-making concepts. First, the concept of the decision itself implies a distinct and identifiable choice. However, in practice decisions are not always easy to specify. Secondly, the decision making process is often depicted as a linear sequence of decomposed stages. However, decision-making is driven by the emotion, imagination and memories of the decision maker (Langley et al., 1995, p. 261), interrupted only by sudden revivals of thought. Thirdly, it is one thing to isolate a single decision, it is another to isolate the process preceding it. Commonly, decisions become intertwined and impossible to detangle from other decisions. Therefore Langley et al. (1995) argue that decision-making should be studied as a whole, in its context, both at the decision maker's level to incorporate insight and inspiration, emotion and memory. And at the collective level it should include history, culture and the organisation's network. Subsequently, Langley et al. propose three additional decision models, each of which deals with a corresponding limitation.

Since decisions are hard to pinpoint, not in place nor time, a fourth model adopts the view that decision-making, instead following a linear path, gradually convergences towards a final solution with a general trajectory of iterations (Hage, 1980). In this model, decision makers approach the situation differently. Instead of contemplating from a decision backwards in time to uncover what necessary steps are required prior, they work forward as if they were on a mission to create a still unknown solution. The underlying philosophy is that a problem is solved exactly simultaneously with finding a solution, which occurs in a process of successive approximations (Barnard, 1970).

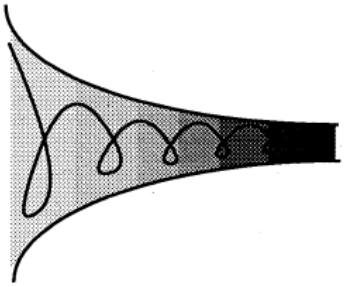


Figure 26 – Decision making as a process of convergence by means of successive iterations (Langley et al., 1995)

Langley etc. advocated to consider the decision maker less as a purely rational actor and more as a human. The fifth model incorporates this and views decision making as a process which is heavily influenced by the inspiration of the decision maker. Each decision maker brings along his education and training, past experiences and his

perception of the world. This materializes in the decision-making process through experience, insight, inspiration and affect. Hence, in this insightful decision making approach, the decision maker relies on 'intuitive sensibilities' to restructure his thinking and in addition is able to create new options (Langley et al., 1995). The decision process displays convergence, however, it is not as steady and gradual as in the previous model. Instead, the process advances by leaps and bounds in moments of occasional insight. These insights inspire and are inspired by other members of the organization.

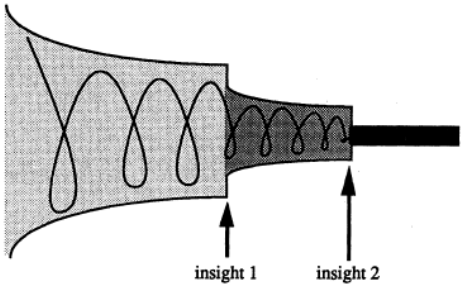


Figure 27 – Decision making based on insights; a first that brings an initial order to a confusing issue, a second that leads to the final decision (Langley et al., 1995, p. 269)

The last model acknowledges the dynamics of the organisation in which the decision-making takes place. As mentioned, it is difficult to put one's finger on the decision itself. Given that decisions interact with each other (McCall & Kaplan, 1985), the decision making process is no longer seen as an isolated sequence of progressive steps. Instead, decision-making is viewed as interacting streams of issues resulting in actions, at times via an identifiable decision. The interactions between different issue streams determines how the decision making unfolds (Langley et al., 1995). Interrelationships can simply be sequential, this entails interactions of the same issue at different moments in time. Predominantly lateral interactions can occur between different issues at the same moment in time. In this case, issues compete with each other for resources. Finally, there can be 'precursive relationships' between issues. Then, the linkages are between different issues at different moments in time, a decision on one issue affects future decisions in other issue streams.

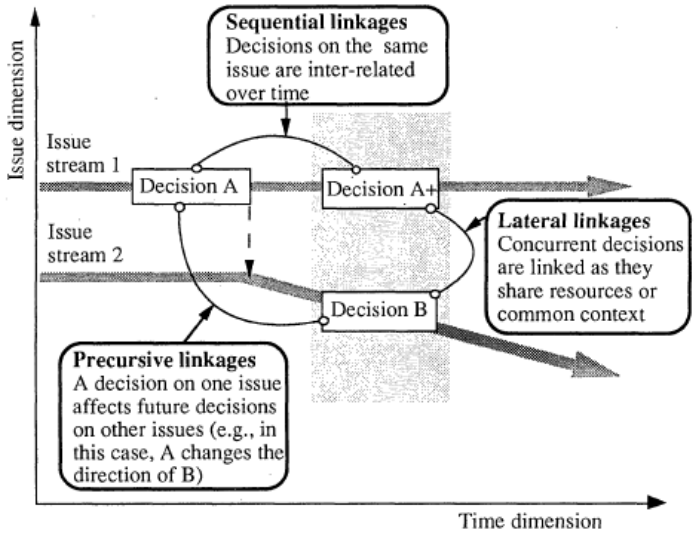


Figure 28 – Issue streams and potential decision linkages (Langley et al., 1995, p. 270)

This view of decision-making, as several issues with various linkages describes how organisational decision making occurs in a network of activities present at an organisation. This complex decision making context is called issue networks, sets consisting of interconnected issues evolving dynamically over time (Langley et al., 1995, p. 274). The organisation's decision-making is seen as the result of the type of organisation and the strength of the interactions between the organisation's issues.

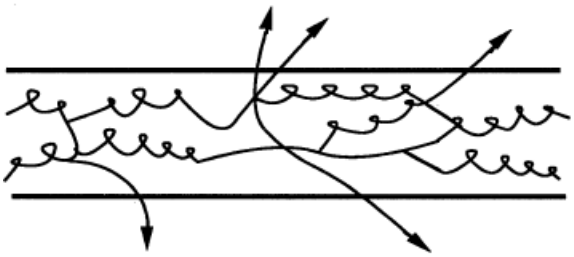


Figure 29 – Decision making a interwoven issue streams, with different strength couplings (Langley et al., 1995)

10.2 Appendix B - Organizational routines – their parts and methods of analysis

Organisational routines have both ostensive and performative characteristics (Pentland & Feldman, 2005). The ostensive part of an organisational routine can be viewed as the routine's structure, the sequence of actions one would use to describe the routine (Pentland & Feldman, 2005). Whilst the performance of the actions undertaken by the employees while they were engaged in an organisational routine is the performative aspect (Feldman & Pentland, 2003).

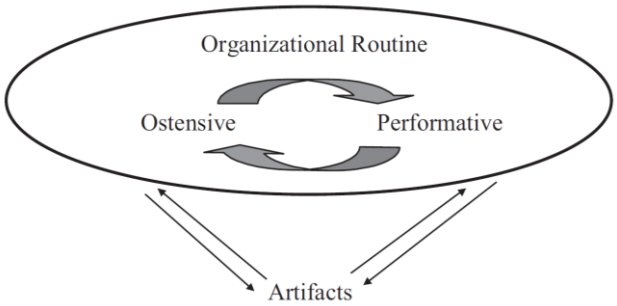


Figure 30 - Key elements of an organisational routine(Pentland & Feldman, 2005)

Within an organisation, various artefacts can be present which can constrain or enforce the ostensive or performative aspect of a routine. These artefacts manifest themselves in various forms, ranging from formal rules and procedures to less tangible artefacts such as the organisation's layout. Artefacts are a useful means to collect data on routines. Rules and procedures hold clues to the ostensive aspect, while various logs contain information regarding the performance aspect of routines (Pentland & Feldman, 2005).

It is a pitfall to assume that formal rules and standard operating procedures determine the sequence of behaviours that employees will follow. Such rules are often implemented in an attempt to prescribe work processes. However, the effect of such procedures in practice is often far from the intent. Even artefacts that aim to standardise behaviour are limited in their ability to specify particular performances, since, it is nearly impossible to cover all the details in rules and standard procedures. In fact, some details need to remain open to provide the ability to take different courses of action when circumstances vary. Further, standard operating procedures may also be mistaken for the ostensive part a routine. They should be viewed as indicators of the ostensive part only, as an effort to codify the ostensive aspect of a routine (Pentland & Feldman, 2005).

Routines generally are stored procedural memory (Cohen & Bacdayan, 1994). A regularly conducted routine gradually becomes more familiar. With that familiarity it becomes easier to perform the routine, but increasingly harder to describe it. Put differently, the performative aspect gradually becomes more and more tacit (Pentland & Feldman, 2005).

In order to obtain a proper understanding of organisational routines, the underlying processes must be understood. Particularly, if we want to influence, design or manage routines (Sutton & Staw, 1995). There are three main approaches to study routines. These range from assuming that a routine is something like a black box by ignoring internal structure, all the way to studying not only each part of a routine, but also its interactions (Pentland & Feldman, 2005).

The first approach of studying routines is discussed, studying routines as an undifferentiated black box. This is the most common approach to study routines (Pentland & Feldman, 2005). Hereby, a routine is studied as a functional whole. The inputs and outputs are examined, without delineating the routine's internal structure. This approach can produce meaningful results without going through the hassle of

unpacking the internal structure of a routine. Hence, it is a sensible, safe approximation for situations in which the research concerns the routine as a whole. Such questions usually focus on the outcome of a routine, like defect rates in a production setting (Oakland, 1996). However, for some research problems it this approach is not accurate enough. If the researcher is not careful, this approach will result in a poor understanding of the routine.

In such cases, the second approach of studying the particular parts of a routine in isolation is more suited. Routines need to be unpacked when attempting to explain their dynamics. Unpacking refers to examining the internal structure of a routine. A routine consists of three aspects, each of which can be examined; the performative aspect, the ostensive aspect and the artefacts (Pentland & Feldman, 2005).

- Performative aspect
  Studying the performative aspect is based on the notion that a routine consists of numerous performances of sequences of actions. These performances can be examined and compared to uncover relationship between context and the actions taken. Often the performance is studied in relation to specific variations in the context, such is the case in most field studies and simulations. This approach of examining the performative aspect of a routine is a well suited in terms of the level of detail and descriptive accuracy that can be reached, although it is not straightforward. Moreover, one should keep in mind that it is practically impossible to simulate performances by employees in context, therefore this approach may miss some nuances in performance. However, this approach allows for caparison of alternative conditions and can generate large amounts of data (Pentland & Feldman, 2005).
- Ostensive aspect
  Empirical research with routines focusses on the ostensive aspect. The primary area of interest in this type of research is the general concept of the routine. The focus is on the routine's idea and general structure, whereby particular performances are often used as examples (Pentland & Feldman, 2005). It is common for this type of study to examine the ostensive aspect of a routine to enable comparison of the different world views of groups. For example, how an employee's position within an organisation influences their perception of the ostensive aspect (Feldman & Pentland, 2003).
- Artefacts
  Researchers gratefully use artefacts as indicators of both the ostensive and performative aspect of organisational routines. For instance, formal rules and standard operating procedures are indicators of the ostensive aspect and work logs reflect the performative aspect. Yet, care must be taken when artefacts are used as indicators of the ostensive part, since it is likely that they do not fully reflect the routine the way it was intended by management. Still, artefacts are very useful to study routines, due to the ease of identifying them and in addition they remain relatively stable over time (Pentland & Feldman, 2005).

Thirdly, the relationships between the components of a routine and the processes by which these parts change can be studied. This is the case, for example, when there is an interest in factors that cause an observed change or either stability in a routine. As well as when there is an interest in drivers for innovation and flexibility, to enhance understanding of such dynamics the routine must be unpacked further.

There are three sets of relationships to consider (Pentland & Feldman, 2005). First, the relationship between the ostensive and performative aspect. Secondly, the relationship between the ostensive aspect and the artefacts. And thirdly, the relationship between the performative aspect and the artefacts.

Interaction between the ostensive and performative aspects

The ostensive and performative aspects of organizational routines occur in multiple, they are mutually constitutive (Pentland & Feldman, 2005). There are always small variations within a routine, resulting in multiple performances. Furthermore, there is no abstract pattern that all employees execute in all cases. Hence, there is variation in ostensive aspects too. Due to the variation in both aspects the interactions between the two aspects are diverse and complex (Pentland & Feldman, 2005, p. 80).

Interaction between the performative aspect and artefacts

Studying this relationship entails matching observed performances with related artefacts (Pentland & Feldman, 2005). There are several factors that influence to what extent the artefacts and performance can be matched. For example, the ease and accuracy with which the performance can be measured. Also, the degree of specificity in artefacts contributes. Matching becomes easier when artefacts are clearly written rules and procedures. Furthermore, if the rules are vague, one can expect more variance in the observed performance. This phenomenon can be used to study power relations. In a command and control governed organisation, artefacts such as the standard operating procedures represent the command. Hence, the match between standard operating procedures and performances can serve as a measure of control within the organisation.

Interaction between the ostensive aspect and artefacts

This relationship is often overlooked, since it is easy to miss (Pentland & Feldman, 2005). Written rules and standard procedures are often presumed to be the main understanding of the routine. This erroneously assumes that the standard operating procedures are the ostensive part, which they are not, they are an artefact. An artefact can only provide clues regarding the ostensive part of a routine. Nonetheless, the interaction between the ostensive aspect and artefact concerns how written rules or similar artefacts align with employees' understanding of the routine. For example, non-alignment can indicate disagreement between workforce and management regarding individuals goals (Pentland & Feldman, 2005).

10.3 Appendix C – Entrepreneurial decision making model

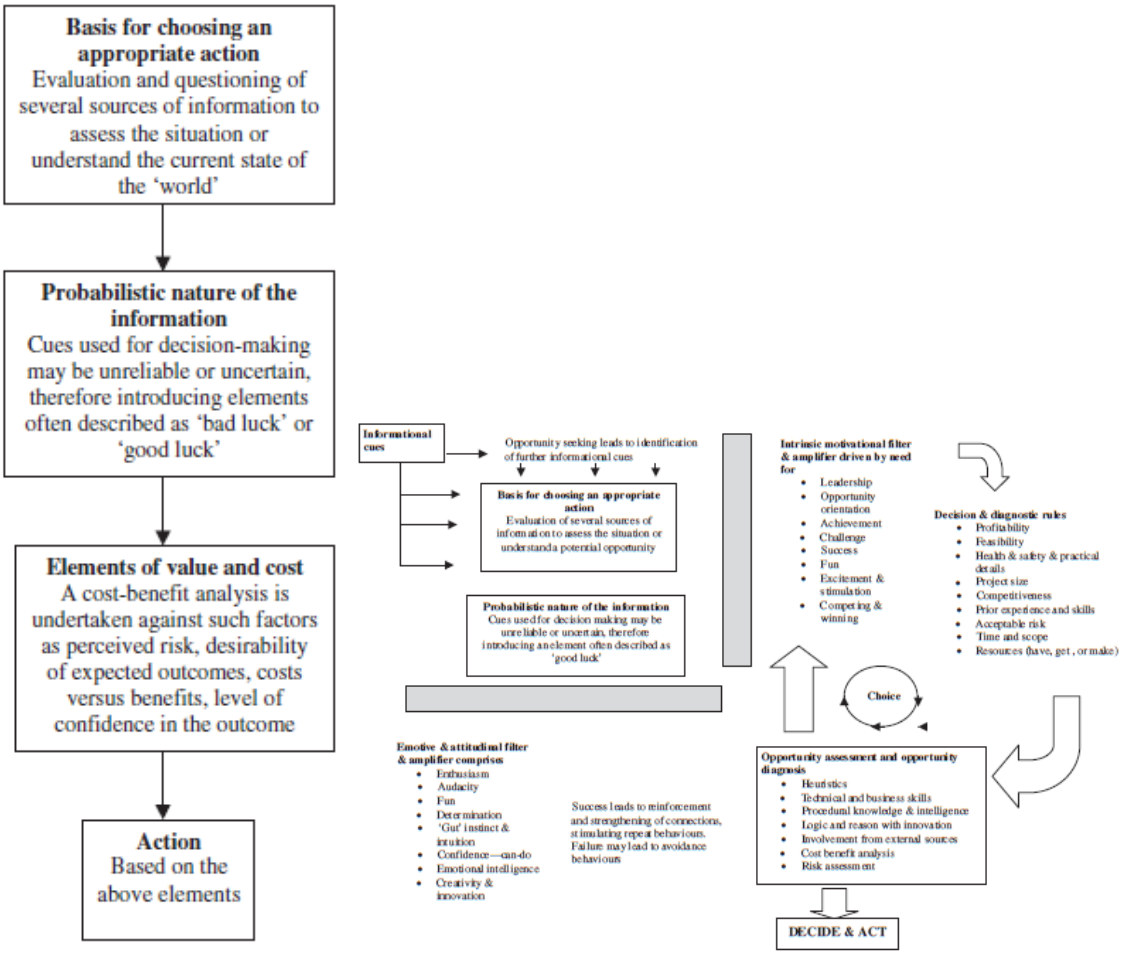


Figure 31 – General entrepreneurial decision model (Wickens & Flach, 1988), *Figure 32 – The entrepreneurial information processing and decision making model* (Pech & Cameron, 2006, p. 71)

10.4 Appendix D - Interview protocol – exploratory interviews

Eerste contact

1. *Introductie*

Oriëntatie fase

1. Uitleg over doel van het onderzoek
   - *Scope; design & construct projecten in NL*
   - *Prijsbepaling onderbelicht, subjectief proces, rationaliteit kan besluitvorming verbeteren, onbekend welke methode hiervoor geschikt is*
2. Uitleg over de rol van het interview binnen dit onderzoek
   - *Identificeren van de randvoorwaarden vanuit de praktijk*
   - *Inzicht krijgen in de geschiktheid van de methodes (verifiëren)*
   - *Identificeren of er beperkingen zijn in het toepassen van de methoden*
   - *Identificeren waar deze modellen verbeterd kunnen worden voor de Nederlandse infrastructuur markt.*
3. Anonimiteit/Geheimhouding + toestemming opnemen
4. Opbouw
   - *Proces bij aannemer*
   - *Eisen/Randvoorwaarden vanuit praktijk*
   - *Geschiktheid van methoden*

Interview fase

1. Het proces waarin de inschrijfprijs bepaald wordt, hoe ziet dat eruit?
   - *Betrokkenen*
     - *Functies*
     - *Projectafhankelijk*
   - *Tijd*
   - *Systematiek*
   - *Gestandaardiseerd/projectafhankelijk*
2. Is dat naar uw mening een rationeel of subjectief proces?
3. Waar wordt de inschijfprijs op gebaseerd?
   - *Criteria*
     - *Klant*
     - *Locatie*
     - *Ervaring*
     - *Aantal concurrenten + sterkte*
     - *Contractvoorwaarden*
   - *Beschikbare informatie*
   - *Geruchten, gericht informatie verzameld*
   - *Constant/projectafhankelijk*
   - *Gelinkt aan doel van bedrijf?*
     - *Winst maximalisatie*
     - *Prestige*
     - *Mensen aan het werk houden*
   - *Wordt er bijgehouden wie een combinatie vormen, wie winnen, voor welk bedrag?*

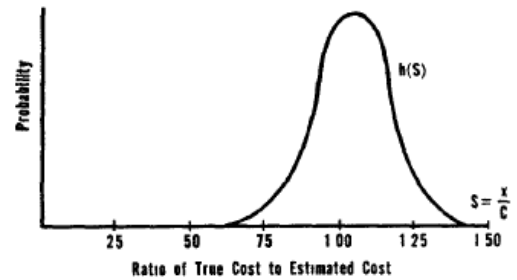
4. Hoe dient een beslissingsondersteunende tool eruit te zien?
    - Meer rationaliteit/ kwantitatieve onderbouwing
    - Checklist
    - Software
    - Team
5. Welke eisen/randvoorwaarden ziet u om een methode toe te passen?
    - *Tijd*
    - *Invloed*
    - *Transparantie*
6. Welke beperkingen ziet u om een methode toe te passen?
    - *Menselijke beslissing + verantwoordelijkheid*
    - *'Kritiek' op functioneren*
7. Kunt u deze methoden ranken op geschiktheid/potentieel?

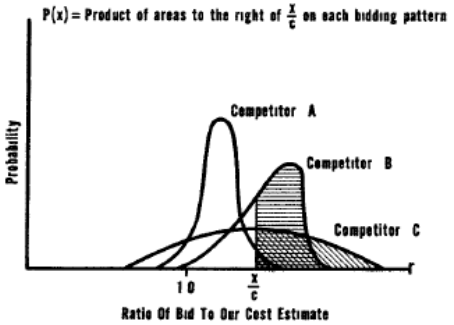
Afsluitende fase

1. Is er iets wat ik vergeten ben?
2. Heeft u opmerkingen over het interview en het onderzoek?
3. Toestemming voor follow-up?
4. Wilt u het transcript inzien?
5. Dubbelchecken anonimiteit
6. Wilt u het uiteindelijk rapport toegestuurd krijgen?
7. Kan ik een beschrijving van het bedrijf/bedrijfsprofiel ontvangen?
8. Bedanken voor medewerking

10.5 Appendix E – Interview protocol – exploratory interviews - talk sheet

Statistisch methoden





Input

- Biedingshistorie van concurrentie

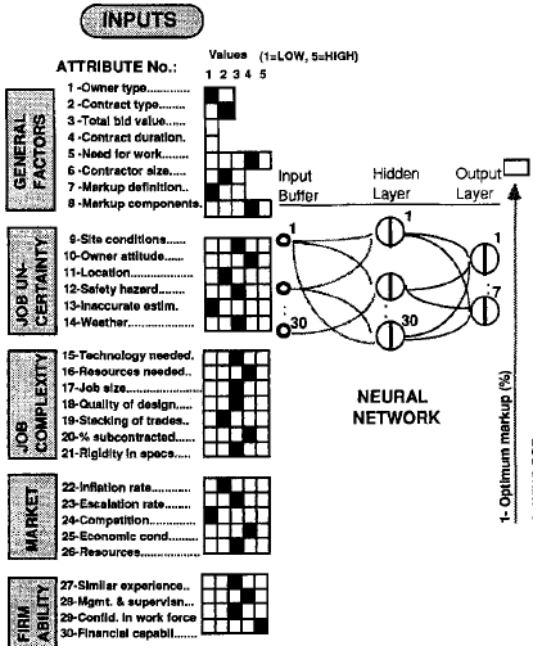
Output

- Interval van voorgestelde marges

Beperkingen

- Biedingsgeschiedenis van alle concurrenten moet beschikbaar zijn
- Aanname dat bieders zich gedragen zoals ze in het verleden deden
- Alleen winstgevendheid en concurrentie als variabelen (puur kwantitatief)
- Aanname is winstmaximalisatie; max (marge x kans)

Multicriteria methoden



Input

- Scores voor meerdere criteria
- Meerdere methoden om tot de inschijfprijs te komen

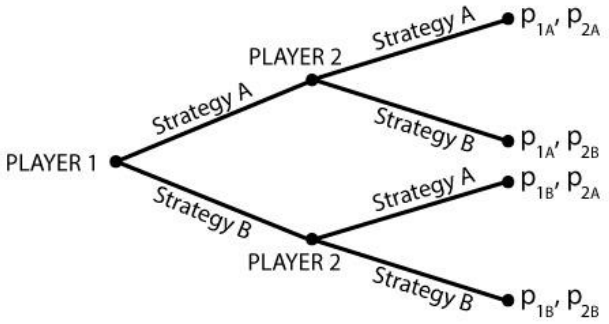
Output

- Suggestie voor marge

Beperkingen

- Onbekend welke methode meest geschikt is om tot de inschrijfprijs te komen
  - veel methoden zijn niet transparant
  - veel methoden gaan uit van winstmaximalisatie

Game Theorie



Input

- Alle mogelijke opties per bieder & de bijbehorende opbrengsten voor alle bieders

Output

- De te verwachten keuzes van de betrokkenen en de bijbehorende uitkomsten

Beperkingen

- Tijdrovend bij meerdere bieders en strategieën
- De concurrenten moeten in te schatten zijn
- Alle te verwachten opbrengsten moeten in te schatten zijn

10.6 Appendix F – Interview protocol – in-depth interviews

Gespreksleidraad met betrekking tot de biedprijs bepaling door een consortium voor grote integrale infrastructuur tenders

De aanleiding voor dit gesprek is een afstudeeronderzoek naar het proces waarin door een consortium wordt bepaald voor welk bedrag er ingeschreven wordt voor grote integrale infrastructuur tenders. Het bepalen van een optimale prijs is namelijk een uitdaging. Besluitvormers worden geconfronteerd met grote onzekerheden, gecombineerd met een beperkte hoeveelheid informatie en tijd. In het onderzoek wordt getracht het besluitvormingsproces in kaart te brengen, om te bepalen welke methode(n) het proces kunnen ondersteunen.

In het onderzoek staan twee vragen centraal;

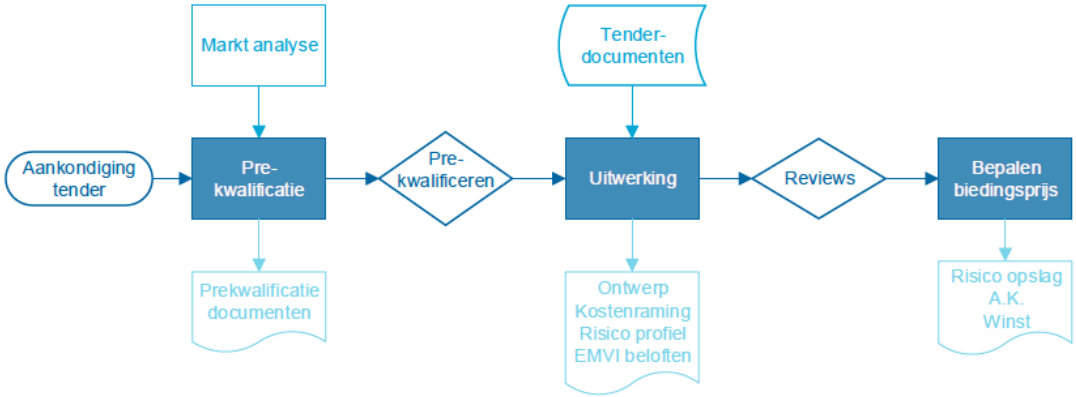
1. Hoe wordt de inschrijfprijs voor een grote integrale tender door een consortium bepaald?
2. Welke beslissingsondersteunende methode past het best bij het besluitvormingsproces dat in de praktijk plaats vindt?

Na een korte kennismaking zal ik het onderzoek nader toelichten. Vervolgens wil ik u in het gesprek vragen naar uw beelden over het besluitvormingsproces waarbij de biedprijs voor een tender bepaald wordt.

Graag zou ik het gesprek opnemen om te kunnen analyseren. Gezien de gevoelige aard van het onderwerp van dit onderzoek blijven de gesprekken en alle informatie die via de interviews wordt verkregen vertrouwelijk en zal niet met derden worden gedeeld. Informatie uit het gesprek kan in geabstraheerde vorm verwerkt worden in definitieve rapportage, maar de informatie zal niet traceerbaar zijn naar individuele respondenten of organisaties. In alle overige gevallen zal vooraf bij de geïnterviewde om goedkeuring worden gevraagd om passages weer te geven in het rapport.

1. Algemeen
   - Uitleg geven over onderzoek en waarom respondent geïnterviewd wordt.
   - Uitleg over opname en verwerking van het interview.
   - Benadrukken dat verstrekte informatie geanonimiseerd, in geabstraheerde vorm verwerkt kan worden in rapportage. Indien anders dan wordt hier vooraf toestemming voor gevraagd.
   - Toestemming vragen voor opnemen gesprek.
   - Vragen of de respondent vragen heeft vooraf.

2. Validatie tenderproces
   Met behulp van de verkennende interviews is een beeld verkregen van hoe het tenderproces verloopt. Dit is vastgelegd in een proces schema, wat voorgelegd wordt aan de respondent.



- Kunt u enkel op hoofdlijnen aangeven of het tenderproces dat gevolgd wordt bij de organisatie waar u werkzaam bent vergelijkbaar is met het opgedane beeld.
  Waar zitten significante verschillen?
- Worden altijd dezelfde stappen doorlopen of zit daar variatie in?
  Variaties in activiteiten, volgorde, diepgang, reden van deviaties.
  In hoeverre wordt een vast proces gevolgd?
  In welke mate is dit weer te geven in een flowchart?

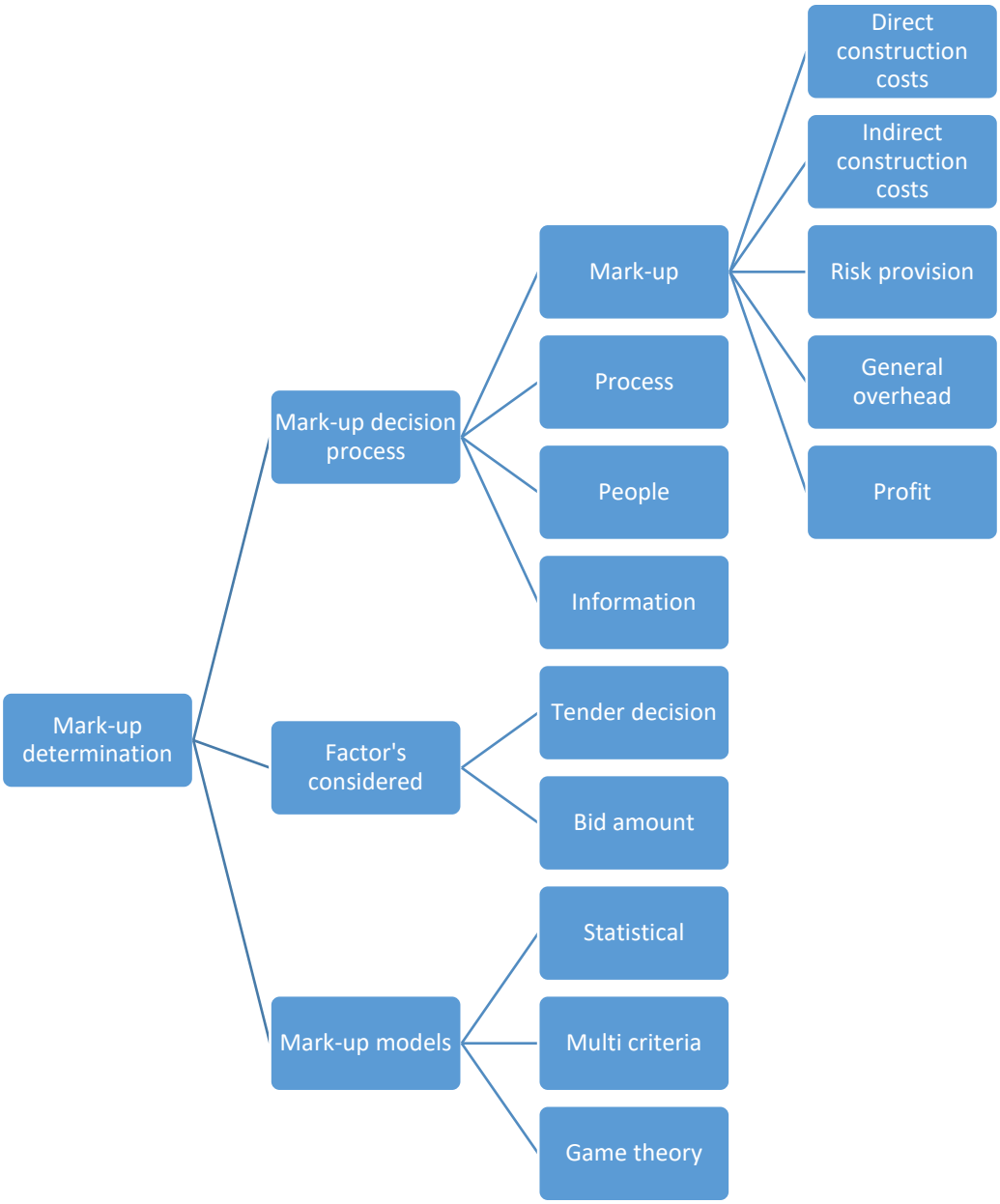
3. Tenderproces
   - Wat is de rol van het proces?
     Procesmatig; als hulpmiddel zodat een complete aanbieding ingediend wordt,
     Inhoudelijk; om informatie te verzamen zodat er een gefundeerde bieding gedaan kan worden.
   - Wat is de rol van het proces in relatie tot het bepalen van de biedprijs?
   - In hoeverre bent u tevreden met het proces?
     Wat zijn de sterktes van dit proces?
     Ziet u tekortkomingen in het proces?

3.1. Informatie verwerking bij het biedprijs besluit
   - Welke informatie heeft u tot uw beschikking bij het bepalen van de biedprijs?
     Prestaties uit het verleden, concurrentie, risico analyse
   - Hoe komt de informatie bij de besluitvormers terecht?
     Welke informatie wordt aangeleverd, welke informatie wordt zelf vergaard?
   - Hoe beoordeeld u de informatie die u aangeleverd krijgt?
     Inhoud, volledigheid
   - Hoe vaak heeft u het gevoel dat u informatie mist?
   - Hoe wordt omgegaan met onzekerheden en ontbrekende informatie?
     Onderbuik gevoel, ervaring, vuistregels, intuïtie, data verleden, prognoses.

3.2. Bepalen van biedprijs door een consortium
   De theorie over mark-up's gaat uit van één aannemer die tendert voor een project. In de praktijk van grote geïntegreerde infrastructuurprojecten dient een consortium gezamenlijk een bod in. De volgende vragen hebben betrekking op deze discrepantie.
   - Wie zijn er bij het bepalen van de biedprijs betrokken?
     Organisaties en personen incl. functies
     Hoe en aan wie wordt de beslissing verantwoord?
   - In welke mate wijkt het vaststellen van een biedingsprijs door een consortium af van het situatie waarin de organisatie zelf een bod doet?
     Hebben alle partijen gelijke inbreng?
     Hoe opereren subdivisies en afdelingen?
   - Hoe wordt de biedprijs bepaald?
     Onderlinge kostenramingen met algemene mark-up vs. elke organisatie bepaald een eigen 'subbiedprijs' incl. risico opslag en winstmarge?
     Consensus, iteraties/ronden
     Data versus intuïtie
   - Hoe en door wie wordt er gestuurd om tot een gezamenlijk bod te komen?
     Verschillen in opvatting, eigen belangen?
     Link met tenderstrategie? Wanneer wordt de te volgen strategie bepaald en hoe wordt dit gecommuniceerd?
   - Welke aspecten beschouwt u doorgaans?
     Intern/extern
   - Welke opties worden daarbij beschouwd?

4. Afsluiting
   - Bedanken voor de medewerking
   - Mogelijkheid aanbieden tot ontvangen rapportage
   - Vragen of er contact mag worden opgenomen indien er onduidelijkheden blijken te zijn?

10.7 Appendix G – Coding tree



10.8 Appendix H – Friedman's model of bidding against unknown competitors

Determining an optimum bid becomes more challenging when it is unknown how many competitors will bid and who they are. For this situation Friedman devised the concept of 'the average bidder'. The behaviour of this 'average bidder' is modelled by combining the probability density functions of the individual competitors into one function. This function is called f(r) and corresponds to a probability density function representing the 'average bidder's bid relative to the cost estimate of the studied contractor. The probability that a certain bid x is lower than that of the 'average bidder' can then be computed by $\int_{x/C}^{\infty} f(r)\,dr$. And the probability that a bid is lower than k average bidders is $\left(\int_{x/C}^{\infty} f(r)\,dr\right)^k$.

Next, Friedman assumed that the probability of k bidders submitting a bid can be determined. He noted this functions with g(k). If this is the case, than the probability that a bid is the lowest bid among k 'average bidders' is

$$P(x) = \sum_{k=0}^{\infty} g(k) \cdot \left(\int_{x/C}^{\infty} f(r)\,dr\right)^k.$$

What remains is the question of how to determine the combined distribution function of the 'average bidders' f(r). To answer this question Friedman fitted a distribution function to his data. He concluded that a gamma distribution often provides a good fit. This distribution is described by the formula $f(r) = \left(\frac{a^{b+1}}{b!}\right) r^b e^{-ar}$, with a and b constants obtained from the fitting the distribution.

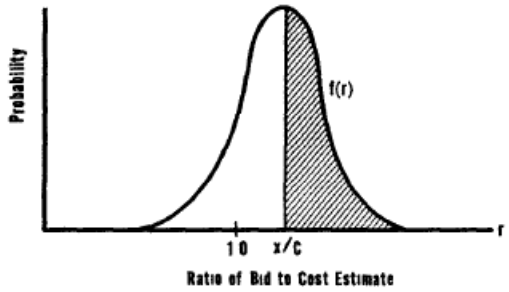


Figure 33: representation of the fitted probability density function of the 'average bidder'

Finally, he assumed that the number of competitors bidding would correspond to a Poisson distribution. A Poisson distribution is defined by $P(X = k) = \frac{\lambda^k}{k!}$ and provides the probability of a number of occurrences appearing in a fixed interval of time or space, if these events occur with a known constant rate λ and independently of the time since the occurrence of the previous event. In this case λ represents the estimated number of competitors. Hence, the fitted probability mass function of the number of competitors is $g(k) = \frac{\lambda^k e^{-\lambda}}{k!}$.

This results in a formulation for the probability of acquiring a project for bid amount x with λ expected competitors;

$$P(x) = \sum_{k=0}^{\infty} g(k) \cdot \left(\int_{x/C}^{\infty} f(r)\,dr\right)^k.$$

$$P(x) = e^{-\lambda} \sum_{k=0}^{\infty} \frac{1}{k!} \left(\lambda \left(\int_{x/C}^{\infty} \frac{a^{b+1}}{b!} r^b e^{-ar}\,dr\right)\right)^k$$

$$P(x) = e^{-\lambda}\, e^{\lambda\left(\int_{x/C}^{\infty} \frac{a^{b+1}}{b!} r^b e^{-ar}\,dr\right)}$$

$$P(x) = e^{-\lambda\left(1 - \sum_{s=0}^{\infty} \frac{1}{1!}\left(\frac{ax}{C}\right)^s e^{-\frac{ax}{C}}\right)}$$

(The summation is the cumulative of the Poisson distribution)

With both the probability of winning and the corresponding profit known the expected profit can be determined; $E(x) = P(x)(x - C')$

$$E(x) = e^{-\lambda\left(1 - \sum_{s=0}^{\infty} \frac{1}{1!}\left(\frac{ax}{C}\right)^s e^{-\frac{ax}{C}}\right)}(x - C')$$

All that is left is to determine the optimum mark-up is to optimise the obtained expression of the expected profit. This is done with the use of extreme value theory. Unfortunately, an analytic solution in closed form expression cannot be computed.

10.9 Appendix I – Acquisition schedule June 2019

Inkoopplanning Rijkswaterstaat

1. Inkoopdomein GWW, inkoop GWW Werken > 1,5 miljoen euro

versie 13 juni 2019

Projectnaam	Opdracht omschrijving	Zaak ID	Inkoopsegment: omschrijving	Inkoopsegment: percentage	Geschatte Contractomvang	Contractsoort	Verwachte marktbenadering	Mate van betrouwbaarheid	Plandatum marktbenadering	Plandatum sluiting marktbenadering	Best Value
Zuid-Nederland: Oevers Brabantse + Midden-Limburgse kanalen	GOVs 7b: Vaarwegen, onderhoud kunstwerken en realisatie Brug 1 Zuid-Nederland	31146597	Overige waterbouw	100	5mio – 15mio	D&C	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q3 2019	
Zee en Delta: Groot onderhoud bruggen	Repareren vermoeiingsschade stalen bruggen	31148573	Lichte staalconstructie / Onderhoudsconservering	50 / 50	1,5mio – 5mio	n.t.b.	Niet-openbare procedure Nationale aanbesteding	Waarschijnlijk	Q2 2019	Q3 2019	
West-Nederland Zuid: Hoofdvaarwegennet	Vervangen klemmen HvB	31150048	Civiele betonbouw nat	100	1,5mio – 5mio	n.t.b.	Meerdere offertes	Zeker	Q2 2019	Q3 2019	
Midden-Nederland: Prestatiecontract droog	Prestatiecontract Zuid 2020 - 2025 Perceel 2	31142566	Overige wegenbouw / Asfaltlijflaag vervanging / Vast onderhoud civiel droog / Civiele betonbouw droog	5 / 45 / 30 / 20	15mio – 35mio	Prestatiecontract	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	Best Value
Midden-Nederland: Prestatiecontract droog	Prestatiecontract Zuid 2020 - 2025 Perceel 1	31142564	Overige wegenbouw / Asfaltlijflaag vervanging / Vast onderhoud civiel droog / Civiele betonbouw droog	5 / 45 / 30 / 20	15mio – 35mio	Prestatiecontract	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	Best Value
Zee en Delta: Hoofdvaegennet	Rotondes Zeeland (RoZe)	31118236	Wegverhardingsconstructies / overige wegenbouw	50 / 50	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Onzeker	Q2 2019	Q4 2019	
Zee en Delta: Remmings- en geleidewerken	GOVs 7c: Realisatie remmings- en geleidewerken Zee en Delta	31145959	Overige waterbouw	100	15mio – 35mio	D&C	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	
West-Nederland Zuid: Stalen bruggen	Reparatiewerkzaamheden vermoeiingsscheuren stalen bruggen	31150222	Lichte staalconstructie / Onderhoudsconservering	50 / 50	1,5mio – 5mio	n.t.b.	Niet-openbare procedure Nationale aanbesteding	Zeker	Q2 2019	Q4 2019	
Programma Baggeren Zout 2020-2024	Baggerwerk Westerschelde	31146531	Onderhoudsbaggerwerk	100	5mio – 15mio	Prestatiecontract	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	
Programma Baggeren Zout 2020-2024	Baggerwerk Umuiden	31146530	Onderhoudsbaggerwerk	100	15mio – 35mio	Prestatiecontract	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	
West-Nederland Zuid: Stormvloedkeringen Keringen Team 1	Groot onderhoud conserveringen combiwanden Maeslantkering en waterreetcpatellingen (WMO's)	31146066	Boden- en oeverbescherming / Kleine kunstwerken	80 / 20	1,5mio – 5mio	D&C	Niet-openbare procedure Nationale aanbesteding	Redelijk zeker	Q2 2019	Q4 2019	
Programma Baggeren Zout 2020-2024	Baggerwerk Maasmond	31146534	Onderhoudsbaggerwerk	100	35mio – 100mio	n.t.b.	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	
Programma Baggeren Zout 2020-2024	Onderhoudsbaggerwerk Nieuwe Waterweg	31146535	Onderhoudsbaggerwerk	100	35mio – 100mio	n.t.b.	Openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q4 2019	
Zuid-Nederland: Oevers Brabantse + Midden-Limburgse kanalen	GOVs 7c: Realisatie remmings- en geleidewerken Zuid-Nederland	31149776	Overige waterbouw	100	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Redelijk zeker	Q2 2019	Q4 2019	
Maasroute	Resterend werk traject Berg - Obbicht Julianakanaal	31144593	Grondverzet nat	100	15mio – 35mio	D&C	Concurrentie gerichte dialoog Europese aanbest.	Zeker	Q2 2019	Q1 2020	
Overnachtingshaven Lobith	Realisatiecontract haven Spijk	31123736	Civiele betonbouw nat	100	35mio – 100mio	D&C	Niet-openbare procedure Europese aanbesteding	Zeker	Q2 2019	Q1 2020	Best Value
Zeetoegang Umond	Realisatie selectieve ontwelding (zout-maatregelen)	31125450			35mio – 100mio	D&C	Niet-openbare procedure Europese aanbesteding	Onzeker	Q3 2019	n.t.b.	
Zuid-Nederland: Natte Centrales TB2020	Natte Centrales TB2020	31146260	Onderhoud technische installaties	100	5mio – 15mio	Prestatiecontract	Openbare procedure Europese aanbesteding	Redelijk zeker	Q3 2019	Q4 2019	
Programma Baggeren Zout 2020-2024	Baggerwerk Waddenzee	31146533	Onderhoudsbaggerwerk	100	35mio – 100mio	Prestatiecontract	Openbare procedure Europese aanbesteding	Zeker	Q3 2019	Q4 2019	
Zee en Delta: Prestatiecontract	Prestatiecontract Zee en Delta Noord	31137096	Onderhoud E&M	100	35mio – 100mio	Prestatiecontract	Niet-openbare procedure Europese aanbesteding	Redelijk zeker	Q3 2019	Q4 2019	Best Value
Zee en Delta: Kustlijnzorg	Suppletiewerken programma Kustlijnzorg 1	31147145	Ontgraving en opspuiting	100	5mio – 15mio	E&C	Openbare procedure Europese aanbesteding	Zeker	Q3 2019	Q4 2019	
Zee en Delta: Kustlijnzorg	Suppletiewerken programma Kustlijnzorg 2	31147147	Ontgraving en opspuiting	100	5mio – 15mio	E&C	Openbare procedure Europese aanbesteding	Zeker	Q3 2019	Q4 2019	
Zee en Delta: Kustlijnzorg	Suppletiewerken programma Kustlijnzorg 3	31147148	Ontgraving en opspuiting	100	5mio – 15mio	E&C	Openbare procedure Europese aanbesteding	Zeker	Q3 2019	Q4 2019	
Zuid-Nederland: Oevers Brabantse + Midden-Limburgse kanalen	GOVs 7a: Oeverwerkzaamheden	31146425	Boden- en oeverbescherming	100	15mio – 35mio	D&C	Niet-openbare procedure Europese aanbesteding	Waarschijnlijk	Q3 2019	Q1 2020	
Zuid-Nederland: Oevers Brabantse + Midden-Limburgse kanalen	GOVs 7a: Noordervaart	31146427	Boden- en oeverbescherming / Overige waterbouw	75 / 25	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Waarschijnlijk	Q3 2019	Q1 2020	Best Value
Zee en Delta: Krammersluizen	Civiele werkzaamheden Krammersluizen	31146564	Overige waterbouw	100	15mio – 35mio	D&C	Openbare procedure Europese aanbesteding	Redelijk zeker	Q3 2019	Q1 2020	
West-Nederland Zuid: Beneden-Lek	Overnachtingsplaatsen Beneden-Lek	31108436	Overige waterbouw	100	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Redelijk zeker	Q3 2019	Q1 2020	
West-Nederland Noord: Ontmantelen baggerspeciedepot Averijhaven	Verwijderen baggerspecie Averijhaven	31143979	Ontgraving en opspuiting	100	15mio – 35mio	E&C	Niet-openbare procedure Europese aanbesteding	Onzeker	Q3 2019	Q1 2020	
Zuid-Nederland: Hoofdvaarwegennet	GOVs 6b: baggerwerkzaamheden Zuid-Nederland, Fase 3	31143303	Onderhoudsbaggerwerk	100	5mio – 15mio	D&C	Niet-openbare procedure Europese aanbesteding	Onzeker	Q3 2019	Q1 2020	
Programma Baggeren Zout 2020-2024	Baggerwerk Noordzee	31146532	Onderhoudsbaggerwerk	100	15mio – 35mio	n.t.b.	Openbare procedure Europese aanbesteding	Zeker	Q3 2019	Q1 2020	

Figure 34 – Rijkswaterstaat's acquisition schedule – June 2019

10.10 Appendix J – Attributing mark-up factors

TABLE 6. Factors Affecting Percent-Markup Decisions

Rank[a] (1)	Factors (2)	Percent of respondents scoring 4 or higher[b] (3)	Score[b] Mean (4)	Median (5)	Mode (6)
1	Degree of hazard	96.3	5.272	5.0	6.0
2	Degree of difficulty	95.1	5.074	5.0	5.0
3	Type of job	90.1	4.654	5.0	5.0
4	Uncertainty in estimate	89.0	4.927	5.0	6.0
5	Historic profit	86.1	4.532	5.0	5.0
6	Current work load	84.1	4.341	4.0	4.0
7	Risk of investment	80.2	4.741	5.0	6.0
8	Rate of return	79.3	4.293	4.0	4.0
9	Owner	77.5	4.313	4.0	4.0
10	Location	76.5	4.259	4.0	4.0
11	Need for work	75.3[c]	4.284	4.0	4.0
12	Reliability of subcontractors	75.3[c]	4.235	4.0	5.0
13	Design quality	75.2	4.235	4.0	5.0
14	Size of job	74.4[c]	4.280	4.0	4.0
15	Economic condition	74.4[c]	4.268	4.0	5.0
16	Competition	73.2[c]	4.268	5.0	5.0
17	Confidence in workforce	73.2[c]	4.037	4.0	4.0
18	Labor environment	71.6	4.086	4.0	4.0
19	Strength of the firm	70.7	4.012	4.0	4.0
20	Project cash flow	68.3	3.963	4.0	4.0
21	Contingency	67.5	4.037	4.0	4.0
22	Subcontracted amount	66.7	3.963	4.0	4.0
23	Supervisory persons	65.4	3.864	4.0	4.0
24	Duration	65.0	3.987	4.0	4.0
25	Capital requirement	56.1	3.585	4.0	4.0
26	General overhead	52.5	3.462	4.0	4.0
27	Labor requirement	46.9	3.272	3.0	4.0
28	Equipment requirement	40.7	2.938	3.0	4.0
29	Job start time	38.3	3.074	3.0	3.0
30	Season	34.1	2.768	3.0	1.0
31	Tax liability	33.3	2.901	3.0	2.0

[a]Ranked on the basis of percent of respondents scoring 4 or higher.
[b]Score scale 1–6: 1 = low importance; 6 = high importance.
[c]Same score, ranked on the basis of mean score.

Figure 35 – Ranking of the factors considered by American contractors when determining the mark-up (Ahmad & Minkarah, 1988, p. 235)

Table 7 Factors affecting the markup size decision

Factors	Percentage of respondents scoring ≥5	4	≤3	Number of respondents	Importance index	Rank
Degree of difficulty	83.10	13.30	3.60	83	81.76	1
Risk involved owing to the nature of the work	70.70	17.10	12.20	82	77.18	2
Current work load	70.40	16.00	13.60	81	76.37	3
Need for work	64.90	13.80	21.30	80	73.57	4
Contract conditions	68.70	17.50	13.80	80	73.37	5
Anticipated value of liquidated damages	62.50	25.00	12.50	80	71.07	6
Owner/promoter client identity	62.60	20.50	16.90	83	70.57	7
Past profit in similar projects	60.50	17.30	22.20	78	69.14	8
Completeness of the documents	55.00	25.00	20.00	80	68.75	9
Project size	55.40	26.50	18.10	83	68.33	10
Risk involved in the investment	55.60	22.20	22.20	81	68.07	11
Type of contract	55.60	24.10	20.30	79	67.81	12
Rate of return	52.50	22.50	25.00	81	76.37	13
Contractor involvement in the design phase	53.60	24.40	22.00	82	66.55	14
Project type	52.50	26.80	20.70	82	66.55	15*
Experience in such projects	53.10	24.70	22.20	81	66.49	16
Project cash flow	54.90	18.80	26.30	80	66.07	17
Risk in fluctuation in labour prices	52.40	22.00	25.60	82	65.16	18*
Quality of available labour	48.80	30.50	20.70	82	65.16	19
Availability of labour	47.90	29.60	23.50	82	64.55	20
Risk in fluctuation in material prices	47.60	28.00	24.40	82	64.11	21
Project location	42.70	37.80	19.50	82	63.41	22
Reliability of company cost estimate	46.20	26.90	26.90	80	63.37	23
Availability of other projects	45.20	26.80	28.00	82	63.07	24
Degree of hazard (safety)	47.40	21.80	30.80	78	61.90	25
Designer/architect/engineer	42.50	27.50	30.00	80	61.43	26
Design quality	46.20	23.80	30.00	80	60.89	27
Number of competitors tendering	42.00	28.40	29.60	81	60.32	28
Competitiveness of competitors	43.20	25.90	30.90	81	59.61	29
Owner's special requirements	37.40	28.80	33.80	80	59.46	30
Tendering method (selective, open)	36.70	34.20	29.10	79	59.31	31
Confidence in company work force	37.40	28.80	33.80	81	59.11	32
Availability of qualified staff	38.70	25.90	35.80	78	58.20	33
Project duration	33.80	30.10	36.10	83	56.45	34
Availability of required cash	32.40	31.30	36.30	78	55.71	35
Type and number of supervisory persons available	34.60	25.90	39.50	80	67.68	36
Labour environment (union/non-union)	35.90	25.60	38.50	78	54.76	37
Portion subcontracted to nominated subcontractor	35.50	17.70	46.80	78	54.64	38
Portion subcontracted to domestic subcontractors	34.60	22.20	43.20	79	53.79	39
Company strength in the industry	25.90	31.20	32.90	81	53.43	40
Identity of competitors	31.70	27.80	40.50	79	53.16	41
General (office) overhead	26.90	32.10	41.00	77	53.11	42
Project start time	42.70	37.80	19.50	83	52.50	43
Type and number of supervisory persons required	32.50	18.10	49.40	83	52.32	44
Job related contingency	23.70	31.90	44.40	72	51.39	45
Public exposure	20.50	33.30	46.20	80	50.73	46
Tendering duration	30.40	26.60	43.00	79	50.09	47
Qualification requirements	21.80	33.30	44.90	78	49.45	48
Availability of equipment	20.80	26.80	52.40	82	47.21	49
Policy in production cost savings	16.70	33.30	50.00	81	55.38	50
Policy in economic use of building resources	12.80	32.10	55.10	78	45.05	51
Government regulations	8.70	38.80	52.50	80	44.11	52
Insurance premium	10.10	21.50	68.40	79	37.61	53
Bond requirements	11.20	23.80	65.00	80	37.32	54
Tax liabilities	7.50	22.50	70.00	80	35.00	55

*Equal Importance indexes; ranked in accordance with the percentage of respondents scoring 5 or higher.

Figure 36 - Ranking of the factors considered by UK contractors when determining the mark-up (Shash, 1993, p. 116)

Table 6 Factors affecting bid/no bid decision

Factors	Percentage of respondents scoring ⩾5	4	⩽3	Number of respondents	Importance index	Rank
Need for work	91.70	7.10	1.20	84	86.39	1
Number of competitors tendering	82.10	11.90	6.00	84	83.50	2
Experience in such projects	85.70	10.70	3.60	84	83.16	3
Current work load	83.40	9.50	7.10	84	83.16	4*
Owner/promoter client identity	82.40	9.40	8.20	85	78.82	5
Contract conditions	75.00	17.90	7.10	84	78.57	6
Project type	77.40	11.90	10.70	84	78.57	7*
Past profit in similar projects	73.80	10.70	15.50	84	76.36	8
Project size	72.90	18.80	8.20	85	75.46	9
Tendering method (selective, open)	68.60	16.90	14.50	83	75.17	10
Risk involved owing to the nature of the work	69.10	13.10	17.90	84	74.83	11
Project location	71.80	18.80	9.40	85	74.12	12
Type of contract	64.70	20.70	14.60	82	71.60	13
Availability of qualified staff	60.80	20.20	19.00	84	71.60	14*
Rate of return	69.50	14.60	15.90	82	71.43	15
Project cash flow	60.20	16.90	22.90	83	69.19	16
Tendering duration	68.60	13.30	18.10	83	69.19	17*
Availability of other projects	57.20	21.40	21.40	84	68.88	18
Availability of labour	56.40	21.40	20.20	84	68.71	19
Completeness of the documents	61.40	19.30	19.30	83	68.67	20
Risk involved in the investment	54.20	21.70	24.10	83	68.33	21
Quality of available labour	56.00	23.80	20.20	84	68.20	22
Designer/architect/engineer	59.00	14.50	26.50	83	67.13	23
Anticipated value of liquidated damages	50.60	28.90	20.50	83	66.61	24
Type and number of supervisory persons available	52.90	22.40	24.70	85	65.21	25
Competitiveness of competitors	51.20	23.80	25.00	84	64.40	26
Contractor involvement in the design phase	47.10	20.00	32.90	85	63.53	27
Confidence in company work force	48.20	26.50	25.30	83	62.99	28
Degree of difficulty	45.20	25.00	29.80	84	61.73	29
Company strength in the industry	44.40	27.20	28.40	81	59.93	30
Reliability of company cost estimate	51.30	16.30	35.00	80	59.79	31
Design quality	45.70	20.50	33.70	83	59.04	32
Risk in fluctuation in labour prices	41.70	25.00	33.30	84	58.84	33
Degree of hazard (safety)	36.60	28.00	35.40	82	58.54	34
Availability of required cash	41.70	14.30	44.00	84	58.50	35
Risk in fluctuation in material prices	48.10	29.80	32.10	84	57.65	36
Labour environment (union/non-union)	39.50	25.00	34.50	84	57.65	37*
Identity of competitors	36.10	21.70	42.20	83	57.49	38
Owner's special requirements	36.10	25.30	38.60	83	56.63	39
General (office) overhead	29.90	28.80	41.30	80	54.01	40
Public exposure	29.30	28.00	42.70	82	54.01	41*
Project start time	28.20	24.70	47.10	85	52.77	42
Portion subcontracted to nominated subcontractors	29.70	27.40	42.90	84	51.81	43
Project duration	31.80	24.70	43.50	85	51.43	44
Availability of equipment	32.20	21.40	46.40	84	51.19	45
Type and number of supervisory persons required	28.90	24.70	49.40	85	50.92	46
Job related contingency	23.90	31.60	44.70	76	50.38	47
Portion subcontracted to domestic subcontractors	23.50	35.50	41.20	85	49.58	48
Qualification requirements	28.00	24.40	47.60	82	49.30	49
Policy in production cost savings	20.80	28.00	51.20	82	47.50	50
Policy in economic use of building resources	19.60	28.00	52.40	82	46.86	51
Bond requirements	20.20	22.60	57.10	84	43.88	52
Government regulations	8.40	44.00	47.60	84	43.71	53
Insurance premium	6.00	22.90	71.10	83	36.66	54
Tax liabilities	6.00	20.50	73.50	83	33.73	55

*Equal Importance indexes; ranked in accordance with the percentage of respondents scoring 5 or higher.

Figure 37 - Ranking of the factors considered by UK contractors when determining whether to bid or not (Shash, 1993, p. 117)

10.11 Appendix H – Output of a Monte Carlo simulation

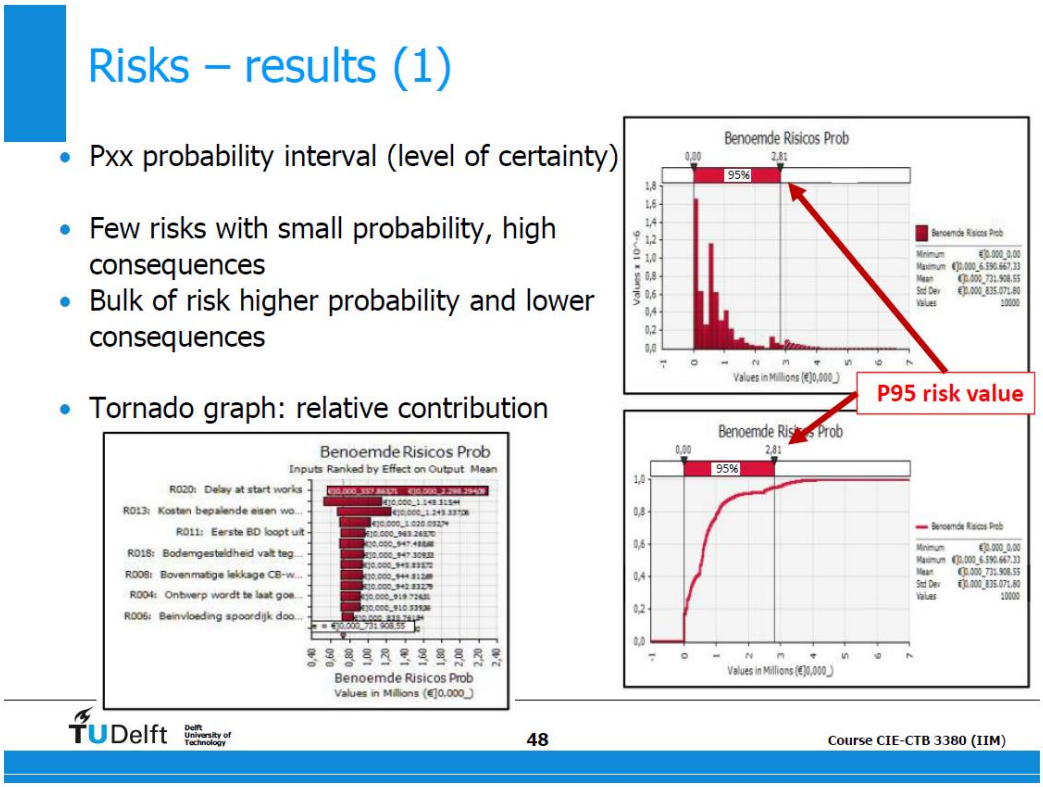


Figure 38 – slide from the lecture risk management and probabilistic costing and scheduling of Course CIE-CTB3380 (2016) to illustrate the outputs of a Monte Carlo simulation.