MASTER THESIS

The Role of the Payment Mechanism for Decision Making in the Early Stage of Dutch DBFM-Contracted Road Infrastructure Development

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The Role of the Payment Mechanism for Decision Making in the Early Stage of Dutch DBFM-Contracted Road Infrastructure Development

A thesis submitted in partial fulfilment of the requirements for the degree of

Master in Science in Business Administration

by Martijn Driesprong

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MANAGEMENT SUMMARY

In this study we concentrate on the extent to which incentives from payment mechanisms in Dutch DBFM contracts for road infrastructure development are integrated in decision making practices. We conclude that the availability incentives and timeliness incentives are fully integrated in the decision making practices in early stages of Dutch DBFM-contracted road infrastructure development. We find evidence for 50 per cent of the maintenance and reliability incentives embedded in the decision making practices and safety incentives were not reflected in the observed decision making practices.

BACKGROUND

After the Dutch parliamentary enquiry on fraud in construction, the market structure for Dutch infrastructure development changes drastically. The new market approach required different collaboration mechanism between RWS and the construction industry which were formalized in different types of performance contracts, including the DBFM contracts. These contracts emphasize on the delivery of and payment for performance levels rather than product and output specifications. The way in which performance levels and payments are related is recorded in the payment mechanism of the contract.

The payment mechanism acts as a normative framework that rewards performance and penalizes underperformance. As a result, the payment mechanism provides with important incentives for decision makers in infrastructure development. These incentives are especially in the early stage of infrastructure development relevant as decisions in these early stages are most influential for the further development of the project. However, the extent to which decision makers use the incentives in their decision making practices has remained unclear. The objective of this study is to clarify the integration of these incentives in decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development.

CENTRAL RESEARCH QUESTION
To which extent are elements of the payment mechanism integrated in the decision making practices in early stages of Dutch DBFM-contracted infrastructure development?

To answer the Central Research Question, we developed a theoretical perspective – or lens – through which we observe decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development and the way these relate to the payment mechanism. We use this lens in the case studies where we observed decision making practices and their relation with elements of the payment mechanism.

RELATED LITERATURE

The early stage in Dutch DBFM-contracted road infrastructure development is largely consumed by the tender process in which the contractor is faced with two incentive regimes: the MEAT-procedure and the payment mechanism. The incentives in the MEAT-procedure are similar to the incentives in the payment mechanism in that they aim for availability during the realization and exploitation stage although the incentives of the MEAT-procedure have an earlier impact, i.e. these incentives emphasise the probability of winning the contract while the payment mechanism emphasise the revenue from the project, if won. Based on an analysis of the standard structure of Dutch DBFM contracts, we find that the payment mechanism in Dutch DBFM contracts is best characterized as an incentive framework for contractors with incentives to timely deliver and maintain reliable, safe and available infrastructure.

Decision making encompasses an extensive field of academic research in decision making primarily building on classic economic theories and more recently on behavioural science. Evidence exist that the assumptions underlying the traditional, economic approach to decision making – rationality, complete information and infinitely sensitivity of the decision maker – often do not hold human reasoning is limited by their computational capacities, time and knowledge. Moreover, in many situations the optimal strategy is not only unknown but unknowable. In these situations, humans are unable to consider all possible strategies and outcomes and arrive at conclusions that satisfy rather than optimize their preferences. This is especially true for the construction sector as decision makers in construction focus on pattern recognition rather deep reasoning, rely on intuition derived from a mixture of gut feelings, experience and guesses, make subjective assessments and decide on partial cues.

Therefore, we take the perspective that decision making in DBFM-contracted road infrastructure development is best characterized as an adaptive toolbox with opportunity-capturing heuristics, consisting of search, stopping and decision rules – i.e., the building blocks – and guide the search for pieces of decision information (cues), indicate when the search for pieces of information (cues) is stopped and specify how the final decision is reached. Elements of the payment mechanism relate to these heuristics as these can provide with cues and decision criteria.

METHODS

We use this theoretical perspective to observe decision making practices in the field. To this end we analyse documents and interview (semi-structured) seven decision makers in three different DBFM-contracted road infrastructure development projects: Coen Tunnel Company, A-Lanes A15 and IXAS Gaasperdammerweg. We concentrate our observations on three focal points: (i) developing a general understanding of the decision making practices, (ii) developing a specific understanding of decision making practices and (iii) developing insight in the role of specific elements of the payment mechanism. We reconstruct the heuristics backwards: first we identify main decisions, then we identify the heuristic and building blocks and finally we analyse the cues and decision criteria on their relationship with the payment mechanism.

OBSERVATION OF DECISION MAKING PRACTICES

We find 51 opportunity-capturing heuristics: 9 selection heuristics, 22 procedural heuristics, 13 priority heuristics and 7 timing heuristics. In total, 24 opportunity-capturing heuristics relate to the payment mechanism and 27 opportunity-capturing heuristics are not directly related to the payment mechanism.

We find that the decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development projects are primarily characterized by technically-oriented leadership relying on experience in prior projects. The main aim of the early stage was to win the bid and subsequently successful completion of the project realization stage. The MEAT-procedure was considered highly important for decisions as decision makers focus their efforts on developing risk mitigation measures for risks defined by RWS.

The sequentiality of the projects was reflected in four developments in the decision making process since the Coen Tunnel Company project. First, the technical perspective in the decision making process shifted from a focus on detailing to information management, demonstrability and 'integrated thinking'. Second, the risk approach in the decision making process shifted from a technical, WBS-based focus on risks to project risks. Third, the focus on objectives shifted from RWS objectives to project objectives. Fourth, the reliance on experience in the decision making process decreased and inclusion of objectively based information validated by expert judgement emerged.

Decision making in the early stage of DBFM-contracted road infrastructure development is not concerned with realizing physical infrastructure; rather the early stage is information-based and involves interpretation of norms, contract requirements and recording interpretations in the final bid. As a result, decision making in the early stage is information-centred and can be described as an information-centred adaptive toolbox with heuristics related to obtaining information, information processing, prioritizing information and converting information into action.

We find that indeed the cues and decision criteria embedded in the heuristics relate to the payment mechanism; however not for all incentives. All availability incentives – compliance with availability requirements, minimizing lane closures and minimizing the impact of lane closures on important routes and route sections – are reflected in the observed heuristics where compliance with the requirements is the most prominent incentive. Four dimensions of compliance with requirements are established: compliance itself, arrangements for non-compliance, demonstration of compliance and creating compliance. No evidence is found for the relation between the safety incentives – prevention of injuries, fatalities and unsafe situations and adequate analysis, documentation and communication before execution of activities – and observed heuristics. Four maintenance and reliability incentives are reflected in the observed heuristics: compliance with performance and other requirements, adequate maturity of the project organization, prioritization of preventive (planned) actions over corrective (unscheduled) actions, timely execution of maintenance activities within recovery period. The incentives for prevention of repeated failures on requirements, reliability of measurement information, repeated non-occurrence of performance penalties and project realization within the agreed vehicle loss hours are not reflected in the decision making practices. The mediating effect of timeliness is reflected in multiple observed heuristics through prioritization of earlier execution of maintenance and traffic congestion mitigation measures, certain time slots and emphasis on the available maintenance nights and recovery periods.

RECOMMENDATIONS

The give rise to several recommendations for practitioners. For all recommendations, we provide further, more specific instructions in the main body of this thesis. First, the results show that safety incentives are not 'top of mind' in decision making practices in the early stage of DBFM-contracted road infrastructure development. We recommend practitioners better integrate safety consideration in their decision making practices. Second, we recommend RWS integrates the MEAT-procedure and payment mechanism in order to reduce complexity and advance unambiguous stimuli to contractors. The ideal situation is obtained when the MEAT-procedure is integral part of the payment mechanism as this eliminates any conflicting requirements and creates unambiguity. Third, we recommend that practitioners aim their attention on 'integrated thinking' rather than details, project risks rather than technical risks, project objectives and RWS objectives rather than only the latter and objectively based information validated by expert judgement rather than experience-based information.

For your notes

PREFACE

In 2006, I started my academic training in Civil Engineering at the University of Twente. Since then, I walked different paths in life and study. Now, nine years later after completion of a thesis in Financial Engineering & Management, I am writing the final words of my master Business Administration.

For this thesis, I have been engaged with consultancy firm Oxand which I have known since my early years in academia. I am grateful to Sander Sieswerda who has provided me with this opportunity and it has given me exactly what I was looking for: a way to combine my interests in large infrastructure projects, financial incentive structures and complex decision making while exploring the life of an capital intensive asset management consultant.

A special acknowledgement goes out to Tim Nillesen who provided structure and focus when needed. I would be remiss not to thank Herman for his enthusiasm, interest and support as well as my other colleagues at Oxand. I cannot, and will not, forget to express my appreciation for the anonymous interviewees; for their time and the open atmosphere in which we discussed decision making in Dutch DBFM-contracted road infrastructure development projects.

I also thank my supervisors from the University of Twente for their involvement. I had the enjoyment of open and constructive feedback from Hans Heerkens. As an expert in decision processes, his insights and direction were indispensable for my thought process and, equally important, the surprising combination of enthusiasm and calmness was refreshing and proved fruitful ground for new energy new energy. I have experienced Klaasjan Visscher as an inspiring lecturer and as a valuable reviewer. His ability to pinpoint exactly the main focus points was invaluable to the completion of this thesis.

In Dutch fashion, I saved 'the best for last'. This thesis is not only my final deliverable for obtaining a Master of Science degree in Business Administration at the University of Twente, it also marks a long unwished-for, but now highly anticipated start of new paths. Laura, thank you – again – for your patience and support and I am looking forward to our new paths together.

Martijn Driesprong

Utrecht, November 2015

"Other things may change us, but we start and end with family" (Anthony Brandt)

For your notes

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GLOSSARY

BAFO	Best and Final Offer; the final offer from prospective contractors to RWS which consists of qualitative – e.g., describing the project approach, planning and design – and quantitative – e.g., describing the prices and financing conditions – documents.
DBFM	A form of public-private partnership in which the responsibility for the Design, construction (Build), Finance and Maintenance is contracted to the private partner.
D&C	A form of public-private partnership in which the responsibility for the Design and Construction is contracted to the private partner.
FMECA	Failure Mode Effect and Criticality Analysis; a method to create insight in physical risks by identifying the main failure modes, underlying causes and effects of the infrastructure.
MEAT	Most Economically Advantageous Tender; a tender procedure in which additional value is assigned to specific, predefined aspects of the requested infrastructure development, i.e. MEAT-eligible elements. This MEAT value is subtracted from the financial aspects of the offer (e.g., the price) in order to obtain the BAFO.
TCRP	Traffic Congestion Restriction Plan; a document in which the main mitigation measures to limit traffic congestion during the realization stage are described. These measures are MEAT-eligible (see MEAT).
RAMS	Reliability, Availability, Maintainability and Safety; RAMS analysis is an umbrella term for different methods to design reliable, maintainable and safe products with high levels of availability.
RMP	Risk Management Plan; a MEAT-eligible document in which main risks and their mitigation measures are described.
RMPO	Risk Management Plan Outline; a first official draft of the risk management plan (see also RMP).
RWS	Rijkswaterstaat; the Dutch public agency responsible for infrastructural development and management.
WBS	Work Breakdown Structure; the decomposition of the infrastructure into specific technical and physical elements (or assets).

1. INTRODUCTION

This chapter introduces the main research problem and describes the research design. We highlight the relevance of the research and discuss the research context. This context is developed into the research strategy.

In section 1.1 we discuss the motive for the research and provide background information. In section 1.2 we narrow in on the problem statement and define the main objective. Our research approach is detailed in section 1.3 in which we describe the knowledge required for the main objective. In section 1.4 we discuss research boundaries and in section 1.5 we highlight important concepts and definitions. We conclude this chapter with an outline of this thesis.

1.1. MOTIVE TO THE RESEARCH

The Netherlands is one of the most densely populated countries in the world and its prosperity strongly depends on trading activities. Mobility and high-performing infrastructure are essential for Dutch accessibility, competitive position and quality of life (Ministry of Infrastructure and the Environment 2012). In practice these goals are achieved by maintenance of existing infrastructure and development of new infrastructure with reference to asset management principles.[1]

1.1.1. New market approach with DBFM contracts

In the last decade, the Dutch infrastructure market transformed drastically. Until 2000 the industry was primarily focused on delivery of specified products (e.g., roads) where nowadays infrastructure contractors deliver performance levels supported by products (e.g., roads with a 20 years maintenance contract). This shift primarily resulted from the parliamentary enquiry on fraud in construction which revealed widespread practices of market fixing practices which severely limited competition and innovation in the construction sector. Strong interrelations existed between government officials responsible for infrastructure development and the construction sector and boundaries between different governmental roles (e.g., as regulator and principal) were unclear (Enquêtecommissie Bouwnijverheid, 2003, p. 21). The commission charged with the enquiry recommended major reforms which included a new structure and culture in both the construction sector and related government agencies. This new culture and structure were together referred to as “new professionalism” and

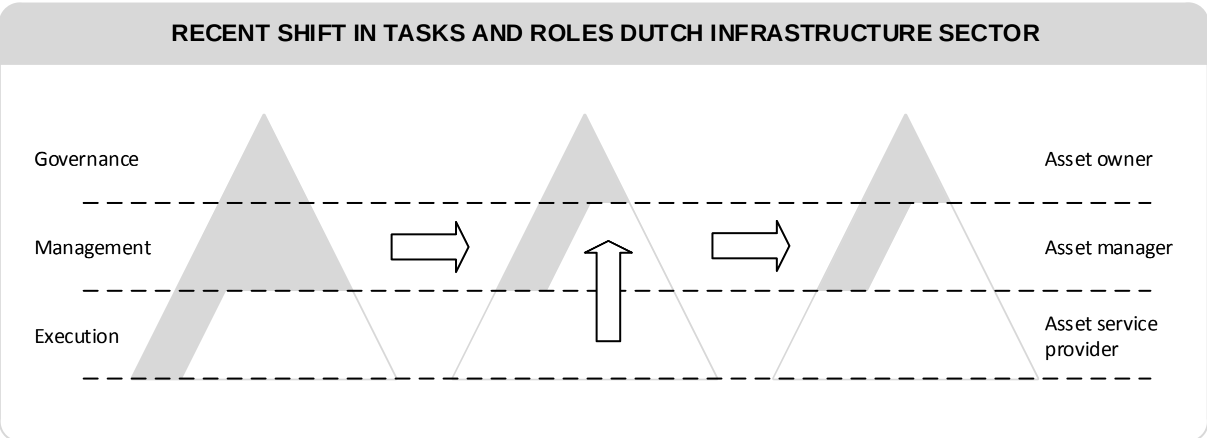

Figure 1 Recent shift in the Dutch infrastructure sector. Public (RWS) roles and tasks are indicated in grey whereas the remaining areas are the responsibility of the private sector (contractor).

[1] Asset management principles focus on the maintenance and development of infrastructure in a comprehensive, systematic, sustainable and risk-controlled manner. A life-cycle approach and is a crucial element of asset management.

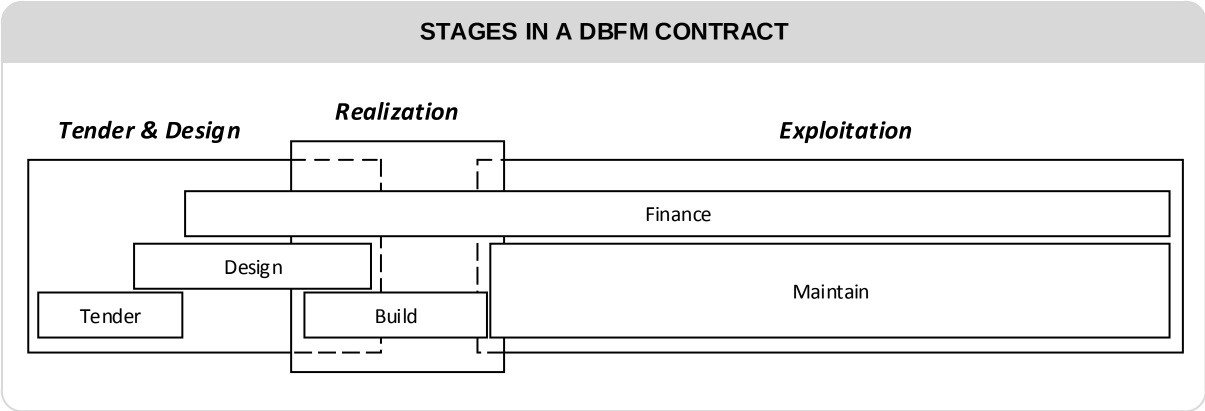

Figure 2 Activities and stages in a DBFM-contracted road infrastructure development project.

characterized by a government at appropriate distance, transparent competition and a sound market mechanism (Enquêtecommissie Bouwnijverheid, 2003, p. 296).

As a result, Rijkswaterstaat[2] (RWS) – the government agency with primary responsibility for infrastructure development – changed their market approach drastically (see Figure 1). Their new role required a transition from management of performance rather than management of output by specification. The new role allows RWS to increase its use of market knowledge for innovation and market discipline for competitive prices. As a consequence, RWSs main activities changed from infrastructure management towards network management.

1.1.2. Performance contracts

The new market structure required different collaboration mechanisms between RWS and the construction industry with rewards for service delivery based on performance rather than rewards for products delivery based on specifications. These collaboration mechanisms have been recorded in performance contracts which specify required performance levels and link these to payments. An important role is reserved for integrated performance contracts which arrange performance delivery over multiple life-cycle phases of a construction project.

The Design, Built, Finance and Maintenance (DBFM) contract is one type of integrated performance contracts and accommodates long-term[3] public-private partnerships in which the responsibility for the design, construction (build), finance and maintenance is tendered to the private partner (see Figure 2). The private partner acts as the asset manager with responsibility for asset performance over the life-cycle of the contract and receives periodic payments for performance delivery in line with the requirements set by the contract principal and asset owner, e.g., RWS. As a result, the contractor obtains, at least partly, responsibility for (Tywoniak, Rosqvist, Mardiasmo, & Kivits, 2008, p. 1554):

- Understanding business costs and performance drivers;
- Determining investments to optimize performance and operational costs;
- Managing the delivery of network performance and investment programs;
- Monitoring asset conditions;
- Devising appropriate maintenance and disposal policies.

Key in these activities is the performance-payment linkages which act as an incentive framework for contractors' performance (Lenferink, Tillema, & Arts, 2013, p. 620). This complete body of

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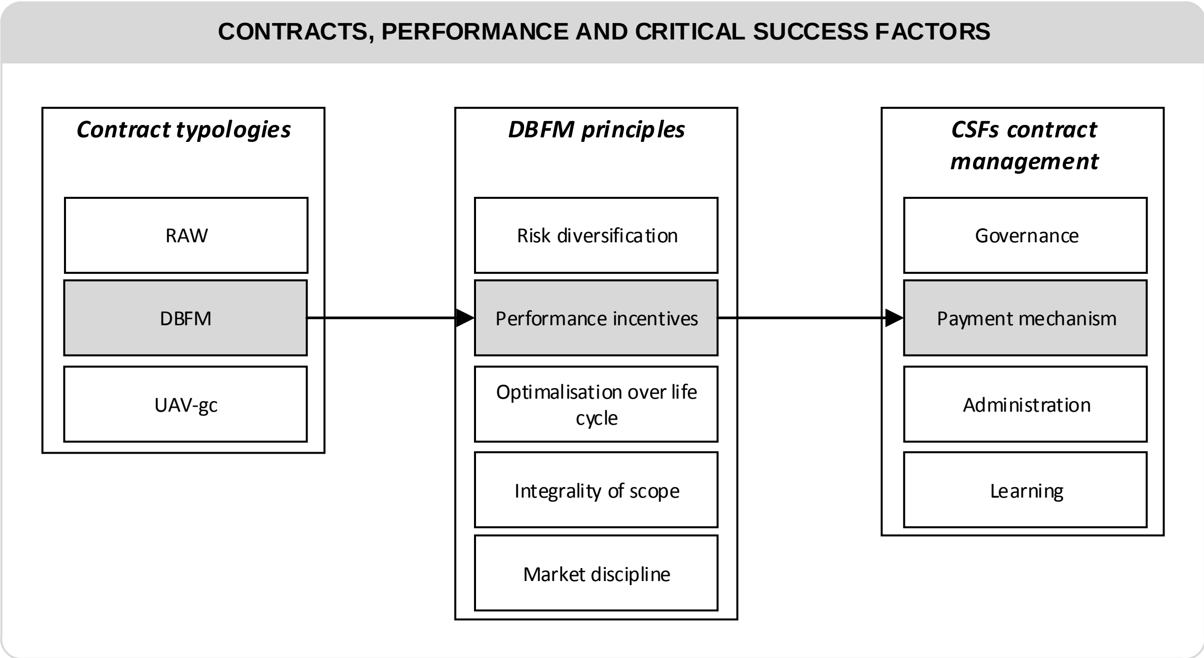
2 Rijkswaterstaat is the governmental agency responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands (Rijkswaterstaat, 2015a).

3 DBFMs may have durations up to 30 years.



performance-payment linkages recorded in DBFM contracts – the payment mechanism – acts as a normative framework that rewards performance and penalizes underperformance. As a result, project valuation and RWS' control over performance delivery in DBFMs relies heavily on early unequivocal performance-payment linkages.

1.1.3. Payment mechanism and decision making

This focus on the payment mechanism is a natural choice since it links payments to performance requirements. This mechanism arranges the payments – and potential deductions from payments – from RWS to the contractor for the demonstrated performance delivery according to the contract. As such the payment mechanism is a key performance management tool: it allows RWS to manage contractor's performance and the contractor to value project performance requirements correctly. This is especially important in Dutch DBFM contract-based infrastructure development since payments for performance delivery are the sole source of income for contractors in DBFM projects (Lenferink et al., 2013, p. 616).

The focus on performance in the integrated contracts requires RWS to specify required performance outcomes rather than product output. These performance requirements need – similar to the traditional way of contracting with RAW specification requirements – early and unequivocal specification. However due to the life-cycle approach and long duration of DBFM contract-based infrastructure development, early clarity in these requirements and other information in these projects is even more important as the information need-availability gap is most influential in tendering and early design stages (see Figure 3) and the most decisive decisions are made in the early stage of the DBFM contract-based infrastructure development project.

In practice, the early stage of infrastructure development is complex, characterized by ambiguous objectives[4] and information in these stages stems from disparate and uncertain sources (Bagies & Fortune, 2006, p. 512). Ambiguity in objectives obfuscates the performance requirements and consequently the performance-payment linkages, i.e. the payment mechanism. This lack of clarity affects decision making in the Dutch DBFM contract-based infrastructure development projects since

[4] Ambiguous goals are common in DBFM contracts. This may have different causes –unclear and conflicting definitions and alignment with other (legacy) projects. In the tender process time is reserved to address these issues, i.e. the 'Dialogue'.

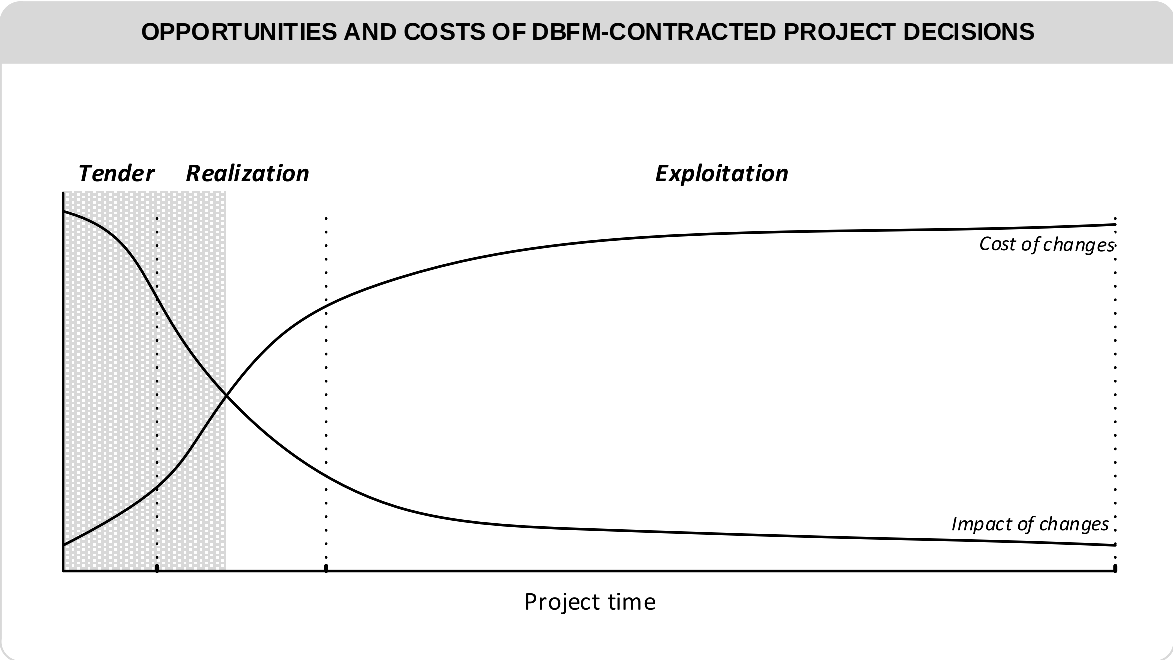


Figure 3 Influence on project performance over time. Early decision making (grey area) allows for high impact at relative lower costs (adapted from Winch, 2010, p. 270)

the performance-payment mechanism provides contractors with important decision rules during the early stage of the infrastructure development project.

However, the extent to which decision makers in the early stage of DBFM-contracted road infrastructure development make use of and are guided by the decision rules from the payment mechanism is unclear. This is primarily due to the life-cycle focus of DBFM-contracts and uncertainty stemming from the large scope and uncertainty of large infrastructure projects. The life-cycle focus in DBFM contract-based infrastructure development frontloads decision making drastically. These decisions have major implications for the (financial) performance over the complete life-cycle of up to 30 years. Furthermore, decision making in the early stage of infrastructure development involves reflection on numerous ambiguous objectives and – internal and external – factors and require information collection from uncertain sources (Bagies & Fortune, 2006, pp. 511–512).

This study aims to shed light on the extent to which decision makers integrate elements of the payment mechanism in the early stage of DBFM based infrastructure development. Understanding decision making and the role of the payment mechanism in practice is a first step towards better project performance management.

1.1.4. Relevance

DBFM-contract based infrastructure development is relatively new in the Netherlands. As of January 2015, RWS has tendered 13 projects since 2004 whereof only four projects had entered the exploitation stage (see Table 18). In their annual review of the DBFM contract, RWS concluded that DBFMs aid the movement towards ‘new professionalism’ as DBFMs allow RWS to act as an asset owner at distance (Rijkswaterstaat, 2014b, p. 47). The pipeline for DBFM projects is filled and in the coming years RWS aims to increase the use of DBFMs. Hence, in the coming years use of the payment mechanism is likely to increase as central performance-payment framework in Dutch infrastructure development.

Currently, RWS is evaluating its DBFM contract management capabilities with a special focus on performance management and the payment mechanism. These issues are especially relevant since

CONTEXT OF THE RESEARCH

Subject matter

- Role of the payment mechanism in early stages of decision making process for DBFM-contracted road infrastructure development

Motive

- Improving control over DBFM-contracted road infrastructure development project performance

Scope in focus

- Individual and human decision making process
- Dutch DBFM contracts for road infrastructure development

Scope in time

- Tender and early design stage

General approach

- Characterizing the decision making process in early stages of DBFM-contracted infrastructure development
- Establishing theoretical relationship between the payment mechanism and decision making process
- Identifying the decision making process in practice
- Establishing empirical relationship between payment mechanism and decision making process
- Reflecting on the role of the payment mechanism in early stages of DBFM-contracted decision making proces

only recently first DBFM contracts entered the exploitation stage and improvements in performance management now may improve decisions in tender & design stages for new projects (Rijkswaterstaat, 2011, p. 49). Our study enables RWS to include experiences with the payment mechanism in their evaluation of DBFM contract management capabilities. Knowledge about the payment mechanism's performance and the influence of the payment mechanism on decisions in tendering and early design can improve the contractors' ability to assess valuable performance and RWS' control over project performance in Dutch DBFM contract-based infrastructure development.

RELEVANCE

Insight in decision making in early stages of infrastructure development + Insight in the integration of elements of the payment mechanism in decision making → Possibilities to further improve control over project performance

1.2. PROBLEM STATEMENT

The payment mechanism in DBFM contracts provide decision rules for contractors – e.g., guidelines for project valuation. However, decision makers in construction – especially in the early stages – are also faced by complexity, surrounded by uncertainty and need to rely largely on subjective judgement and experience (Fayek, Ghoshal, & AbouRizk, 1999, p. 23). The extent to which decision makers integrate the elements from the payment mechanism in their decision making practices has remained unclear. Reliance of decision makers on the payment mechanism is our central research problem.

PROBLEM DEFINITION

The extent to which decision makers in early stages of Dutch DBFM-contracted infrastructure development integrate elements of the payment mechanism in their decision making practices is unclear.

Insight in the relationship between the payment mechanism and decision making allows the contractor to reflect on the effectiveness of the current decision making practices. For RWS, this study contributes to their efforts to evaluate their contract management abilities. Moreover, insight in the extent to which elements of the payment mechanism align with contractor's decision making practices in the early stage of DBFM-contracted road infrastructure development contributes to RWS's ability to manage contractor's performance. This contribution to better project control with insight in the payment-decision making linkages is our main objective.

MAIN OBJECTIVE
Contribute to better control over project performance in early stages of Dutch DBFM-contracted road infrastructure development by creating insights in the extent to which decision makers integrate elements of the payment mechanism with their decision making practices.

We examine literature on decision making in the early stage of road infrastructure development and study the payment mechanism in Dutch DBFM contracts. Potential linkages and relationships are identified and we discuss these with practitioners in the field of Dutch DBFM-contracted road infrastructure development decision making. Differences in the potential linkages and relationships and the observations from the experts provide insight in potential improvements of the payment mechanism and decision making practices.

1.2.1. Knowledge requirements

The main objective consists of two elements, i.e. the objective *of* the research and the objective *in* the research. The former describes the external goal and relevance for practitioners – contribute to better project performance – while the latter describes the knowledge required for the external goal. These knowledge requirements focus on the payment mechanism – decision making linkages and is detailed in the Central Research Question (CRQ).

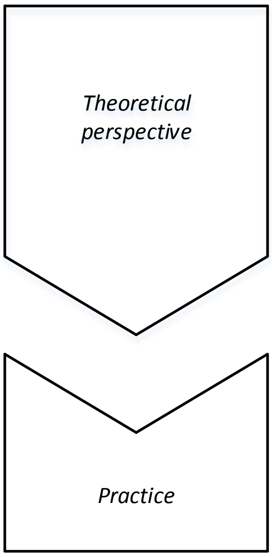
CENTRAL RESEARCH QUESTION
To which extent are elements of the payment mechanism integrated in the decision making practices in early stages of Dutch DBFM-contracted infrastructure development?

This Central Research Question is supported by different Research Questions (RQs). In line with the steps for empirical research proposed by Flynn et al. (1990, p. 250), these Research Questions are best seen as guidance throughout the research project. The specific Research Questions are reflected in Figure 4. We start with the development of a theoretical perspective on the payment mechanism, decision making and potential linkages. Then, the theoretical perspective is confronted with observations from practitioners in the field. We specifically aim to clarify the decision making practices used by decision makers in the early stage of DBFM-contracted road infrastructure development. Lastly, the theoretical and empirical findings allow reflection on the central Research Question and provide recommendations for improvements of the payment mechanism and decision makers.

1.3. RESEARCH STRATEGY

The study is explorative, i.e. we aim to create insights decision making practices in relationship to the payment mechanism rather than testing or explaining relationships. Hence, we focus on the relation between two variables: elements of the payment mechanism and decision making practices. More specifically, we examine the decision making practices – i.e. heuristics with search cues and decision

RESEARCH QUESTIONS



1. What are the elements in which the payment mechanism in Dutch DBFM contracts for road infrastructure development may be decomposed?
2. How is the decision making process in the early stage of infrastructure development characterized?
3. How can elements of the payment mechanism in Dutch DBFM contracts relate to the decision making process in early stages of infrastructure development?
4. Which decision making practices are used in early stages of DBFM-contracted road infrastructure development?
5. How is the payment mechanism related to the decision making practices used in early stages of DBFM-contracted road infrastructure development?

Figure 4 Research questions as guidance throughout the research project.

criteria – and analyse the extent to which elements of payment mechanism are reflected in these decision making practices. Our research strategy consists of three main elements: (i) literature study, (ii) case studies and (iii) reflection on the case study results.

With the literature study we focus on different perspectives on decision making and the underlying reasoning processes. A well-known approach for a literature review is based on the grounded theory which allows for minimization of interpretive biases and lets "the data speak for itself" (Wolfswinkel & Wilderom, 2011, p. 47). However, for this study a grounded theory approach is not appropriate for three reasons. First, a grounded theory-based literature review is also time-consuming and requires clearly demarcated criteria for inclusion and exclusion of articles. Unfortunately, this study is limited by both constraints. Second, we aim to establish exploratively a theoretical lens *describing* how decision making is characterized rather than a state-of-the-art theoretical framework *prescribing* how decision making transpires. Hence, we perform a literature study rather than a systematic literature review in order to create an overview of relevant literature rather than build a comprehensive framework. Third, our main variables of interest are decision making practices and elements of the payment mechanism. Whilst literature on decision making practices is abundant, it is also context-specific. In addition little literature on payment mechanism is available, making a systematic approach troublesome. For these reasons, we create a body of literature of peer-reviewed literature reviews which we enrich with backwards and forward citation analysis.

Preliminary research on decision making in construction emphasizes on the ambiguous environment in which the decision making practices takes place and intuitive nature of decision makers (e.g., Bagies & Fortune, 2006; Fayek et al., 1999; Morren, 2014). In line with these findings, we follow Morren's (2014) heuristic approach to the Central Research Question by establishing a theoretical lens heuristic-based decision making literature combined with an analysis of DBFM contracts (see the schematic research approach in Figure 9). We describe the way in which decision makers arrive at their decisions, identify potential decision criteria and search cues embedded as elements in the payment mechanism and construct a theoretical lens that describes how these elements may link to the way in the decision making practices.

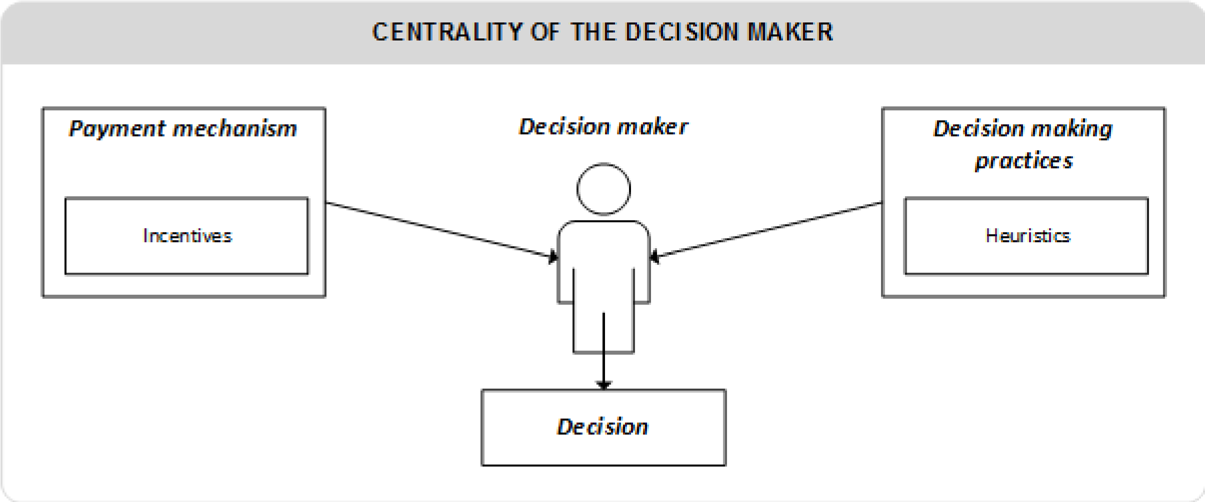


Figure 5a The decision maker in our study as the decision maker is responsible for evaluating decision information (e.g., incentives from the payment mechanism) with use of decision making practices (e.g. heuristics).

The search cues and decision criteria are important concepts in this theoretical lens as these describe the pieces of information – i.e. cues – decision makers look for to evaluate different decision alternatives with reference to some threshold value – i.e. decision criteria. As infrastructure development is part of construction, we specifically draw from literature on decision making in the construction sector. The resulting theoretical lens is then used as the bases for the case study in which we examine decision makers in the early stage of DBFM-contracted road infrastructure development.

UNIT OF ANALYSIS

Decision making practices in early stages of Dutch DBFM-contracted infrastructure development.

We focus on the way in which these decision makers address a decision problem – e.g., a design, construction or maintenance challenge – which decision making practices are used and how these relate to elements of the payment mechanism. Here the payment mechanism may provide with search cues and decision criteria, providing an important basis for the decision making practices in Dutch DBFM-contracted road infrastructure development. Based on empirical findings we are able to answer the Central Research Question and formulate recommendations improvements for decision making practices and the composition of the payment mechanism.

Our focus is on the individual decision maker responsible for obtaining and processing decision information in order to make a decision. In Figure 5a we included a schematic representation of the centrality of the decision maker. Elements of the payment mechanism may contain decision information – e.g., search cues and decision criteria. The aim of this study is to examine the extent to which these elements are integrated in the decision making practices. In Chapter 3, we discuss our research approach and methods used in more detail.

1.4. RESEARCH BOUNDARIES

We focus on the payment mechanism and the decision making in the early stage of DBFM-contracted road infrastructure development. We built on the study by Morren (2014) who studied the integration of risk appetite with bid / no bid decision making; however – in addition to the focus on the payment mechanism – a number of distinct differences exist. First we focus on decision makers rather than decision making in business units in a construction firm. As a result, we put emphasis on the way decision makers use procedures rather than the procedures themselves. Second, we specifically focus on different projects in road infrastructure development governed by a DBFM contract whereas Morren (2014) targeted smaller projects within one company. Our specific focus on high-revenue DBFM-contracted projects with long maturities differs from the smaller traditional project cases used in Morren (2014) and might impact the decision making practices used. Third, we focus on decision making after the decision to participate in the tender process. Hence, we are concerned with bid mark-up and related design decisions rather than the decision to bid or not to bid.

Our focus on the integration of elements of the payment mechanism in decision making practices limits the extent to which we reflect on general decision making practices in the early stage of DBFM-contracted road infrastructure development: we focus on decision making practices related to the payment mechanism and the general practices only marginally examined. Moreover, we take a heuristic-based approach – which we further justify in the literature study – and hence we consider primarily *information used* (cues and decision criteria) by decision makers rather than *information available* to the decision maker. Within the heuristic-based approach, decision makers do not necessarily collect – in contrast to the traditional rational decision making approach – a large, varied set of information for their decisions; rather they collect information they find important and useful and stop when they believe that adequate information is available to arrive at the decision. As a result, our ability to explain why other available information is not used is limited. This positive approach to decision making – i.e. focussed on what information is used rather than what information is not used – however aligns with our aim to obtain in-depth insights in the extent to which elements of the payment mechanism are integrated in decision making practices. Moreover as a result of the in-depth focus on the reasoning process underlying decision making practices, we are able to provide with some insights in the reasons for using specific pieces of information (cues) and which not. We discuss these insights in Chapter 5.

1.5. MAIN CONCEPTS AND DEFINITIONS

For clarity, we discuss main concepts and provide preliminary definitions. In the literature review, we discuss these concepts in more detail.

DBFM contract
A DBFM contract is a legal agreement between a principal (e.g., RWS) and a contractor for the design, construction, financing and maintenance of a specified product or service at a specified service level. For Dutch road infrastructure development, DBFM contracts are primarily concerned with infrastructure availability where the product is road infrastructure and the service component consists of availability of that infrastructure.

Early stage in road infrastructure development
In line with the research boundaries, the early stage of a road infrastructure project starts after the decision to participate in the tender. The end of the early stage is project-dependent but for clarity we define the early stage of an infrastructure project as the period between the decision to participate in the tender to the point where the preliminary design is completed.

Decision making practices
Decision making practices describe the way decision makers in practice arrive at their decision. In later sections, we define the decision making practices in more detail as heuristics with different building blocks aided by cognitive capacities.

Cues and decision criteria
A cue is (a piece of) information used by decision makers in order to evaluate a decision alternative. A decision criterion is a specific characteristic of a decision alternative which the decision maker reflects

against some threshold value to accept or reject the alternative. Cues and decision criteria are closely related: a single cue or a combination of multiple cues may form a decision criterion, i.e. the current date and expiration date on a can of milk are separate cues to base a decision on; however, the difference between both can be a decision criterion. For example, a decision maker may decide to purchase a can of milk when there is seven days between the current and future expiration date.

Payment mechanism
The payment mechanism is a payment regime incorporated in the DBFM contract which prescribes the payments available for the delivery of agreed performance. In essence, the payment mechanism consists of three elements, i.e. the gross availability payment, the availability penalty and the performance penalty. The payment mechanism prescribes gross availability payments from the project principal (e.g., RWS) to the contractor and allows for reductions in case of unavailability or non-compliance with other performance requirements.

1.6. THESIS OUTLINE

In this chapter we discussed the motive, central problem and approach for this research. This thesis proceeds with a literature review on the decision making and the payment mechanism which is concluded with the presentation of our theoretical perspective on the integration of decision making in the early stage of infrastructure development and elements of the payment mechanism (Chapter 2). In Chapter 3 we discuss our empirical approach more detail and in Chapter 4 we report the findings from the field study. We conclude in Chapter 5 with a reflection on the Central Research Question, discuss the findings and provide recommendations.

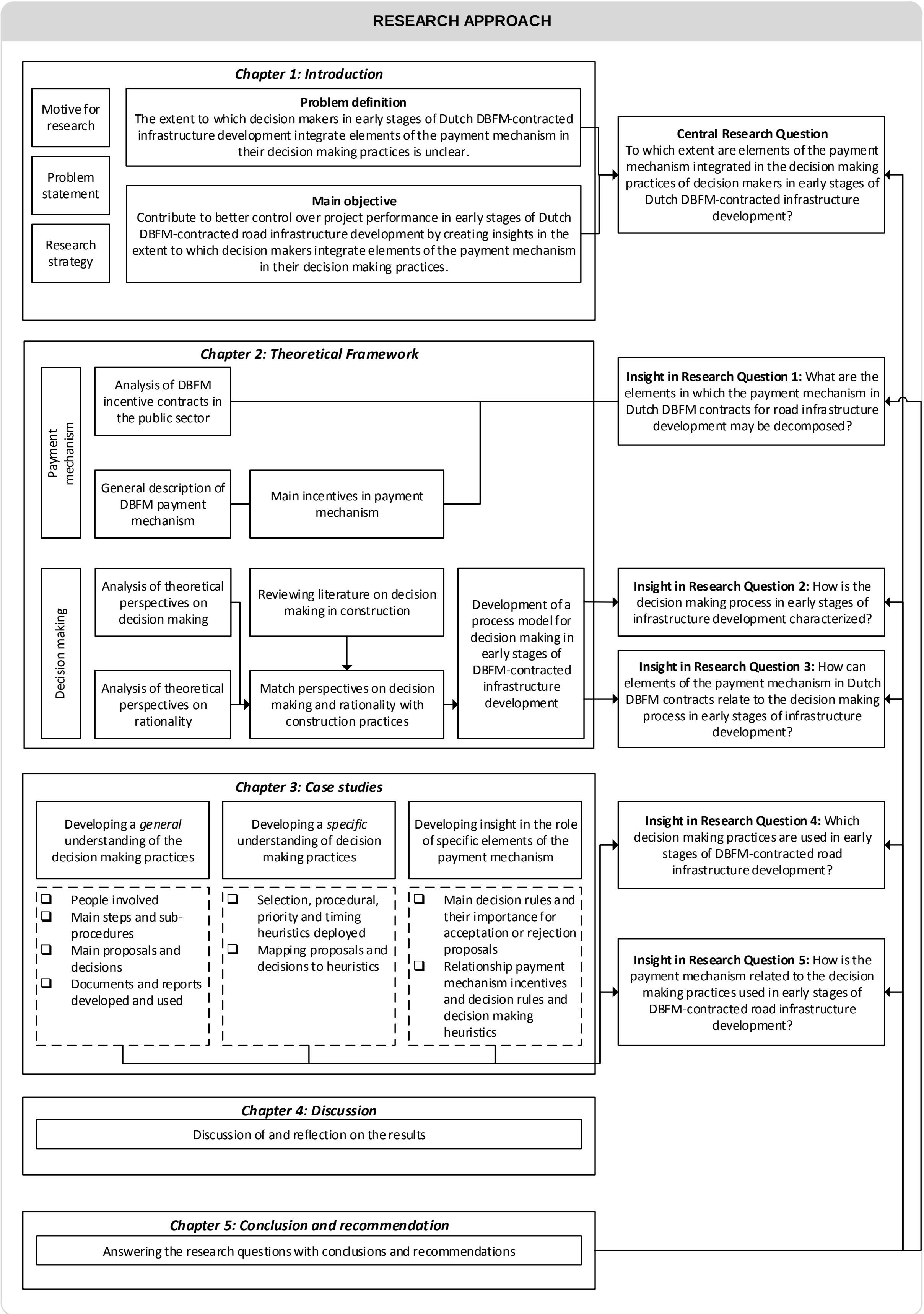


Figure 6 Research approach to obtain insights in the integration of the payment mechanism and decision making in Dutch DBFM-contracted road infrastructure development.

2. THEORETICAL FRAMEWORK

In this chapter relevant literature with reference to the Central Research Question and Research Question 1-3 is discussed. First, we focus on Research Question 1 and characterize the payment mechanism in DBFM contracts for road infrastructure development. Second, we discuss decision making in the early stage of infrastructure development in order to answer Research Question 2. Third, in answering Research Question 3, we bring the characterization of the payment mechanism and decision making in the early stage of DBFM-contracted road infrastructure development together. We discuss potential relationships between decision making practices and payment mechanism which allows us to present our theoretical lens in which early decision making for infrastructure development is integrated with the payment mechanism.

2.1. CHARACTERIZING THE PAYMENT MECHANISM

RWS' new market approach to infrastructure development – outlined in Chapter 1– implies that RWS acts as a distant procurer of performance levels. This retracted role is expressed in the slogan 'the market unless' and substantiated in DBFM contracts. DBFM contracts aim to improve public service delivery, efficiency, project control, risk sharing and use of life-cycle assessments. Especially involvement of private financers results in close supervision on project control and progress which results in (Ministerie van Financiën, 2010, p. 46):

- life-cycle optimization;
- realizing the budget;
- lower costs with lower likelihood of budget overruns;
- improved availability during exploitation stages (e.g., resulting from more intelligent maintenance).

Although DBFM contracts provide access to market discipline by inclusion of private financers, there are also disadvantages associated with DBFM contracts. Involvement of private funds result for instance in higher funding costs and private financing conditions add to the project's complexity. Only large Dutch infrastructure development projects provide sufficient opportunities to counter these disadvantages and allow for scale advantages to be capitalized in DBFM contracts.[5]

Private financers emphasize particularly on contractual clauses of the DBFM contract that describe the way in which income is generated. RWS has linked these clauses to specific performance deliveries in the form of conditions for payments and conditions for deductions from these payments. The entirety of contractual clauses concerned with payments and their deductions is the payment mechanism.

PAYMENT MECHANISM
The payment mechanism consists of contractual clauses recorded in the DBFM contract that regulate conditions for payment, i.e. it governs the deduction of amounts from the gross availability payment resulting from failing availability and performance requirements.

[5] RWS is required to draft a Public-Private Comparator (PPC) for projects which are expected to exceed 60 million Euros. In these PPCs the benefits and disadvantages of DBFM contracts are evaluated against more traditional procurement types. DBFM contracts result often in added values of 5-15%. DBFM-contracted Development of the Second Coen Tunnel, for example, resulted in an added value of 15% (Ministerie van Financiën, 2010, p. 46).

Payment conditions vary across projects since the context of projects differs and RWS for that reason emphasizes on different conditions. However, the structure of the payment mechanism is similar over all DBFM contracts. In this section, we give a brief overview of the early stage in Dutch DBFM-contracted road infrastructure development, discuss the general elements of payment mechanisms and analyse project specific differences for our case study projects. This analysis allows us to answer Research Question 1, i.e. characterize the payment mechanism in Dutch DBFM road infrastructure development contracts.

RESEARCH QUESTION 1

What are the elements in which the payment mechanism in Dutch DBFM contracts for road infrastructure development may be decomposed?

The analysis is based a review of relevant documents and reports, including the Route Decisions, Selection Guidelines, Tender Guidelines and (concept) DBFM agreements for specific projects. The general structure described in this section is based on the Government-wide model DBFM agreement Infrastructure 2014 (Rijkswaterstaat, 2014a) and the Government-wide model DBFM Tender Guideline Infrastructure 2012 (Rijkswaterstaat, 2012).

2.1.1. Early stage in Dutch DBFM-contracted road infrastructure development

The early stage of Dutch DBFM-contracted road infrastructure developments are primarily guided by and outlined in four documents: Route Decision, Selection Guidelines, Tender Guidelines and (concept) DBFM agreement. These documents include numerable provisions and requirements, overlap and refer to each other. In administrative and tender processes these documents ultimately converge in one document: the DBFM agreement (see Figure 7).

The convergence process starts with a political intention for a specific infrastructure development project as part of the Dutch primary road network. This intention is formalized by a procedure recorded in the Infrastructure Act. This act aims to ensure alignment of the – to be developed or amended – infrastructure with the environment, society and different infrastructure sections and results in a Route Decision. The Route Decision provides the first project boundaries with a generic description of the infrastructure placement and specific measures to mitigate disturbances for the environment. The Route Decision is valid for a 10-year period in which the project realization is to take place. To this aim, RWS executes a Public-Private Comparator to examine the added value of a DBFM contract setting over other contract settings, e.g., Design & Construct.[6]

The preceding steps take place in the public domain with sole responsibility of government officials, e.g., from RWS and the Ministry of Finance. When the conclusion is reached to use the DBFM contract setting, private parties are involved with the project. This involvement starts with an European Union-wide announcement of the to tender and the publication of the Selection Guidelines. These guidelines stipulate the tender process, grounds for exclusion and capability requirements.[7]

Eligible contractors are required to submit the outline of their risk management plan which includes measures for a select number of predefined risks. This 'Risk Management Plan Outline' (RMPO) focuses on the main risks identified by RWS and is used as a 'funneling product' to narrow down the number of prospective contractors. The RMPO measures are included in the concept DBFM agreement and the

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[6] D&C contracts are often preferred over DBFM contracts when the scope is unclear or too complex or in cases with high licensing and permit risks.

[7] Exclusion grounds and capability requirements describe the minimum prospective contractor's required financial health, track records and accordance to legal and social responsibilities.

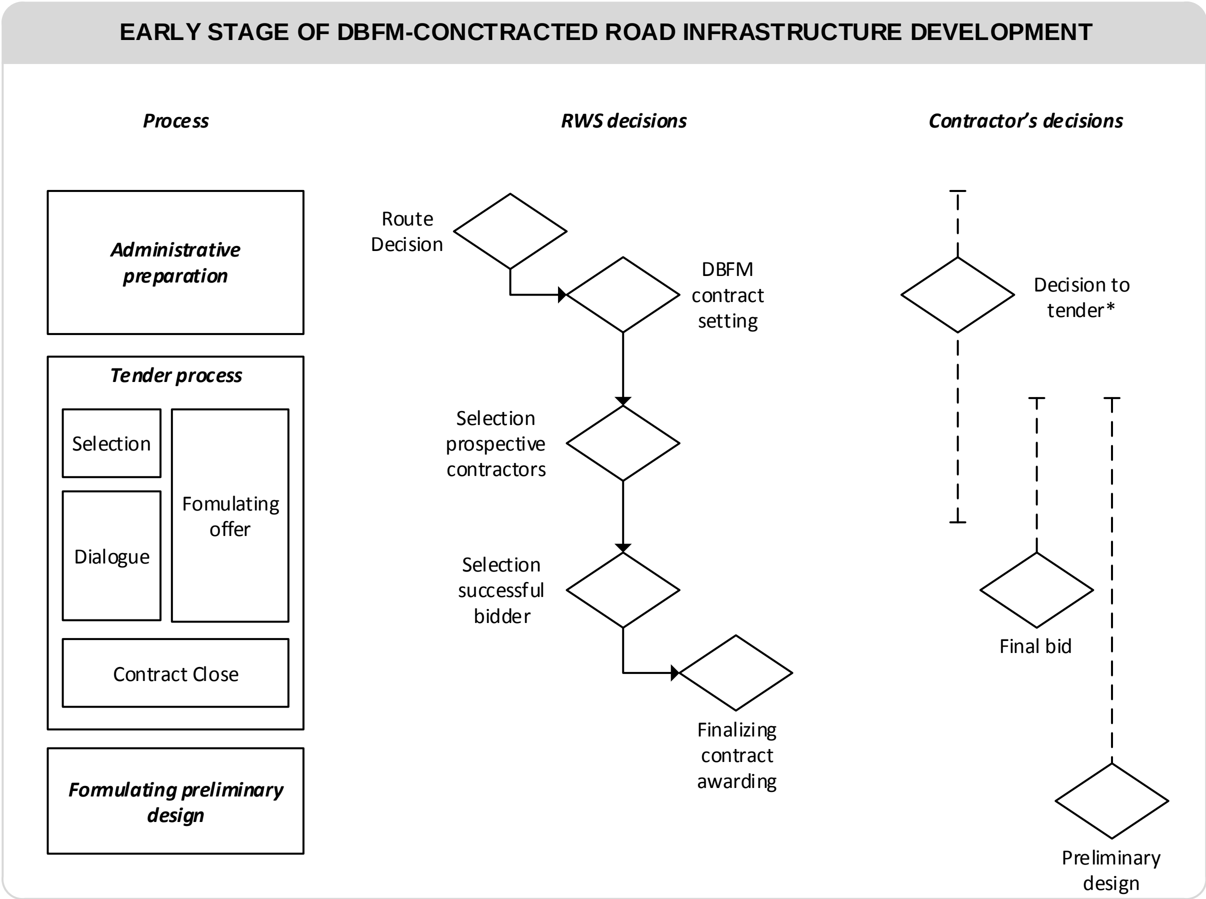


Figure 7 *Schematic overview of the early stage of DBFM-contracted road infrastructure development in the Netherlands.*
** The decision to tender also involves partnering. Until half-way the tender process, prospective contractors may withdraw without fines.*

remaining prospective contractors are required to submit additional plans and documents prescribed in the Tender Guidelines. These plans and documents include a more specific Risk Management Plan (RMP), a Traffic Congestion Restriction Plan (TCRP), the general project planning (realization), general project management plan, general description of the engineering and design processes and the financial underpinnings (e.g., financial planning and letters of support).

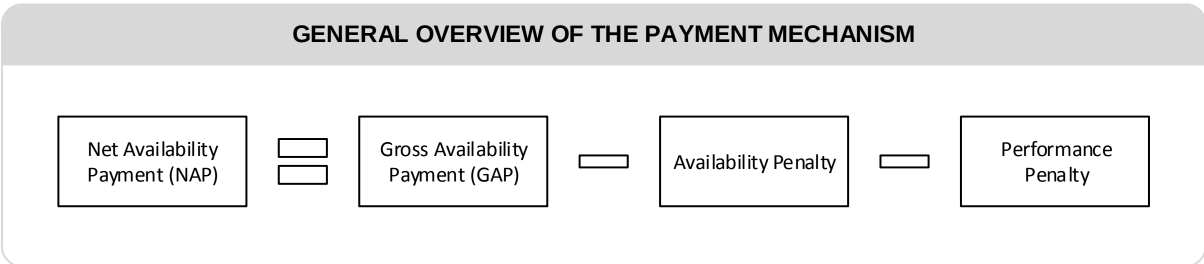
All prescribed documents in the Tender Guidelines are important; however, the contract is awarded to the successful bidder based on – ceteris paribus – the best and final offer (BAFO). The BAFO is established by an adjustment of the net present project value – e.g., price – with the Most Economic Advantageously Tender (MEAT) procedure. In the MEAT-procedure predefined, specific elements[8] are valued based on the extent to which qualitative elements of the prospective contractor's offer contribute to RWS' predefined, specific objectives. These objectives are non-financial in nature but considered highly important by RWS. Therefore, RWS assigns fictive value to measures that contribute to obtaining the objectives, i.e. the MEAT value. The total MEAT value obtained from this procedure is deducted from the net present project value to obtain the BAFO. RWS awards the contract to the prospective contractor which offers eligibly – complying with all requirements – the lowest BAFO; accordingly, the MEAT value provides with a BAFO-discount increasing the probability of winning the contract for the contractor. For RWS this procedure provides with the opportunity to select the contract to the contractor best equipped to address RWS' objectives.

8 In Dutch DBFM contracts for road infrastructure development, two documents may provide MEAT-value: the Risk Management Plan (RMP) and Traffic Congestion Restriction Plan (TCRP).

After contract awarding, main documents underpinning the winning bid are included and formalized in appendices of the DBFM contract. These appendices include the program of requirements with system definitions, output specifications and management specifications, financial and insurance details, change processes, rights of other stakeholders and definitions. The second appendix is especially relevant for our discussion as it describes precisely the payment mechanism. In the next sections, we discuss the payment mechanism in more detail and characterize the payment mechanism as a collection of incentives aimed at reliability, availability, safety, maintainability and timeliness of infrastructure and its development.

2.1.2. Overview payment mechanisms in Dutch DBFM contracts

In contrast to its designation, the payment mechanism only partly arranges payments from RWS to the contractor; main attention is paid to quarterly deductions for underperformance, i.e. penalties from the maximum payment. In addition, a select number of one-off payments for achieving certain milestones and compensations for electricity usage[9] are incorporated in the payment mechanisms in DBFM contract. These one-off payments are linked to achieving specific project milestones, e.g., end of (parts of) construction.



The arrangements for quarterly payments focus on three elements which jointly determine the quarterly (net availability) payments to the contractor: the highest possible payments, availability penalties and performance penalties. The highest possible payment is referred to as the ‘gross availability payment’ (GAP) which reflects the emphasis of the payment mechanism on availability. The GAP is a quarterly payment to the contractor for service delivery specified in the contract. In the early stage of the project development, the gross availability payment is a fraction – i.e. 20-40 per cent – of the gross availability payment during maintenance stage of the project. Two penalty categories are may influence the final effective – or nett availability – payment: the availability penalty (AP) and the performance penalty (PP).

Availability penalty: payment deductions for unavailability of the infrastructure

Availability penalties are deducted from the gross availability payment when the agreed availability level of the infrastructure is not met. The total availability penalty for each quarter is the sum of all availability deductions – i.e. a standard fine which differentiates only over periods of the day – which result from a contractor’s request for a lane closure in order to execute maintenance activities or a lane closure resulting from failure of an availability requirement.[10] In case of a lane closure, the availability penalty is determined as the monetary value attributed to the specific section and time at which the lane is closed. In addition, the importance of traffic patterns and routes inflicted are factored in the availability payment.

9 We do not discuss compensations for electricity usage as part of the payment mechanism as these arrange payments for incurred expenses rather than service delivery.

10 A number of exceptions are recorded which are not eligible for an availability penalty, e.g., incidents, certain periods, request for closure from RWS and refusal of the traffic manager for closure.

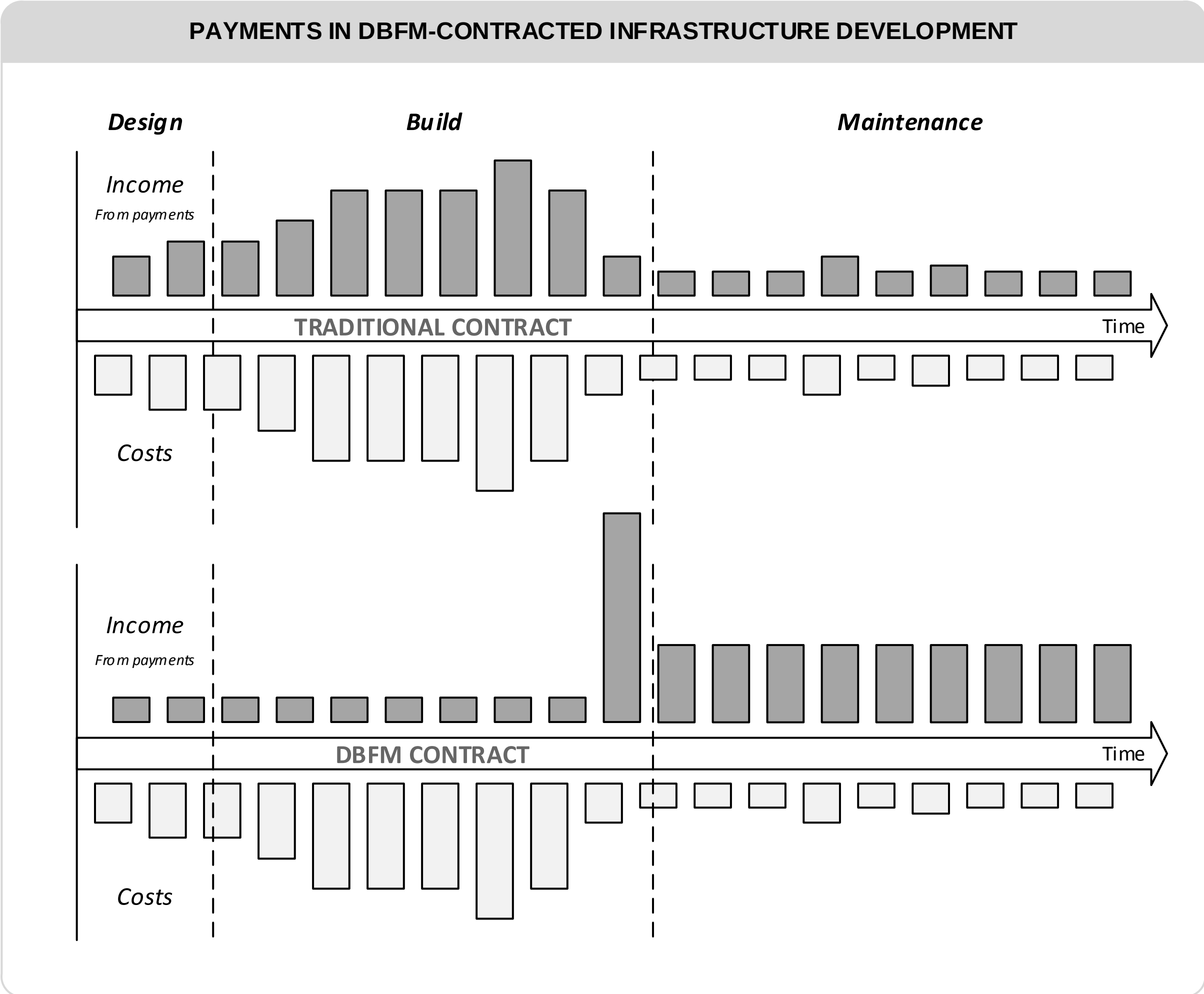


Figure 8 Typical projected cash flows for infrastructure development projects governed by different types of contracts. The projected cash flow from the DBFM contract is typically steady; however, the actual payments may differ as a result of availability or performance penalties.

The availability penalty emphasizes on ensuring availability of the infrastructure. However, as a result of the long maturity of DBFM-contracted projects, maintenance activities are necessary to guarantee long-term availability. Hence, at a certain point in the contractual period the contractor has to request a lane closure which will result in an availability penalty. Postponement of maintenance actions increases the likelihood of a failure on the availability requirements which again results in a lane closure and availability penalties. While during these involuntary lane closures maintenance actions are still required, the combined lost income due to unavailability penalty and maintenance costs may be significantly higher than for planned lane closures. Moreover, the contract includes provisions that allow RWS to impose multiple performance penalties on top of the availability in cases of unplanned unavailability which increase when pre-defined repair periods are not met. The arrangements underlying the availability penalties clearly give preference to preventive, planned actions rather than corrective actions.

Unplanned unavailability is heavily penalized while penalties for planned unavailability are less severe. At specific time slots and with specific intervals, planned unavailability is not penalized by contractual provisions. These time slots are primarily reserved for the realization stage in which the construction of new infrastructure takes place; however, also in the exploitation stage contract-specific provisions exist that allow the contractor to request penalty-free lane closures for maintenance activities. The rationale of these budgets for penalty-free lane closures is to provide contractors with sufficient time to execute required maintenance activities.

Moreover each year, month, week and day of the contractual period is split into different time-slots to which different values for availability deductions are attributed (e.g., nightly lane closures are less expensive than lane closures during rush hour). This differentiation stimulates contractors to plan activities that require lane closures in time slots when availability is considered less important by RWS.

Performance penalty: payment deductions for underperforming service delivery

Performance penalties are deducted from the gross availability payment when the agreed performance level is not met. Similar to the availability penalty, the total performance penalty is the sum of all performance deductions. However, these deductions do not necessarily depend on characteristics of the infrastructure at certain points in time since performance penalties are also imposed when the project organization fails to meet pre-specified maturity levels, in case of unsafe situations or in case of excessive disruptions during construction activities. Another major difference between availability and performance penalties is that imposition of former is mandatory while the latter are optional and at RWS' discretion.

Four categories of performance penalties are defined: safety, process control, maintenance and lost vehicle hours. Deductions arising from the safety category may be imposed in the event of unsafe situations – with or without injuries – which are a result of contractor's actions or failures. In these cases the contractor is often not 'in control' which may result in the imposition of deductions arising from the process control category. However, the deductions may also be imposed independently in situations in which the maturity-level of the organization – externally audited – is not up to pre-defined levels or failure to timely execute corrective (repair) maintenance actions. Hence, performance penalties may be imposed in addition to availability penalties, especially when pre-defined recovery periods are not met. These performance deductions fall under the maintenance category since these may arise when the contractor is unable to execute maintenance activities in a timely manner. Moreover, deductions arising from failures in process control may be added in serious events when failures on availability requirements are not repaired in a timely manner e.g., due to shortcomings in the contractor's management processes. Deductions arising from the maintenance category may also be imposed if the contractor fails certain non-availability requirements. These 'performance requirements' do not lead to availability penalties but timely action is required since these requirements are linked to recovery periods and performance deductions. Failure to meet this recovery period may result in performance penalties. Deductions arising from the lost vehicle hours category may only arise during the realization stage of the contract when the unavailability during construction exceeds the calculations communicated in the tender bid. However, the consequences of these exceedances are severely since these result in both availability penalties – since the unavailability takes place outside of the predefined time-slots – and performance penalties.

The performance penalties primarily emphasis on overall project control. Long-term compliance with the performance requirements is further stimulated with a bonus percentage. For longer periods with no performance penalties, a bonus percentage is deducted from the performance penalty; however, for repeated performance failures RWS may impose additional performance deductions as well.

2.1.3. MEAT procedure and the payment mechanism

In section 2.1.1 we discussed the early stage in Dutch DBFM road infrastructure development which is for a large part consumed by stage tender process. As a result, decisions in the early stage are likely to be focused on the main objective of the tender process, i.e. putting together the winning bid or offer. This offer consists of two elements: the quantitative price and the qualitative offer. The qualitative offer is included in the quantitative asking price through the MEAT-procedure, i.e. the qualitative offer is assessed by RWS and the assigned MEAT value is then deducted from the quantitative price. The resulting BAFO – i.e. quantitative price minus the MEAT value – is then used to select the winning contractor. The way in which the MEAT procedure monetizes RWS' qualitative objectives shows similarities with the way in which the payment mechanism links performance to payments. Where the MEAT procedure assigns value to measures that provide additional qualitative performance on specific objectives, the payment mechanism assigns penalties to underperformance on qualitative agreed requirements. However, there is a difference: measures that receive favourable MEAT-treatment increase the probability of winning the contract – although potentially costly – while measures that reduce the probability of unavailability or performance penalties may only monetize after contract awarding. These incentives are not necessarily in line.

The MEAT procedure in tender processes for DBFM-contracted road infrastructure development specifically focus on creating additional quality for two specific objectives: mitigating specific risks and limiting traffic congestion. Risks are typically project-specific and borne by RWS although contractor risks are also raised. These risks may include non-issuance of permits, delayed preparatory third-party activities and misaligned stakeholders and can have a great impact on the quality of the project development and final infrastructure layout. After contract-awarding, mitigation measures for these risks are included in the contract. These measures may influence the design, construction planning and maintenance activities and hence improve the availability of the road infrastructure during realization and maintenance. However, their impact on availability or performance is distant and indirect. In addition, the direct costs of implementing the measures may be substantial.

The primary focus of many risk mitigation measures is reliability of planning. Measures for limiting traffic congestion are more closely related to the payment mechanism as measures included in the MEAT-eligible Traffic Congestion Restriction Plan are penalty-free. Consequently, contractors are stimulated to weigh the benefits of penalty-free measures after uncertain contract awarding against the certain disadvantage of a relatively higher BAFO.

In sum, RWS influences decisions in the early stage of DBFM-contracted road infrastructure development through both the MEAT procedure and payment mechanisms. While incentive regimes focus on similar objectives, there is a substantial difference on the contractor's decision making. While the MEAT procedure stimulates the contractor to focus specifically on certain risk mitigation measures and limiting traffic congestion during construction in order to win the contract, the payment mechanism stimulates the contractor in the focus availability, safety, process control, maintenance and limiting traffic congestion during construction after contract awarding. Hence, the former increases the contractor's opportunity to generate revenue and the payment mechanism actually increases the contractor's revenue.

2.1.4. Main incentives of the payment mechanism

Now we understand the main mechanisms behind the availability and performance penalties we can highlight a number of objectives and characterizing incentives of the payment mechanism. Availability penalties in the payment mechanism focus primarily on availability of the infrastructure while performance penalties focus on safety, adequate management and maintenance processes and minimizing congestion.

RAMS incentives

Infrastructure is said to be available when the contractor is compliant with the availability requirements and has not requested a lane closure for maintenance activities.[11] The emphasis on

[11] Numerable exceptions exist in which a lane is closed after a request but availability penalties are not imposed. These exceptions are generally applicable on the realization stage of the project.

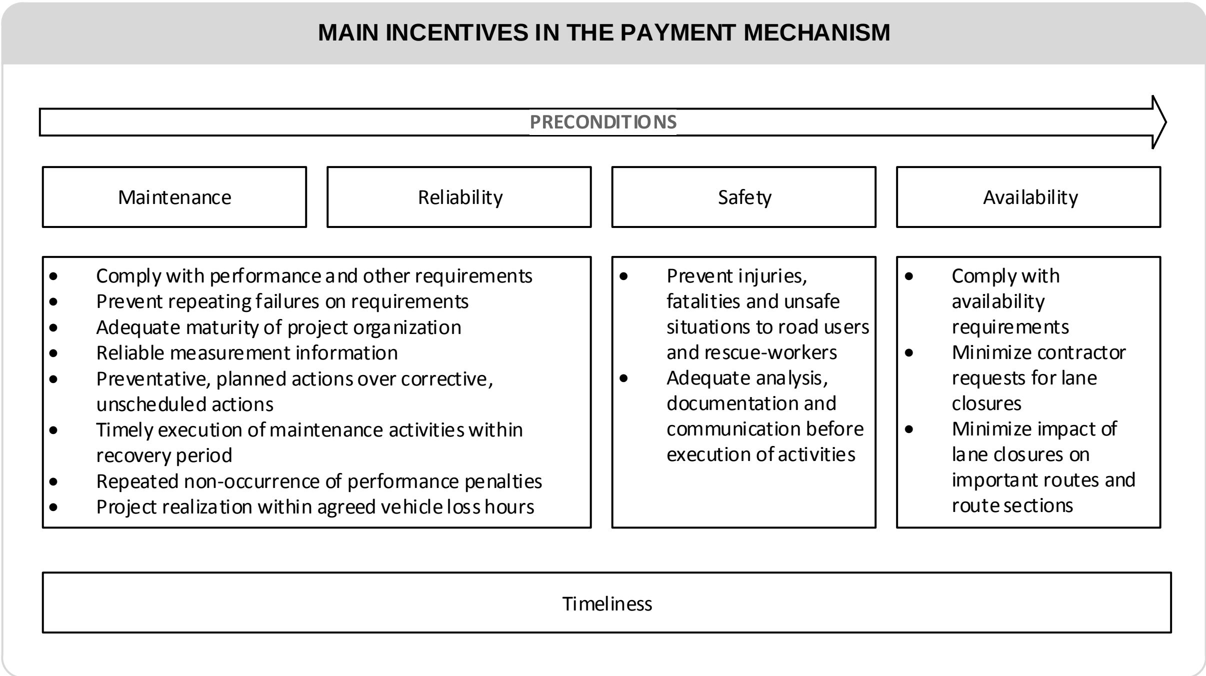


Figure 9 Main incentives of payment mechanisms in Dutch DBFM contracts for road infrastructure development.

compliance with availability requirements is a direct result of RWS' objective to provide infrastructure that allows for a 'smooth and safe transfer' (Rijkswaterstaat, 2011, p. 15). Failures on availability requirements are generally unplanned, associated with unsafe situations and lead directly to virtual[12] or real lane closures. Consequently, the availability requirements in the payment mechanism not only emphasize *availability* but also on *safety* and *reliability*, i.e. insight into the time to failure of the infrastructure.

Minimizing the number of lane closure requests for maintenance activities is another focal point of the payment mechanism. Two factors contribute to this objective. First, in line with the rationale of DBFM-contracted road infrastructure development, contractors are stimulated to consider in all life-cycle stages the impact of design and construction decisions on the impact of maintenance activities on potential lane closures. This focus on *maintainability* stimulates contractors to develop solutions that minimize the number of lane closures required for maintenance activities. Second, minimization of lane closure requests – and closures due to availability requirement failures – requires reliable infrastructure and to that aid in-depth information on the *reliability* of the infrastructure.

Focus on reliability, availability, maintainability and safety is not only reflected in incentives resulting from availability penalties. Different well-known methods in engineering also focus on these RAMS[13] aspects. For example, RWS considers that "the primary performance of virtually any function of a system may be described, determined and monitored on the basis of these four [RAMS] properties" (Rijkswaterstaat, 2010, p. 7). In newer contracts, RAMS analysis is required as one of the capabilities of the contractors. The RAMS-focus is also explicitly reflected in the four categories of performance penalties. The focus on process control, swift maintenance actions and realizing the infrastructure

12 Two types of lane closures are considered in DBFM contracts: (i) virtual lane closures in which the lane is not available according to the contract whilst available for road users and (ii) real lane closures in which the road is neither available according to the contract and for road users.

13 RAMS is the acronym for reliability, availability, maintainability and safety. RAMS analysis is an umbrella term for different methods to design reliable, maintainable and safe products with high levels of availability.

within predefined vehicle loss hours emphasize reliability of processes in order to stimulate safety and availability (see Figure 9).

Timeliness

Time is an influential mediating factor for the payment mechanism incentives. Many of the incentives are strengthened by the influence of time: availability penalties are summed over all clock quarters and the performance penalties are generally linked to recovery periods after which additional penalties are due. Moreover, availability penalties are related to route- and time-specific vehicle loss hours and maintenance actions are penalty-free in certain time-slots and at certain frequencies. The impact of performance and availabilities penalties on the net availability payments differ over time. During the realization stage the gross availability payments are lower than during exploitation; increasing the potential influence of availability penalties on the net availability payments. On a higher level, time is an important mediating factor through the financial structure of DBFM-contracted projects. All expenses are privately funded until (partial) completion of realization stage and – during the exploitation stage – at the end of each quarter and payments according agreed performance are due. Exceeding the agreed construction date results in longer periods in which interest rate costs are due to the private financer while early delivery may result in lower financing costs. In Figure 9 we refer to the effect of time by *timeliness*.

Altogether, the payment mechanism in Dutch DBFM contracts for road infrastructure development is best characterized as an incentive framework for contractors to deliver and maintain reliable, safe and available infrastructure on time.

The question still remains to which extent these incentives have impact on decision made in the early stages of DBFM-contracted road infrastructure development. In the next section, we discuss this issue in more detail and characterize decision making in early stages of infrastructure development. This characterization allows us to develop potential linkages between decision making and the payment mechanism in section 2.3.

2.2. DECISION MAKING IN THE EARLY STAGE OF INFRASTRUCTURE DEVELOPMENT

Decision making is practiced everyday by any individual on earth. Scientists have shown longstanding interest in decision making which traces back to Classic Greek philosophers (Tsoukiàs, 2008, p. 138,140). Nowadays decision making theory encompasses an extensive field of academic research primarily building on classic economic theories and more recently on behavioural sciences. In this section, we discuss different perspectives on decision making and relate these to infrastructure development.

2.2.1. Perspectives on decision making

Decision making theorists have long focused on economic problems. An important assumption underlying the economic perspective on these problems is that decision makers are 'economic men' which are completely informed, rational and infinitely sensitive (Edwards, 1954, p. 380). As such, they have knowledge on all possible courses of action – or strategies – and their outcome which allows the decision maker to order all strategies on their potential outcomes according to their preferences and choose the associated most optimal outcome. This economic perspective characterizes the decision maker as "a maximizer, who will settle for nothing less than the best" (Simon, 1978, p. 2).

The economic perspective on decision making requires the decision maker to formulate the decision problem, identify all possible strategies with their outcomes and make a judgement of these strategies to select the superior strategy (see Figure 10). Based on a preference set the decision maker then judges the outcomes and the final decision is reached as the selection of the strategy related to the 'best' outcome (Bakht & El-diraby, 2015, p. 2).

ELEMENTS OF DECISION MAKING

Formulation of

- Decision problem
- Objectives and preferences
- Decision criteria

Identification of

- Strategies: different courses of action
- Related outcomes

Selection of

- Strategy with outcomes fulfilling objectives, decision criteria and preference

Figure 10 Basic elements of decision making.

Decision making theorists have long focused on this classic economic perspective; however, in practice decision makers are faced by two major difficulties that violate the assumptions underlying this perspective. First, evaluation of all possible strategies and outcomes requires the decision maker to obtain complete information on the problem and its context. In construction – especially early stages in a construction project – the context is characterized by ambiguity and uncertainty (Bagies & Fortune, 2006, p. 511); hence in many cases identification, let alone the evaluation, of possible strategies and outcomes is unfeasible. The second difficulty faced by decision makers concerns the formulation of the decision problem. Problem formulation requires decision makers to clearly define evaluation criteria to select the 'best' strategies. However, research has shown that construction practitioners base their judgement on a combination of facts, data, experience, faith, intuition and bias which obscures both problem formulation and evaluation of potential strategies (Bakht & El-diraby, 2015, p. 2).

As a result of incomplete information and lack of a clear problem formulation, characterization of decision making in construction from a classic economic theory perspective has limited use. We therefore focus on a more loose definition advanced by Hansson (2005, p. 6) and define[14] decision making as "a goal-directed behavioural process in the presence of options".

DECISION MAKING

Decision making is a goal-directed behavioural process in the presence of options

This definition transcends classic economic decision making theory[15] and accommodates decision makers that violate the assumptions underlying the 'economic men'. Precisely the acknowledgement of these violations gave rise to development of new perspectives on decision making.

The first major advancement relaxed the complete information assumption which was put forward in Von Neumann and Morgenstern's (1944) laurelled work on risky choice. The theory of risky choice described decision makers as 'economic men' which also take probabilistic future outcomes into account. This perspective allowed for expected utility decisions based on objective probabilities which

[14] The focus on goal-oriented behavior in the presence of options implies some form of judgement and choice. Both concepts are important cornerstones underlying decision making; however, for clarity and focus we do not expand on these.

[15] Generally referred to as the theory of riskless choice or the theory of utility maximization.

PERSPECTIVES ON REASONING AND RATIONALITY

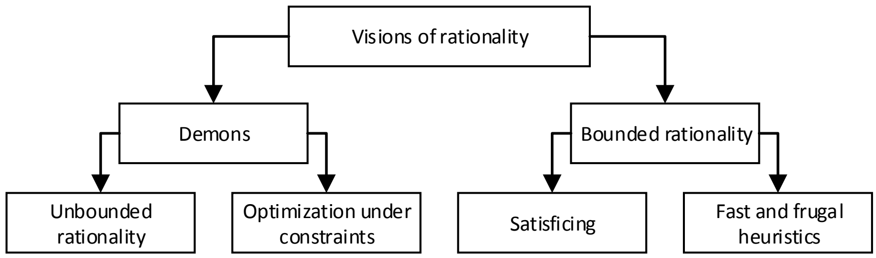


Figure 11 Perspectives on reasoning and rationality (adapted from Gerd Gigerenzer & Todd, 1999, p. 7)

was later extended to subjective probabilities (Savage, 1954). This extension allowed for the incorporation of perceived risk in the evaluation of economic opportunities.

Extending the expected of utility maximization towards subjective expected utilities also had implications for the rationality assumption. In their empirical work on human rationality Tversky and Kahneman[16] (1974, 1981) described the limitations of the human cognition in considering and valuing all potential courses of action and outcomes. They postulated that conditions for rationality models hold and can lead to optimality but that the beliefs and choices differ from optimal beliefs and choices. This assertion loosened the strict (economic) rationality assumption underlying decision theory and gave way for different perspectives. These different perspectives on rationality form the starting point for our discussion on Research Question 2, i.e. characterizing the early decision making for infrastructure development.

RESEARCH QUESTION 2

How is the decision making process in the early stage of infrastructure development characterized?

2.2.2. Perspectives on reasoning and rationality

Project managers in infrastructure development are "intendedly rational decision-makers, satisficing in the face of uncertainty, whose rationality is both bounded and shaped by impulse" (Winch, 2010, p. 13). Much as the economic men they aim to *optimize* their actions to obtain *optimal* preferred outcomes. However, in contrast to the economic rationality, uncertain environments and external influences may change their perspective on optimality which may lead to acceptation of strategies which *satisfy* their preferred outcomes.

The distinction between satisfactory and optimal outcomes reflects different reasoning mechanism underlying human decision making processes. While some decision makers use reasoning mechanism to select a single strategy that outperforms all other strategies (economic men), others reason to select a strategy that fulfils their preferences. The latter may, depending on the individuals preferences or internal rationality, result in suboptimal strategies. Consequently, identification of the reasoning mechanism used by decision makers has important implications for characterization of the decision making process (Legrenzi, Girotto, & Johnson-Laird, 1993, p. 37).

Gigerenzer and Todd (1999, p. 7) differentiate between two models of reasoning and rationality (see Figure 11). The first model assumes that "the human mind has essentially unlimited demonic or

[16] Awarded with the Nobel Memorial Prize in Economic Sciences in 2002.

supernatural reasoning power” (Gerd Gigerenzer & Todd, 1999, p. 7). These unbounded rational ‘demons’ are essentially economic men which optimize their actions towards desired outcomes considering all potential actions and outcomes. The complete information assumption underlying this type of reasoning allows for a mathematical representation of the human mind; however in practice, humans have limited cognitive capacity (Gerd Gigerenzer & Gaissmaier, 2011, p. 456). Moreover, human decision making is often concerned with beliefs on likelihood and uncertainty. Assessments of related probabilities in unbounded rational reasoning is a complex task, again conflicting with the limited cognitive capacity faced by humans.

One way humans may reduce complexity is through use of a limited number of heuristic principles but these may lead to “severe and systematic errors” (Tversky & Kahneman, 1974, p. 185). Tversky and Kahneman (1981) have shown that decision makers are especially sensitive to changes in the presentation of the decision problem. Moreover, they are often unaware of these ‘framing effects’ and unable to resolve inconsistencies in changed preferences to different representations (Tversky & Kahneman, 1981, pp. 457–458). At best humans reasoning is focused on optimization constrained by time, knowledge and their computational capacities.

The limited human cognitive capacities are an important rationale for the second class of models of reasoning and rationality outlined by Gigerenzer and Todd (1999, p. 7). Where Tversky and Kahneman (1974) consider decision makers’ biases within the classic rationality framework for economic men, Simon’s (1978, p. 14) concept of ‘bounded rationality’ focus on reasonable rather than economic men: “Reasonable men reach reasonable conclusions where they have no prospect of applying classical models of substantive rationality” (Simon, 1978, p. 14). In many situations, he argues, the optimal strategy is not only unknown but also unknowable. Therefore, bounded rational – or ‘reasonable’ – men focus on satisfactory outcomes rather than optimal outcomes. With this ‘satisficing’ method of reasoning, decision makers use “experience to construct an expectation of how good a solution we might reasonably achieve, and halting search as soon as a solution is reached that meets the expectation” (Simon, 1990, p. 9).

The decision making process based on a bounded rationality reasoning is characterized by three building blocks (Gigerenzer & Todd, 1999, p. 24; see Figure 12):

- The search rule guiding the search process for information or alternatives;
- The stopping rule specifying criterions for the termination of the search process;
- The decision rule providing guidance to make the final decision.

Bounded rational decision makers arrive at their final decision with use of these rules. These decision rules generally take the form of “we accept information of type A” (search rule), “we stop searching when B occurs” (stopping rule) and “we prefer U over W when the information found has value C” (decision rule). Each of these rules consists are essentially rules of thumb focussing on specific pieces of information (cues) and decision criteria. In appendix C.3.2 we included an example in which a decision maker has to decide on whether to take a glass of milk from an opened can (U) or not (W). He first decides to search for the expiration date (cue A), decides to stop the search when the expiration date is found (decision criteria B) and decide to take a glass of milk when the expiration date is later than the current date (decision criteria C; composed of two search cues: current and expiration date). This representation shows that the final decision is reached through a process of subsequent decisions, each with their own cues and decision criteria.

Evidence exists that these building blocks relate to heuristics rather than some form of unbounded rationality. For instance, Stanovich and West principles (2000, p. 664) argue that decision makers simply accept a limited number of possible explanations while the search for counterfactuals – to falsify

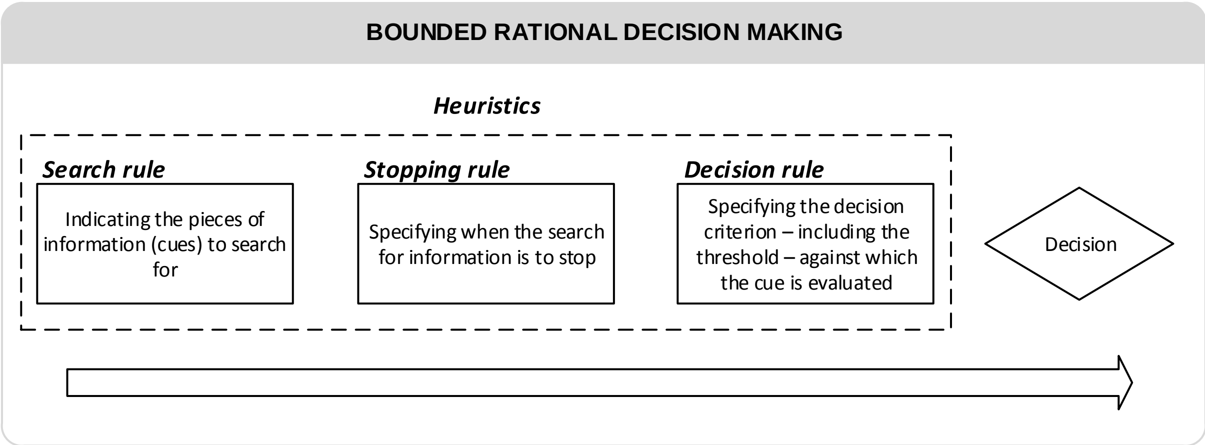


Figure 12 Bounded rational decision making process with heuristics and their building blocks.

the validity of these explanations – is not governed by a systematic or comprehensive method. The relationship between the building blocks and heuristics-based reasoning is further detailed in the second species of reasonable men considered by Gigerenzer and Todd (1999, p. 14). This typology is based on 'fast and frugal' heuristics and requires even less deliberation from the decision maker as the heuristics are designed to use a minimum of time, knowledge and computational capacity (Gerd Gigerenzer & Todd, 1999, p. 14). Fast and frugal decision makers use simple heuristics based on a combination of their experience, knowledge and 'gut feeling'. The heuristics often are based on rules of thumb – or search cues – and are 'fast and frugal' as much information is ignored when a satisfactory result is found.

As we discuss in section 2.2.4, a large body of evidence exists that decision makers in the construction sector base their decisions on partial cues and a satisficing reasoning approach (Moselhi, Hegazy, & Fazio, 1991, p. 606) which is best described by the 'fast and frugal' heuristic-based decision making process. In the next section, we describe this decision making process in more detail.

2.2.3. Fast and frugal heuristic-based decision making

Much research and academic debate in the field of fast and frugal heuristics is focussed on the effectiveness of specific heuristics (cf., Brandstätter, Gigerenzer, & Hertwig, 2006; Chater, Oaksford, Nakisa, & Redington, 2003; Hilbig, 2008; Newell, Weston, & Shanks, 2003; Scheibehenne, Miesler, & Todd, 2007). Evidence exist that fast and frugal heuristics are simple and especially applicable to decision making in settings with new, prior unknown information (Martignon & Hoffrage, 2002, p. 60). This effectiveness is, at least partly, a result of (i) human's inability in obtaining and processing all available information[17] and (ii) the 'ecological rationality' underlying 'fast and frugal' reasoning, i.e. feedback from the environment (Garcia-Retamero, Hoffrage, & Dieckmann, 2007, p. 1212; Hertwig, 2005, p. 626).

These findings reflect two of the research fields advanced by Gigerenzer and Todd (1999, p. 29): ecological rationality[18] and the adaptive toolbox. The adaptive toolbox is a concept that describes the cognitive capacities and fast and frugal heuristics individuals possess, develop and context-dependently deploy (Gerd Gigerenzer & Gaissmaier, 2011, p. 456). As such the adaptive toolbox can

17 Heuristics are "strategies that ignore information to make decisions faster, more frugally, and/or more accurately than more complex methods" (Gerd Gigerenzer & Gaissmaier, 2011, p. 454).

18 The central aim of the study of ecological rational heuristics is to establish appropriate environmental conditions for 'fast and frugal' conditions in which these are effective.

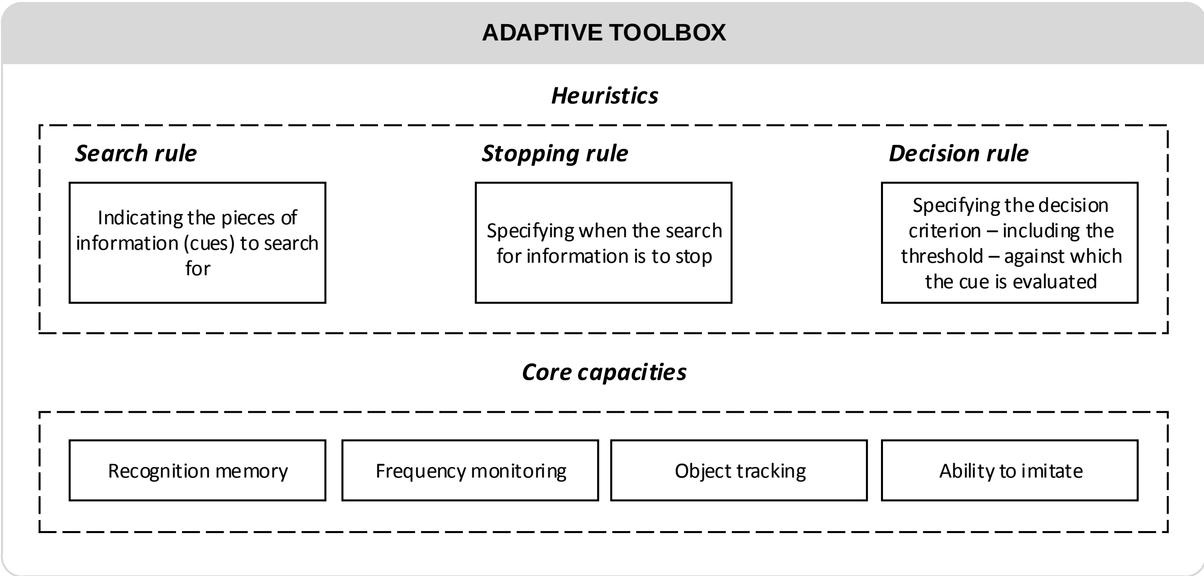


Figure 13 Core mental capacities and building blocks of heuristics within the adaptive toolbox.

be seen as the operationalization of 'fast and frugal' heuristic-based decision making. Four main characteristics of the adaptive toolbox are distinguished (Gerd Gigerenzer & Selten, 2002, p. 9):

- It consists of heuristics rather than a general-purpose decision making algorithm;
- The heuristics are fast, frugal, and computationally cheap rather than consistent, coherent and general;
- The heuristics are adapted to particular environments, past or present, physical or social (i.e. ecological rational);
- The bundle of heuristics in the adaptive toolbox is orchestrated by some mechanism reflecting the importance of conflicting motivations and goals;

The toolbox is adaptive, fast and frugal as the cognitive capacities – recognition memory, frequency monitoring, object tracking and the ability to imitate (Gerd Gigerenzer & Gaissmaier, 2011, p. 456) – allow the decision maker to learn and deploy only the heuristics necessary for the decision at hand.

Fast and frugal heuristic-based decision making – i.e. an adaptive toolbox – may be deployed in any context by anyone. However, especially entrepreneurs make use of heuristics while managers in large organizations revert to 'unbounded rational' decision models based on predefined methodologies and procedures. Entrepreneurs use heuristics since their decision environment is often complex and uncertain. Moreover, use of heuristics allows entrepreneurs to exploit opportunities which they otherwise never would have exploited (Busenitz & Barney, 1994, p. 25).

Bingham and Eisenhardt (2011, p. 1439) show that these opportunity-capturing heuristics may be classified in selection, procedural, temporal and priority heuristics (see Figure 14). Selection heuristics guide the choice for which opportunities to pursue. These heuristics support decision makers to allocate scarce resources to an advantageous set of opportunities. Rules of thumb to detail resource allocation and other actions to opportunities are classified as procedural heuristics and allow decision makers to organize their actions to exploit the opportunity efficiently and effectively. While the selection and procedural heuristics demand relatively few cognitive capacities, the priority and timing heuristics require higher levels of cognitive sophistication. This is a result of the deployment of rules of thumb for ranking of opportunities and actions (priority heuristics) and specifying timing and sequences of activities (timing heuristics). The trade-offs required for these heuristics consume higher levels cognitive capacity.

OPPORTUNITY CAPTURING HEURISTICS

	Selection	***Procedural***	***Priority***	***Timing***
Heuristics	Guiding the choice of opportunities *“which opportunity to pursue or ignore”*	Detailing the actions to execute an opportunity *“which actions to take o exploit the opportunity”*	Specifying the ranking of opportunities or actions *“which opportunity to address first, second, …”*	Specifying the timing of opportunities or actions *“in which sequence rhythm, or pace”*
Cognitive sophistication	*Lower order* Selection on single opportunity rather than interrelations	*Lower order* Focus on single opportunity and not on interrelation of activities	*Higher order* Requires comparison of opportunities and actions	*Higher order* Focus on lead times and sequences to link multiple opportunities
Importance	Allocating scarce resources to promissing opportunities	Organizing actions to execute the opportunity effectively	Targetting efforts on most attractive opportunity set	Regulating tempo and maintaining momentum of actions

Figure 14 Characteristics of opportunity-capturing heuristics (adapted from Bingham & Eisenhardt, 2011, p. 1453)

In the next sections we discuss the decision making practices in infrastructure development as deploying and developing an adaptive toolbox with opportunity-capturing heuristics. To that end we first substantiate the applicability of the adaptive toolbox in the construction sector.

2.2.4. Decision making in the early stage of infrastructure development

In earlier sections (e.g., see section 2.2.1) we discussed the two main limitations of the traditional, (economic) perspective on decision making in construction: decision makers rarely (i) have full information available and (ii) clearly define the decision problem. Decisions in early stages of construction projects usually lack a clear basis, the complexity is overwhelming and the identification of a rational basis for decisions is difficult and time-consuming. Bounded rationality and limited capacity of information processing faced by decision makers limit their ability to consider all relevant variables and understand the complex relationships among decision variables (Deng, 1994, p. 552). Moreover, the construction decision making is characterized by a “complex network of heterogeneous decision criteria, an unprecedented flux of information flow among decision makers, a crowding pool of diversified participants and a plethora of options for design and construction alternative[s]” (Bakht & El-diraby, 2015, p. 1).

As a result, decision makers in early stages of construction processes primarily focus on pattern recognition rather than deep reasoning (Moselhi et al., 1991, p. 607). This form of deductive-based reasoning, requires decision makers in the construction sector to rely on “intuition derived from a mixture of gut feelings, experience, and guesses” (Ahmad, 1990, p. 595) and make subjective assessments in a complex environment (Chua & Li, 2000, p. 349; Fayek et al., 1999, p. 23). This deductive-based reasoning process makes use of partial cues (Moselhi et al., 1991, p. 606) and resembles the satisficing reasoning process underlying 'fast and frugal’ heuristic-based decision making. For this reason, we characterize decision making in early stages of infrastructure development by the adaptive toolbox with fast and frugal heuristics.

Naturally, the decision making approach relies on the type of decisions under consideration inarguably other perspectives on the decision making practices in the early stage of DBFM-contracted road infrastructure development apply. Moreover, the adaptive toolbox perspective is similar on several points to the traditional approach where the search cues are similar to the 'scores', criteria analogue to 'weights' and alternative identical to 'options'. However, there are three main arguments for supporting the 'fast and frugal' approach over the traditional approach to decision making in the early stage of DBFM-contracted road infrastructure development:

- A crucial difference in these approaches is that a decision maker with a traditional perspective stops the search for new information and makes a decision when all available information is collected and reviewed. A heuristic-based decision maker stops the search for new information when he or she believes sufficient information is gathered – hence potentially ignoring other information; making it faster and more 'frugal' than the traditional approach. As the reasoning process of decision makers in construction focuses on incomplete information, partial cues and is based on experience, gut feeling, (subjective) guesses and deductions, a heuristic-based approach better aligns with the construction sector: decision makers in construction base their decision on a specific set information at hand which is not necessarily identical to the set of all information available;
- Our study focuses on a specific decision maker making a specific decision. A specific decision problem in the early stage of infrastructure development has generally binary outcomes, e.g., accept or reject an alternative or action. This closely aligns with the fast and frugal heuristic-based approach to decision making while the traditional approach aims to select the 'best' option often out of a larger set of options;
- Our primary objective is to describe to which extent elements of the payment mechanism are integrated in the decision making practices while a traditional, optimization-based perspective to decision making also allows an examination of the weighing of specific types of decision information. Although the latter provides with more information, it requires more analysis and normative interpretations of the researcher in which assumptions on the reasoning process are required while the additional information is not required for the primary aim of this research.

Hence, although different perspectives may prove useful for the analysis of decision making in the early stage of DBFM-contracted road infrastructure development, we conclude that the 'fast and frugal' perspective and underlying reasoning process operationalized with the adaptive toolbox better aligns with the construction sector, our unit of analysis and our primary research objective. In the remainder of this section we discuss the contents of the adaptive toolbox of decision makers in the early stage of infrastructure development with a discussion on the four types of opportunity-capturing heuristics advanced by Bingham and Eisenhardt (2011).

The adaptive toolbox in the early stage of infrastructure development

In section 2.1.1, we discussed activities in early stages of infrastructure development. The majority of these activities focus on winning the tender bid and consequently detailing this winning bid into specific plans. Developing a winning bid is eminently aimed to capture the opportunity of revenue and profit from the prospective project. Moreover, in Figure 3 (p. 4) we have shown that the decisions early in the project are more efficient (i.e. high impact at lower costs) while decision makers are faced by uncertainty, complexity and time-pressure and likely rely on 'rules of thumb' and partial cues.

Therefore, decision makers in the early stage of infrastructure development are confronted with different opportunity-capturing decision problems for which they need to develop and deploy

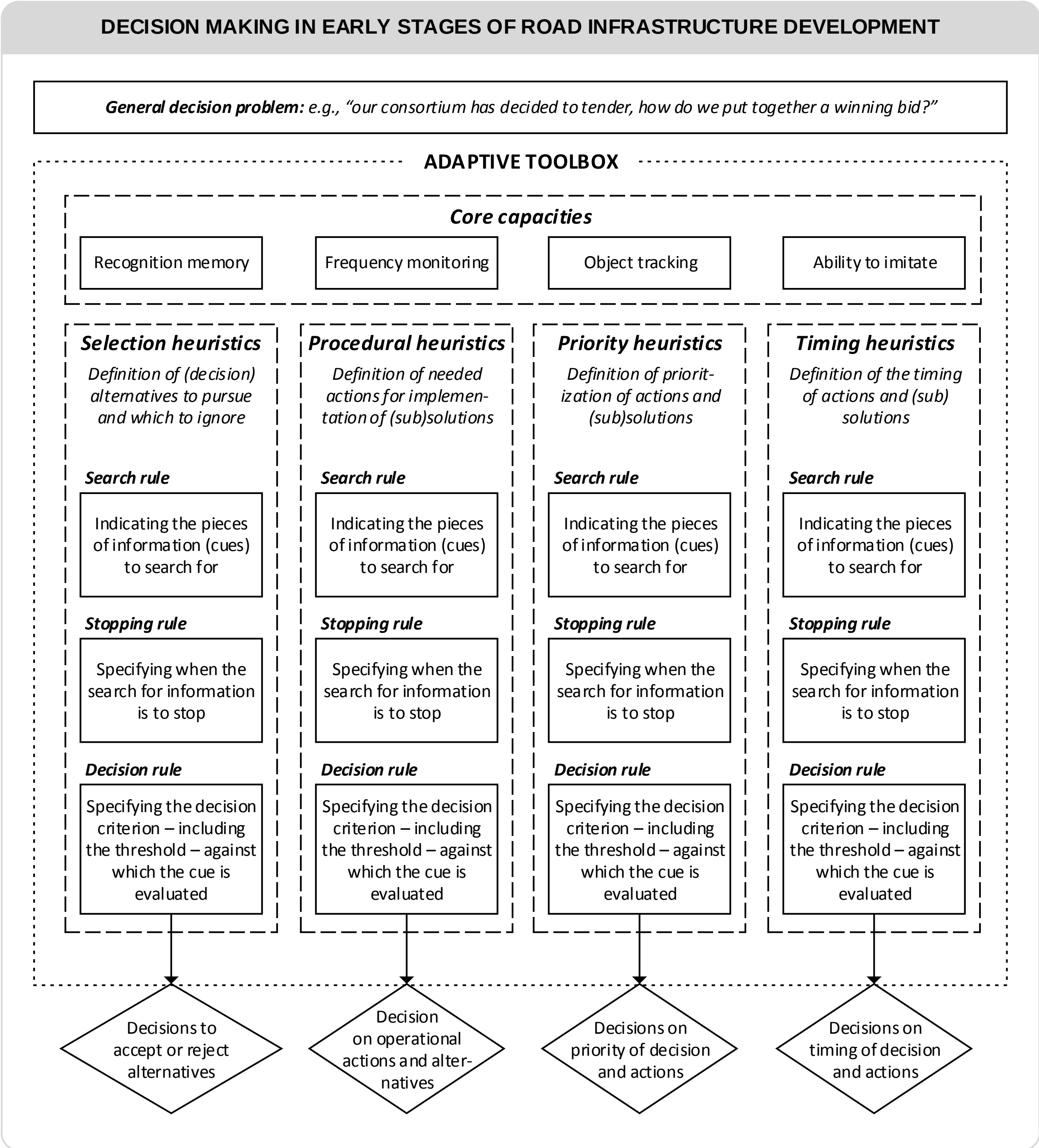


Figure 15 Characterization of decision making in early stages of infrastructure development with the adaptive toolbox concept and opportunity-capturing heuristics. Note that the search, stopping and decision rules are defined identically as these are the building blocks for each heuristics. However, the exact wording is heuristic-specific and may differ strongly across the opportunity-capturing heuristics.

heuristics (Morren, 2014). We consider the collection of opportunity-capturing heuristics as an adaptive toolbox for decision makers in the early stage of infrastructure development (see Figure 15).

Decision makers use their adaptive toolbox with 'fast and frugal' opportunity-capturing heuristics aimed to select (partial) solutions, develop action plans and detail alternatives, determine priorities for actions and alternatives and schedule and plan activities. Selection heuristics are deployed for acceptation or rejection of design, construction and maintenance activities to include in the best and final offer. More specifically, selection heuristics may guide decisions on specific risk mitigation measures, traffic congestion mitigation measures and the project's net present value or price.

Procedural heuristics support the development of detailed action plans for the winning bid, and subsequently for the project. These action plans may focus on gathering more information – e.g., detailing specific measures – and require therefore higher levels of cognitive sophistication. Decisions on the priority of alternatives and actions are the primary focus of the priority heuristics. Priority heuristics support efficient allocation of resources and require a more holistic view on the complete project (e.g., preference of some requirements over others). Similarly, timing heuristics require higher levels of cognitive sophistication as it supports decisions on sequences and timing of actions (e.g., construction planning).

The adaptive toolbox with opportunity-capturing heuristics consist of the search, stopping and decision rule building blocks and are supported by the core mental capacities that allow the decision maker to imitate complete heuristics and collect, store, recall and update partial information (cues) used in heuristic building blocks. This allows decision makers to adapt their the configuration of building blocks and mental capacities to different settings, i.e. adapt the heuristics to the ecological rationality.

In this study, we focus on a specific setting which allows us to create an overview of the adaptive toolbox deployed in the early stage of Dutch DBFM-contracted road infrastructure development and assess its ecological rationality. Our characterization of decision making in early stages of infrastructure development as an adaptive toolbox with opportunity-capturing heuristics aided by cognitive capacities provides with a perspective – or theoretical lens – to relate in the next section the decision making process to the payment mechanism in DBFM contracts. This perspective is then used to observe decision making practices in early stages of infrastructure development. We discuss this lens in the next section and report our findings of decision making practices in early stages of Dutch DBFM-contracted road infrastructure development in Chapter 3.

2.3. CONCLUSION THEORETICAL FRAMEWORK

The main aim of the literature review was to develop a lens through which we observe decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development and the way these relate to the payment mechanism. We described the early stage in Dutch DBFM-contracted road infrastructure development which is largely consumed by the tender process. In answering Research Question 1 we described different elements of the payment mechanism and characterized the payment mechanism as an incentive framework for contractors to deliver and maintain reliable, safe and available infrastructure on time. We discussed financial incentives including the one-off payments and periodic payments and focussed on the non-financial conditions for these payments. Categorization of these conditions may lead to different decompositions; however, in line with common practice and RWS aims we concluded that the payment mechanism is best characterized as an incentive framework for contractors to deliver and maintain reliable, safe and available infrastructure on time.

To answering Research Question 2, we reviewed relevant literature on decision making. Our discussion on decision making in the early stage of infrastructure development focussed on the limitations of traditional perspectives of decision making. We argued that given the complex, uncertain environment of early stages of infrastructure development these traditional perspectives provide insufficient insight for our research setting. In complex, uncertain – and even ambiguous – settings, decision makers are limited by their computational capacity and for that reason unable to consider all possible strategies and outcomes. As a result the reasoning process underlying decision making in infrastructure development is characterized by the adaptive toolbox concept which consists of 'fast and frugal' search, stopping and decision rules and core mental capacities aimed at recognition and imitation. Given the influence of the tender process in the early stage of Dutch DBFM-contracted road infrastructure development, we argued that decision makers in these early stages primarily deploy these building blocks to construct 'fast and frugal' opportunity-capturing heuristics to guide decisions that allow the decision makers to develop the winning bid. In line with Morren's (2014) perspective on decision making in construction, we concluded that the decision making process in the early stage of infrastructure development is best characterized as an adaptive toolbox with opportunity-capturing heuristics that are ecological rational and supported by recognition and social cognitive capabilities.

Now we developed an in-depth understanding of both the payment mechanism and decision making in Dutch DBFM-contracted road infrastructure development, we focus on answering Research Question 3 and relate the payment mechanism to the decision making.

RESEARCH QUESTION 3
How can elements of the payment mechanism in Dutch DBFM contracts relate to the decision making process in early stages of infrastructure development?

2.3.1. Relation payment mechanism and decision making in early stages of Dutch DBFM-contracted road infrastructure development

We characterized the payment mechanism as an incentive framework for contractors to deliver and maintain reliable, safe and available infrastructure on time. The payment mechanism aims to stimulate contractors to deliver performance and arranges all payments from RWS to the contractor. As such, the payment mechanism provides guidelines along which contractors capture the opportunity of developing the winning bid and detail the design after contract awarding. Therefore, the payment mechanism may provide contractors with cues and decision criteria to reflect their decisions on the impact on the impact according to the payment mechanism.

We characterized decision making in the early stage of Dutch DBFM-contracted road infrastructure development with an adaptive toolbox with opportunity-capturing heuristics that are ecological rational and supported by recognition and social cognitive capabilities. In this characterization, the heuristics are construed of search, stopping and decision rules – i.e., the building blocks – which guide the search for pieces of decision information, indicate when the search for information is stopped and specify how the final decision is reached.

These building blocks can relate to the payment mechanism by providing cues and decision criteria for the search, stopping and decision rules (see Figure 16). For each decision, decision makers may search for cues – e.g., incentives – in the payment mechanism. This search is stopped at some point – e.g., when all cues in the payment mechanism are found or a certain period of time has passed – after which the cues are reflected on decision criteria embedded in the decision rules. Based on the cues found, the decision maker may decide to accept or reject an alternative or action under consideration based on the decision criteria – e.g., the impact on payments.

Hence, we conclude that the elements of the payment mechanism in Dutch DBFM contracts can relate to the decision making process in early stages of infrastructure development with the provision of cues and decision criteria related to the building blocks in the adaptive toolbox of opportunity-capturing heuristics.

This perspective on the relationship between the decision making process in early stages of infrastructure development and the payment mechanism in Dutch DBFM contracts provides with a lens to observe the relationship in practice. It frames the ecological rationality within which we observe decision making practices and allows us to make inferences across decision makers about the way in

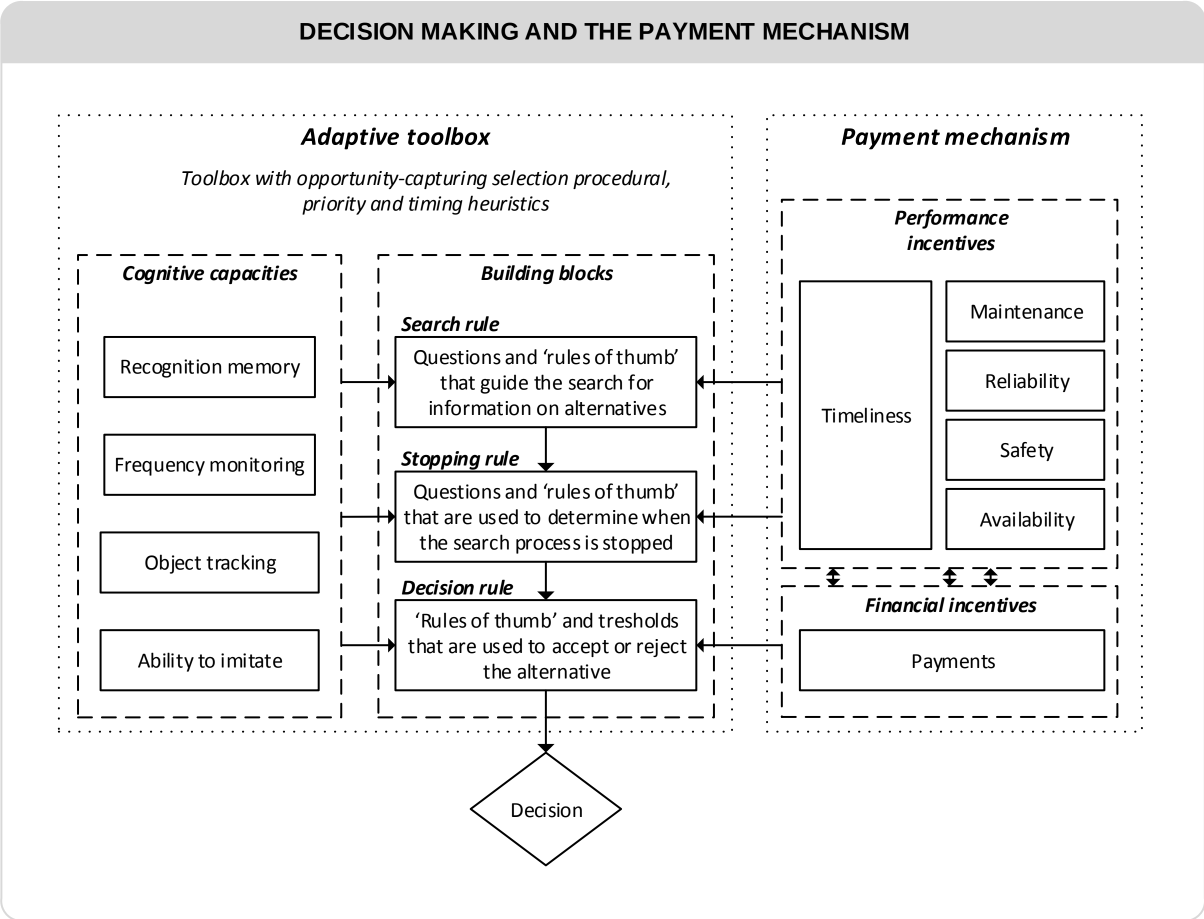


Figure 16 Theoretical lens on relationship between the payment mechanism and decision making in early stages of Dutch DBFM-contracted road infrastructure development.

which the payment mechanism relates to decision making in the early stage of Dutch DBFM-contracted road infrastructure development.[19]

Based on Figure 16, we included a detailed observations scheme in Appendix A. This observation scheme provides the basis for our field study in which we examine decision making practices and extent to which decision making practitioners use the payment mechanism in early stages of Dutch DBFM-contracted road infrastructure development. We discuss this scheme and our case study approach in the next chapter.

[19] Hence, this structure forms a theoretical lens for describing linkages between decision making and the payment mechanism observed in the field rather than a prescribing these relationships and testing them in the field.

3. METHODS

In this chapter we outline our methodological approach and discus the observation scheme in more detail. We follow the steps for empirical research proposed by Flynn et al. (1990, p. 250), delineated in the research questions. We build on the answers to Research Questions 1-3 and use the theoretical lens developed in Chapter 2 as a theoretical basis for our case study approach. We discuss the general observation scheme and discuss more in-depth various elements of the case study research (data collection, data analysis and issues for reliability and validity).

3.1. OBSERVATION SCHEME

In Section 2.3 we put forward the observation scheme (see Appendix A). We focus on two variables and the relationship between these variables: decision making practices and elements of the payment mechanism. The payment mechanism is conceptualized as an incentive framework with financial incentives related to availability, maintenance, reliability, safety and timeliness.

We conceptualized the decision making practices as an adaptive toolbox with heuristics to arrive at decisions. As we discussed, decision making in the early stage of road infrastructure is primarily concerned with opportunity-capturing – i.e. winning the bid and the associated revenue and profit – hence, we consider four categories of opportunity-capturing heuristics in the adaptive toolbox: selection, procedural, priority and timing heuristics. These heuristics consist of three building blocks or (search, stopping and decision) rules in which cues – i.e. (pieces of) decision information – and decision criteria are embedded.

Our aim is to create insight in the extent to which elements of the payment mechanism are embedded in decision making practices, i.e. the integration of payment mechanism incentives and conditions for these incentives in cues and decision criteria of the heuristics (CRQ). To this end, the observation scheme is structured as three subsequent steps of observations (see Figure 17). First we focus on the main decisions made based on design, construction or maintenance challenges. These decisions relate to the four categories of opportunity-capturing discussed earlier: (i) decisions to accept or reject alternatives (e.g., specific risk mitigation measures), (ii) decisions on operational actions and alternatives (e.g., how to detail alternatives), (iii) decisions on timing of alternatives and actions (e.g., construction planning) and (iv) decisions on the priority of alternative and actions (e.g., detailing RMPO measures before other RMP measures). Second, we focus on heuristics used to arrive at these decisions since the decisions are an inherent outcome of the decision making practices. We decompose these heuristics into the three building blocks: decision rules, stopping rules and search rules and

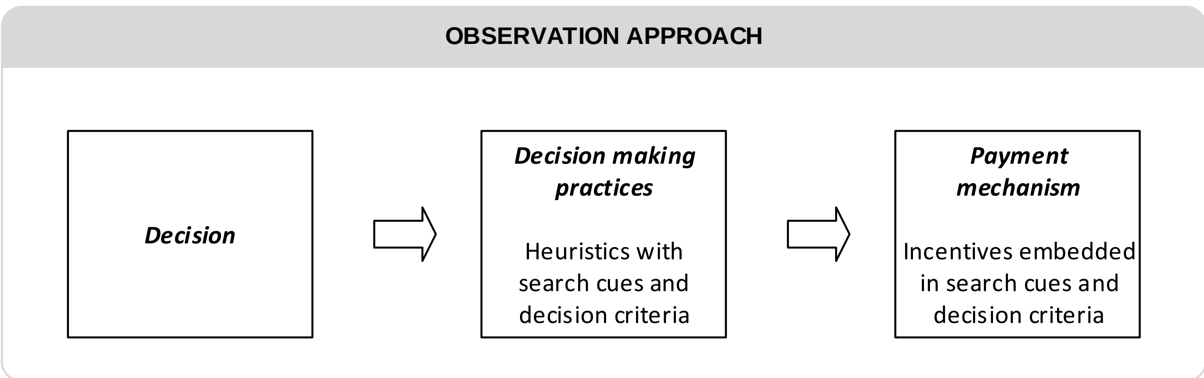


Figure 17 Outline of the observation scheme in which we observe subsequently a decision, heuristics related to the decision and elements of the payment mechanism embedded in the heuristics. See Appendix A for the complete observation scheme.

extract the cues and decision rules. Third, we analyze the heuristics – and hence building blocks with cues and decision rules – for elements of the payment mechanism.

With this three-step approach we can establish insight in the way in which elements of the payment mechanism are integrated in heuristics, allowing us to answer the Research Question 4, Research Question 5 and the Central Research Question: "*to which extent are elements of the payment mechanism integrated in the decision making practices in early stages of Dutch DBFM-contracted road infrastructure development?*" In the remaining sections we discuss our methods in more detail.

3.2. CASE STUDY RESEARCH

The field of decision theory and decision making is voluminous; however, the theoretical foundations of decision making remain a perceived weakness in construction management (Winch, 2010, p. 13). This applies in particular to the use of the payment mechanism in decision making. The focus on identifying elements of the payment mechanism that integrate with decision making practices in infrastructure development requires a reconstruction of current decision making practices in relation to the payment mechanism. This reconstruction allows us to identify a rule set that accommodates these practices and allows us to construct a model representation of these practices. However, the use of models in decision making is highly context dependent and requires concrete context-dependent knowledge which is not available in predictive theories and universals (Flyvbjerg, 2006, p. 224).

Our unit of analysis –decision making practices – is related to historic events, i.e. prior decisions; however, we the decision making practices themselves are part of the adaptive toolbox and as such we focus more strongly on current, contemporary reasoning processes and decision making practices which we are unable to influence. These two elements – i.e. contemporary events and inability to influence events – are important conditions for exploratory case study research (Yin, 2003, p. 11) which is supported by the explorative formulation of our Central Research Question. Therefore, we obtain our data on decision making practices from a explorative case study approach.

An case-study approach allow us to examine the relationship between the payment mechanism and decision making in-depth and provides with an understanding of the "dynamics present within single settings (Corbin & Strauss, 1990, p. 6; Eisenhardt, 1989, p. 534; Verschuren & Doorewaard, 2007, p. 184). An important benefit for the case study approach is the ability to make implicit deliberations explicit. This is especially useful as decision making in construction is intuitive-based (e.g., Bagies & Fortune, 2006; Fayek et al., 1999; Morren, 2014).

Different categorizations of case studies exist; an important categorization criterion is the number of cases included in the case study. Generally, two categories are distinguished: the single case study and the (comparative) multiple case study. The latter provides with the advantage to broaden the observational field to multiple – similar or distinct – settings which sheds light on the phenomenon under consideration. Moreover, the reliability as of the result is broadened by use of multiple information sources (Yin, 2003, p. 41). This study focuses on multiple cases, i.e. multiple decision makers in different project settings. In the next sections we discuss the way in which cases are selected, data is collected from these cases and how the data is analysed.

3.3. DATA COLLECTION

Reliability of outcomes from case study research are aided by use of multiple sources, i.e. triangulation. One of the benefits of case study research – especially with multiple case studies – is the ability to use different sources in terms of cases and instruments. However, use of multiple sources requires clear delineation of the research scope (Yin, 2003, p. 28). The unit of analysis plays an important role as it is a good proxy for the case definition in case study research (Yin, 2003, p. 29); hence, we select decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development as our cases. To this end, we refer to the theoretical framework and define the decision making practices as the adaptive toolbox with opportunity-capturing heuristics. In the remainder of this section, we discuss the methods for selecting these cases and research instruments related to the cases in more detail.

3.3.1. Case selection

Cases in this research are selected from Dutch DBFM contracted road infrastructure development projects. An overview of these projects is included in Table 18 (Appendix B). For the selection of decision making practices in DBFM-contracted road infrastructure development, we draw from projects based on three selection criteria. First, the we focus on Dutch projects for road infrastructure development. Second, we focus on projects that have left the tender stage in order to also study the early design decision making practices. Third, the project data and interviewees must be accessible for the researcher.

Oxand – the originator of this study – is able to secure project data and interviewees for three projects which left the tender stage. As a result, we collect our data from decision makers at the following DBFM-contracted road infrastructure development projects:

- Coen Tunnel Company – development Second Coen Tunnel and Westrandweg;
- A-Lanes A15 - widening A15 between Maasvlakte and Vaanplein;
- IXAS Gaasperdammerweg – tunnelling A9 between Holendrecht and Diemen.

As a result of the focus on reasoning processes underlying the adaptive toolbox, decision making practices are inextricably related to decision makers themselves. These decision makers interact with others which highlights the potential importance of group dynamics in the decision making process. However, as we focus on the individuals reasoning process we limit our examination to individual decision makers.

We consider to broad categories of decision makers: (i) technical-oriented decision makers primarily involved with engineering and developing technical measures and (ii) managerial-oriented decision makers primarily involved in the process control of the process. As we encountered in interviews, almost all decision makers consider themselves engineers; therefore, this categorization only moderately differentiates between the decision makers. In Section 3.3.2 we discuss the decision makers used for the observations in more detail.

3.3.2. Research instruments

Use of multiple sources is vital to the validity of case study results (Yin, 2003). Therefore, we collect our data from different sources and with different research instruments. The different sources include different decision makers in different projects; the different research instruments refer to the way we collect data from these sources. We use two types of research elements: document study and semi-structured interviews.

Document study

The document study consists of a literature study (as discussed previously) and documentation concerning the decision makers' decision making practices. Moreover, the insights obtained from the document study are included in the semi-structured interview to create a broader perspective.

The documents include a presentation on the payment mechanism (1), DBFM contracts (4), tender guidelines, selection guidelines, reports on specific risk assessments (1) and reports on management procedures (1). In addition, notes from presentations on the decision making processes (1) are included and a specific templates for collecting decision-relevant information are used.

Semi-structured interview

The semi-structured interview are used to collect insights in the search cues and decision criteria embedded in the decision making practices. The semi-structure accommodates the exploratory nature of this research and allow an open discussion with interviewees while we create insights in the decision making practices. We interviewed 7 decision makers for 1-2 hours based on an interview protocol. A list of interviewees and the interview protocol are included in Appendix C). We selected 7 interviewees based on their availability and experience as decision maker in the DBFM-contracted road infrastructure development. We included two types of decision makers: technical-oriented decision makers focussed on engineering and development of technical managers and managerial-oriented decision makers focussed on process control. Of the decision makers, three are primarily concerned with maintenance activities (e.g., exploitation stage-oriented, budgeting), three are primarily concerned with business management and business control (e.g., construction planning, quality control) and one decision maker was primarily focussed on engineering design solutions (e.g., specific measures). However, all decision makers noted that they are technical-oriented and the characterization above is not limitative for their involvement in the projects. The early stage of DBFM-contracted road infrastructure development generally starts with a small group of relative senior decision makers, requiring the decision makers to be versatile in their activities. We select the interviewees from this group.

All interviews were taped for reference during case study analysis in order to limit ambiguities in interpretation. Questions were intentionally formulated as open but specific questions in order to create a large focussed set of data for our analysis. Moreover, interviewees were invited to speak openly over their factual decision making practices and refrain from judgements. This approach was chosen to minimize ex-post rationalization of decision making and maximize insight in reasoning processes. In addition to the general questions bellow, we discussed various project-specific considerations in-depth which allowed the interviewer to increase robustness of inferences about the heuristics used. A full overview of the interview questions is included in Appendix C which provides a clear overview of the structure and data collected.

3.4. DATA ANALYSIS

In line with Eisenhardt (1989, pp. 539–540) we analyse within-case data and examine cross-case patterns. The within-case analysis allows us to familiarize with the individual heuristics and to construct a sequence of events. This overview then provides the basis for an analysis for causality (Voss, Tsikriktsis, & Frohlich, 2002, p. 213). This is especially useful for making the implicit heuristics and underlying reasoning process explicit. To this end, we breakdown the heuristics into to three building blocks. Although our unit of analysis is the decision making practices, we discuss these practices on a project level. This allows us to prevent repetition of the project context, ensure the anonymity of decision makers involved and frame decision making practices in the ecological rationality.

The cross-project pattern analysis is key to the case study approach as it may allow us to generalize within-project findings to a larger population. Furthermore, multiple sources – both in terms of multiple projects and multiple data sources within each project – improves reliability of results (Eisenhardt, 1989, p. 540). Our cross-project analysis focuses on the collection of general decision making practices present in all projects, i.e. decision makers and projects. This allows us to improve the external validity of our findings over decision making in Dutch DBFM-contracted road infrastructure development projects.

3.4.1. Within-case analysis

Within-case analysis is based on the collected data described earlier. This data set is open coded with different categories (e.g., “decision”, “building block”, “general project characteristic”, “cue”, “decision criteria”) and then used as a basis for detailed case descriptions. We follow the research approach outlined in Figure 6 (p. 11) and focus on three specific aspects: general decision making (including main decisions), specific opportunity-capturing decision making practices and the role of specific elements of the payment mechanism in these practices (see Figure 18):

- *Developing a general understanding of the decision making practices*. This involves insight in the people involved, main steps and procedures, main decision problems and decisions and documents and reports used;[20]
- *Developing a specific understanding of decision making practices*. This involves creating insight in heuristics used;
- *Developing insight in the role of specific elements of the payment mechanism.* Here we focus on the main incentives defined earlier and how these play a role in decision making practices (e.g., search cues and decision criteria).

As noted earlier, for various reasons we describe these practices and its context at a project-level. Hence, the general decision making process and case context is for many decision making practices identical. An important objective of our approach is to make the implicit reasoning process and the subjective judgements of decision makers in the early stage of DBFM-contracted road infrastructure development explicit. To that end, we first categorize the decision at hand into one of the categories related to the four opportunity-capturing heuristics. For this we use the codes assigned to the decision and questions as ‘does the decision have a direct impact on the final offer or design?’, ‘does the decision give a ruling on some weighing, prioritization or ranking?’, ‘does the decision prescribe detailing efforts or procedures for development of alternatives?’ and ‘does the decision specifically

FOCAL POINT CASE STUDIES

Developing a general understanding of the decision making practices

- People involved
- Main steps and sub-procedures
- Main proposals and decisions
- Documents and reports developed and used

Developing a specific understanding of decision making practices

- Selection, procedural, priority and timing heuristics deployed
- Mapping proposals and decisions to heuristics

Developing insight in the role of specific elements of the payment mechanism

- Main elements of the payment mechanism and their importance for decision making
- Relationship payment mechanism incentives and decision rules and decision making heuristics

Figure 18 Focal points for the case study on general, specific and payment mechanism-related decision practices.

[20] Where possible, we use these documents and reports as an additional information source to build the case.

relate to the timing of actions?’ Second, we define decision making practice as a heuristic, i.e. as a ‘rule of thumb’. To this end, we interpret the main message behind the decision made and describe this as a rule or instruction. Third, we decompose the heuristic into the three building blocks, i.e. the search rule, stopping rule and decision rule. For this, we use the coding described earlier (e.g., ‘search cue’, ‘decision criteria’, ‘building block’) and interpret the heuristic in the adaptive toolbox format. These heuristics are reported and discussed in the context to their relation to the payment mechanism.

We distinguish different heuristics when the search cues and decision criteria are different. We choose not to define categories of search cues and decision criteria up front in order to limit researcher bias and allow the interviewees to answer with a minimized pre-existing frame. However, in the cross-case analysis we did assign the cues and decision criteria to categories.

3.4.2. Cross-case analysis

The within-case analysis provides with a body of decision making practices (heuristics) used in the early stage of DBFM-contracted road infrastructure development. An analysis of the cross-case patterns can provide insights in the generalizability of conclusions drawn from the heuristics. Moreover, it may improve the internal validity of the findings as differences and similarities are highlighted in the cross-case analysis. Finally, cross-case analysis is an additional step for triangulation and hence contributes to higher reliability of the results.

Similar to the within-case analysis, we distinguish three focal points (see Figure 18); however, in the cross-case analysis we pay specific attention to the heuristics related to the payment mechanism (focal point 3). To this end, we extract – using the building blocks and assigned coding – the cues and decision criteria in the heuristics related to the payment mechanism and link these to specific elements of the payment mechanism (availability, timeliness, maintenance, reliability and safety). This allows us to generalize the within-case study findings to decision making practices in the early stage of DBFM-contracted road infrastructure development and assess the extent to which elements of the payment mechanism are integrated in the decision making practices.

3.5. RELIABILITY AND VALIDITY

In order to increase the reliability and validity of the research, we follow Yin (2003, p. 33) and use multiple sources of evidence (see research methods), use an observations scheme (see Appendix A) and use an interview template (see Appendix C). Moreover, we analyse each case in a similar fashion in order to increase the replication logic and so the external validity of our findings (Yin, 2003, p. 35).

Regarding the aspect of reliability, it important to note that the interviews are semi-structured and the interviewees are invited to speak open and free. This limits the effect of ex-post rationalization of decisions. Moreover, the reverse approach from decision to heuristics and building blocks allows us to highlight and discuss conflicting answers.

The aspect of multiple sources closely relates to triangulation which is especially important for external validity, i.e. generalization. We collect our data from different decision makers with different backgrounds and roles in the project which we support with additional documents. Moreover, we used identical interview structures for all interviews. As a result, the results from the case study are comparable on the different focal points. However, we conceptualize the decision making practices as an adaptive toolbox with opportunity-capturing heuristics, the generalization in the cross-case analysis is limited to the decision makers included in the research and the projects in which these decision makers were involved. This is a direct result of the person-specific reasoning processes. Nonetheless, the findings allow us to conclude on the ecological rationality of the heuristics which allows for generalizations to some extent.

In the next chapter we report the result of the case study obtained from implementing the methodology outlined in this Chapter. We also answer Research Questions 4 and 5 in Chapter 4.

4. CASE STUDIES

This chapter presents observed decision making practices in Dutch DBFM-contracted road infrastructure development and their relation with the payment mechanism. As outlined in the previous chapter and Appendix B, we obtained these practices from decision makers in three specific DBFM-contracted road infrastructure development projects:

- Coen Tunnel Company – development Second Coen Tunnel and Westrandweg;
- A-Lanes A15 - widening A15 between Maasvlakte and Vaanplein;
- IXAS Gaasperdammerweg – tunnelling A9 between Holendrecht and Diemen.

Based on the theoretical lens developed in the theoretical framework, we developed an observation scheme (see Appendix A) which we use to create insight in the decision making practices.

The remainder of this chapter is structured as followed. First we discuss each project, decision making practices observed within the project and the relation between these practices and the payment mechanism individually. Then we discuss similarities and differences in the cross-project analysis and highlight the main incentives of the payment mechanism reflected in heuristics.

4.1. WITHIN-PROJECT ANALYSIS

In line with the focal points of our case study approach (see Figure 18), we report for each project the project context, general decision making practices and decision making heuristics related to the payment mechanism. Note that our unit of analysis is the decision making practices used in Dutch DBFM-contracted road infrastructure development. To that end, the project descriptions are structured in three sections: we first highlight the project context which allows us to frame the environment, i.e. a project overview with technical, financial and organizational characteristics. Moreover we describe differences between the general contract structure outlined in Section 2.1. We follow-up on that with a discussion on the general decision making process which in which we discuss important decision problems (see observation approach in Figure 17). In the third section, we highlight the decision making practices – i.e. heuristics – that were used in the project. Here we also highlight the relationship of the observed heuristics to the payment mechanism. A complete overview of the observed heuristics is included in Appendix D which provides us with an answer to Research Question 4, i.e. decision rules used in early stages of DBFM-contracted road infrastructure development.

RESEARCH QUESTION 4
Which decision making practices are used in early stages of DBFM-contracted road infrastructure development?

4.1.1. Coen Tunnel Company

Project context[21]

The Coen Tunnel Company won the estimated 1.2 billion Euro DBFM-contract for development of the A5 highway between the Raasdorp junction and the Coen Tunnel, the Second Coen Tunnel itself and

[21] On the Coen Tunnel Company website http://tweedecoentunnel.nl/ (retrieved at November, 13 2015), an excellent – Dutch – book on the project is provided.

the connection to junction Coenplein. It was the second project for infrastructure development tendered as a DBFM-contracted in the Netherlands and the first DBFM-contract tendered by RWS.[22]

The A5 is elevated up to 20 meters above ground level and increases accessibility of North-Holland with a North-East bypass along Amsterdam. The Second Coen Tunnel increase the number of lanes available for passage of the North-Sea Cannel from four to nine (i.e. three North-bound and two reversible lanes). The contract scope includes refurbishment of the existing Coen Tunnel tube and a maintenance contract for 24 years after construction.

The tender process was announced in 2005, contract was awarded in 2006 and construction of the Second Coen Tunnel started in 2009. In 2013, the Second Coen Tunnel was completed and refurbishment of the existing – or First – Coen Tunnel started. In 2014 the project entered the 24 year maintenance stage when the First Coen Tunnel was put back into service.

Organization
The Coen Tunnel Company was created as commercial partnership between seven parties: Arcadis, Besix, CFE, Dredging International, Dura Vermeer, TBI Bouw and Vinci Concessions. After contract awarding, these parties acquired equity shares in the Coen Tunnel Company which was from that moment on a limited company. Fortis Bank, Bayerische Landesbank, Royal Bank of Scotland (RBS), Bank Dutch Municipalities (BNG), KfW IPEX-Bank and the European Investment Bank (EIB) provided additional funds up to 593 million Euros.

The equity holders acquired the right to execute project activities that related to their experience and knowledge. As a result, winning the tender bid resulted in both revenue from activities and profits from providing equity capital.

Contract
The general structure of the Coen Tunnel Company DBFM contract is identical to the basic agreement discussed in Section 2.1. However, the payment mechanism deviates on one major incentive: exceedance of the vehicle loss hours estimated in the tender process is only penalized with availability penalties and not with additional performance penalties. Moreover, a budget of 'maintenance nights' and 'maintenance weekends' was available for the realization project stage in which lane closures were not penalized. These penalty-free lane closures were also available for the exploitation project stage and eligible for MEAT-treatment, e.g., the prospective contractor was requested to include a number of required 'maintenance nights' between 35 and 45 needed for regular maintenance activities. Hence, although the contractor was awarded for lower required 'maintenance nights' reliable estimation of the required nights was less penalized than in the standard agreement where exceedances were additionally penalized with performance penalties.

In their best and final offer, the Coen Tunnel Company offered 35 'maintenance nights' and 8 to 11 'maintenance weekends' during the realization stage. Additionally, 35 'maintenance nights' were rewarded to the Coen Tunnel Company for maintenance during the exploitation stage.

The height of the unavailability penalty relates – in addition to the route affected – to the time slot in which the unavailability occurs. Two time slots are included in the contract: night time slot (23:00-5:00) in which the maximum unavailability penalty is EUR 20.000 for each 15 minutes and the day time slot (5:00-23:00) in which the maximum unavailability penalty is EUR 40.000 for each quarter.

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[22] Development of the N31 was the first DBFM-contracted road infrastructure development project in the Netherlands; however, this project was formally initiated by the Province of Frisia (see Appendix B).

Table 1 Overview of the key figures and trivia of the Coen Tunnel Company project.

Scope	Financials	Trivia
• Development of 10 km highway A5 (Raasdorp–Coen Tunnel; four lanes); • Development of Second Coen Tunnel (five lanes); • Infrastructure maintenance (existing and new-built).	• RWS estimated contract value: 1.2 billion Euros; • One-off payment: 100 million Euros; • Gross availability payment: 9.7 million Euros.	• Second infrastructure development tendered as a DBFM contract; • Winning contract awarded to seven participating contractors.

General decision making process

Decision making in the early stage of the Coen Tunnel Company project was primarily directed by the tender manager, supported by a staff with years of experience in infrastructure construction and D&C[23] projects. The experience in earlier projects was decisive for the general decision making process from decision to participate in the tender procedure to the best and final offer and the first decisions to into the preliminary design.

Characterizing decision making within Coen Tunnel Company

Decision making within the Coen Tunnel Company was strongly technical-oriented. Decision makers relied on their technical training and experience in D&C settings. As a result, decision making process followed technical design and development. Tender management decomposed the project along the technical decomposition into major physical works requested by RWS which was then assigned to specific teams responsible for that specific part of the technical decomposition (e.g., a team for road design, tunnel installation and maintenance organization development). The activity of decomposing the work into physical works is generally referred to as the Work Breakdown Structure (WBS).[24]

In addition to the technical orientation, decision making was characterized as uncertainty on the risk profile during maintenance. However, this concern was only present under those involved in preparation of the maintenance organization. Parts involved in design and realization emphasized on their output and the safety margins used in civil engineering. One of the interviewees characterized this perspective as followed: “we develop this for the required maturity, so there is no uncertainty in the life-cycle (..). We design the concrete to last over a 100 years; we have to replace the road surface once in the eight or twelve years, depending on the asphalt, the installations once in the five years.” As such, the engineering rationale presumes absence of uncertainties. Nevertheless, on upper-level tender management decision makers were aware of the uncertainty – i.e. potential failure – over the technical life-cycle. They realized that their training and experience was insufficiently adaptable to the newness of the DBFM-contracted type of infrastructure development. However, an interviewee noted that “the soup would cool down before it was time to eat it.” Decision makers were convinced that the requirements should not be interpreted as strict as in the contract. In discussions after contract awarding, decision makers would be able to lessen the impact of unavailability requirements.

The primary focus of decision making in the early stage of infrastructure development was to create insight in the costs as input for the BAFO. Activities involved creating budgets for each technical

[23] D&C is and abbreviation for ‘Design and Construct’ a contract form in which both the design and construction of the project was delegated to private contractors.

[24] The WBS is an important basis for developing infrastructure and is construed based on the contract, rather than an element of the contract.

Table 2 Overview of selection opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Increase MEAT-value by minimization of the offered number of 'maintenance nights'.**
Selection #2	**Reduce uncertainty by creating frequent 'life buoys' with budgets for maximum availability over the life-cycle'.**
Selection #3	Include measures in the bid that eliminate the concerns of RWS underlying the formal risks outlined in the Risk Management Plan.

component. Each technical component was detailed into volumes and acreages in order to determine the cost price. Each equity partner had its own opinions on the required margins but the interviewees were not involved in these discussions nor were there documents available. Hence, detailing the cost price of realization and maintenance along the WBS played – with the margin mark-up decision – an important role in decision making. Additionally, on the higher level of tender management, analysis were carried out to include potential loss from failures from unavailability. As one interviewee noted, “we knew we were going to fail at some point but no-one was able to tell me when and how much.” Gut feeling played an important role in the calculations as well. “One of the calculators had experience since Dura Vermeer – actually it was before Dura and Vermeer merged and he was from Vermeer – was involved in infrastructure development. He arrived at the price based on the square meters, cost prices and a mark-up for maintenance. He was less appropriately qualified in the latter.” This quote reflects the D&C approach to the Coen Tunnel Company project: people involved were very capable in estimating the essentials for the realization based on their experience. The resulting confidence in their technical and financial estimations was conveyed to activities for the exploitation stage. However, the experience from which the confidence was deduced was not necessarily applicable to the maintenance activities

Main decision problems

The primary aim of decision making in the early stage of Coen Tunnel Company project was to increase reliability of the price. To that end, decision problems on construction design, realization and maintenance were discussed. The interviewees put forward three important decision problems: realization planning and sequences of activities (e.g., on which side of the North Sea Cannal do you start the construction activities), existing infrastructure (e.g, which elements of existing infrastructure are we going to replace immediately and which can wait?) and budgeting unavailability in maintenance stages (e.g., which budget do we need to reserve for unavailability in the exploitation stage of the project). In Appendix D.1, we included an overview of observed opportunity-capturing heuristics related to these decisions. In the next section, we discuss the heuristics related to the payment mechanism.

Decision making heuristics related to the payment mechanism

Decisions in early stages of the Coen Tunnel Project are diverse. Based on interviews and document studies 17 opportunity-capturing heuristics were observed. In appendix D.1 an overview of these heuristics and their building blocks is provided; here we report only the heuristics. We first describe the heuristics with relation to the payment mechanism and highlight this relationship. Then, we discuss briefly why the remaining heuristics are not related to the payment mechanism.

Selection heuristics

In Table 2 an overview of the three observed selection opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project is included. The selection heuristics are used to determine which measures and alternatives to include in the final offer to RWS.

Two of the observed selection opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 2). The first observed selection heuristic (Selection #1) describes the way in which the decision makers arrive at their offer of the number of 'maintenance nights' to include in the offer. The interviewee noted that minimization of the 'maintenance nights' was preferred for the associated MEAT-value. Maximum MEAT-value was obtained for the an offer with at maximum 35 penalty-free nights for lane each year closures. To this end, interviewed decision maker searches for the required capabilities of the organization to organize required maintenance activities within the minimum number of maintenance nights specified in the MEAT-procedure (i.e. 35 nights each year) and stops searching when the assessment of the organization capabilities of maintenance activities was made. When the assessment showed that the Coen Tunnel Company had the ability to organize the required maintenance activities within the minimum prescribed 'maintenance nights', it was concluded that this minimum number of 'maintenance nights' was included in the offer in order to capture the MEAT-value associated with minimization of the number of 'maintenance nights'.

This heuristic relates to the payment mechanism through the emphasis on maintainability, reliability and – to a lesser extent – timeliness, i.e. timely execution of maintenance activities. As one of the observed decision makers noted "[minimizing 'maintenance nights'] is just a matter of organization." When the decision maker was convinced that he[25] was able to, at a later stage in the project, organize the required maintenance activities within the minimum 'maintenance nights' with minimum risk of awarding unavailability penalties, the primary focus was on obtaining MEAT-value.

The second observed selection heuristic (Selection #2) describes the way in which the decision maker arrive at the budgets for unavailability penalties to include in the offer. In order to minimize the uncertainty of costs associated with unavailability penalties, the decision maker searched for the most likely frequency of availability penalties. Each discipline responsible for development of a part of the WBS was asked for the likely frequency of failures. Based on these frequencies the maximum of the unavailability penalties was calculated on a normative frequency of five years. This budget was then presented to the tender manager and when the tender manager decided that the proposed budget was defendable for the tender board, the search was stopped. It was concluded that the budgets for unavailability penalties was based on full unavailability penalties in the five years when the tender manager was convinced that this frequency was defendable to the tender board.[26]

Clearly, this heuristic relates to the availability element of the payment mechanism. The primary aim of the heuristics is to 'price unavailability' and include this in the offer. In line with the general decision making practices in the Coen Tunnel Company project, the decision maker approached this along the technical route, i.e. retrieve information on component failures from all technical disciplines. Based on the normative frequency of component failure, the normative frequency of availability penalties was determined. However, rather than complying with availability requirements, minimizing contractor request for lane closures or and minimizing the impact of lane closures on the important routes and route sections, this heuristic focuses on the financial impact resulting from lane closures. Moreover, after initial assessment of the impact of the payment mechanism on the offer – i.e. the budget for unavailability to include over the contract life-cycle – expert judgement was used to adjust the budget and make it defendable for the tender board.

Note that this decision making practice reflects the close resemblance and interrelations between 'fast and frugal' heuristics and the traditional (bounded) rational approach. Examining the building blocks

[25] For readability and to create anonymity for the interviewees, we make use of masculine forms to refer to gender-specific roles. The reader may read 'he' as 'she'.

[26] Note that in addition to a tour along the various discipline an additional procedural heuristic was deployed (see Table 3, Procedural #1).

Table 3 Overview of procedural opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism; italic-faced only marginally.

Procedural #1	**Use a FMECA analysis on WBS-based availability requirement categories to determine the technical components for which risk mitigation measures are to be developed.**
Procedural #2	*Include personnel with physical risk knowledge and life-cycle analysis to create insights in the risk of unavailability penalties.*
Procedural #3	Include managers with D&C engineering experience in the project.
Procedural #4	Implement the Systems Engineering Approach.
Procedural #5	Rely on prior experience of parent company in detailing maintenance budgets.
Procedural #6	The WBS is leading in determining the project activities.

of the heuristic in more detail (see Table 19, p. D-1), shows that some elements – especially the search rule – aligns with the traditional approach: including many pieces of information from various disciplines. However, overall – especially the stopping and decision rules – the decision making practices are better described as an adaptive toolbox characteristics as it fulfils the main characteristics outlined in 2.2.3: (i) it is not a general-purpose decision making algorithm; (ii) there is no strong consistency and coherence between the search and stopping rule in the building blocks and; (iii) the heuristic is adapted to social environment, i.e. defendability to the tender board.

The third observed selection heuristic (Selection #3) describes the way in which the decision maker determined focal points for measures to include in the offer. This heuristic is not directly related to the payment mechanism; rather it focuses on capturing the MEAT-value to win the bid.

Procedural heuristics

In Table 3 an overview of the six observed procedural opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project is included. The procedural heuristics are used to determine action plans for project development and to detailed measures.

Two of the observed procedural opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 3). The first observed procedural heuristic (Procedural #1) describes how the decision maker decides for which technical components risk mitigation measures are to be developed. Two search cues were used: (i) relationship between availability penalties and the WBS and (ii) the FMECA-based Risk Priority Number of availability requirement categories. When the relationship between the availability penalties and the WBS was assessed, the requirements categorized according to the WBS and the Risk Priority Number for availability requirement categories was established, the search was stopped. It was decided that risk mitigation measures were developed for a technical component of the infrastructure when the associated availability requirement categories have been assigned a high Risk Priority Number. For infrastructure components with low Risk Priority Numbers for the related availability requirement categories no risk mitigation measures where developed.

This heuristic is related to the payment mechanism in a similar fashion as selection heuristic #1 (see Table 2). Moreover, procedural heuristic #1 was used in a later iteration to increase the accuracy of the maintenance budget and put more emphasis on reliability and less on timeliness. In order to prevent unavailability, a risk analysis was executed on availability requirements linked to the WBS (i.e. FMECA) and for the main risks, mitigation measures were developed. Hence, this procedural heuristic aimed to avoid availability penalties by minimizing failures on availability requirements.

The second observed procedural heuristic (Procedural #2) describes the way in which knowledge and experience in physical risk knowledge and life-cycle analysis is included in the project in order to create insight in the risk of unavailability penalties. The decision maker searches for persons that possess this knowledge and experience in the parent and other companies and stops searching when people are found. When one of the parent companies employs personnel with physical risk knowledge and experience in life-cycle analysis, that employee is included in project. When this personnel is not available within the parent company, it is decided to hire consultants with these credentials.[27]

This heuristic only relates marginally to the reliability element of the payment mechanism and emphasizes on increased accuracy of the maintenance budget. Decision makers recognized that specific knowledge and experience was needed to create reliable estimates in a DBFM-contract setting which was not available in the current – D&C-focused – staff. As one of the decision makers recalled, “everything was new” and there were “large uncertainties on the availability penalties over the life-cycle.” As a result, he recognized a for life-cycle analysis experience and physical risk knowledge which was sourced first from parent companies and later hired from experienced consultants. These decision makers then brought forward the heuristic described in procedural heuristic #1.

The remaining observed procedural heuristics (Procedural #3, #4, #5 and #6) are not directly related to the payment mechanism. Procedural heuristics #3 and #6 emphasized on including technical experience in the project –experience in a different contract setting – while procedural heuristic #4 describes how the decision to implement the Systems Engineering Approach was made, i.e., following from a (non-availability or -performance) requirement. Procedural heuristic #5 describes the way in which much of the maintenance budget detailing was executed. Where procedural heuristic #1 emphasizes on an availability-requirement linkage, this heuristic builds on prior experience of the parent companies and consultant firms. This experience did not include a DBFM contract-type payment mechanism. As one of the decision makers noted he and the tender manager “were not convinced that [a further detailing of the in the maintenance budget] was the way to go.” As a result, at a later stage procedural heuristic #1 was deployed.

Priority heuristics

In Table 4 an overview of the six observed priority opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project is included. The priority heuristics are used to assign priorities to measures and actions. These priorities are used to decide which actions are detailed first and which measures are more likely to be included in the bid.

Four of the observed priority opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 4). The first observed priority heuristic (Priority #1) describes the way in which the importance of requirements in general is determined. The decision maker first searches for the relationship between the requirement and the project stage and stops when this relationship is established. When the requirement relates to the realization stage – i.e. design and construction – the requirement is used as a primary reference for detailing measures to include in the bid. In other situations, the requirement is not used as primary reference.

This heuristic reflects the prominent D&C approach to the Coen Tunnel Company project. Moreover, it relates to the payment mechanism as it prioritizes availability on the availability date[28] over availability in the exploitation stage. Hence, the heuristic reflects the emphasis in the early stage of project development on one-off payments rather than the quarterly net availability payments.

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[27] Similar to Selection #2 – and even more so – this heuristics may also be described with a traditional bounded approach since it describes a more general-purpose algorithm rather than a ‘rule of thumb’-type of heuristics that is adapted to the project environment.

[28] The availability date is a contractual date at which it is agreed that the infrastructure is available. The availability date marks the end of the realization stage and the beginning of the maintenance stage.

Table 4 Overview of priority opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Compliance with requirements related to the realization stage is more important that compliance with requirements related to the exploitation stage.**
Priority #2	**Focus with measures and alternatives on preventing unavailability in the short-run rather than preventing unavailability on the long-run.**
Priority #3	**Use the availability requirements as a guide rather than take them literally in the development of measures and alternatives.**
Priority #4	**Focus on the revenue from realization rather than maintenance of the infrastructure.**
Priority #5	Make trade-offs against the preferred alternative implied in the in program of requirements.
Priority #6	Focus on the cost price and margin in determining measures to include in the bid.

However, exceedance of the realization stage also results in availability penalties from the contractual availability date. As such, this heuristic relates to the timeliness element of the payment mechanism and focuses on compliance with the availability requirements on a certain point in time.

The second observed priority heuristic (Priority #2) describes a similar prioritization, i.e. the way in which the importance of measures for the bid is determined. When reflecting on (prospective) measures, the decision maker searches for the period in which the measure prevents unavailability and stops when the timing of the impact on preventing unavailability is determined. When the measure prevents unavailability on the short-run, it is decided that the measure receives a high priority in detailing and inclusion in the final bid. When unavailability prevention occurs on the long-run, the measure receives a low prioritization.

This heuristic clearly relates to the availability and timeliness element of the payment mechanism. The decision makers indicated two reasons for the preference of short-run over long-run impact on unavailability. First, preventing short-run impact was perceived ‘more certain’ and related to the focus on the realization stage (see priority heuristic #1). Second, decision makers indicated that measures aiming to prevent unavailability on the long-run could also be implemented later on. Moreover, the net present value impact of unavailability penalties in later stages of the project was lower than those in earlier stages (“in the end [of the contract period] you are still able to take a hit”).

The third observed priority heuristic (Priority #3) describes how decision makers arrived at the importance of availability requirements. First, the decision maker searched for RWS’ intention of the availability requirement and stopped this when an interpretation was established. In some situations this interpretation was reviewed with RWS, for other decision problems the decision maker used experience from prior projects. When the interpretation resembled the contractual formulation closely, the availability requirement was used as a primary reference for detailing measures. In other decision problems, the availability requirements were less influential in detailing the measures.

This heuristic relates to the payment mechanism with the emphasis on compliance with availability requirements. However, the heuristic also implies that compliance with some availability requirements is considered more important than others. Or, as one decision maker noted, “if the availability requirements are taken literally, the infrastructure had to resemble ‘a billiard cloth’ over the contract life-cycle.” As this could have been a costly endeavour – both in direct realization and maintenance costs as in indirect unavailability penalties – decision makers applied expert judgement to obtain insight in the relative weights of the availability requirements.

Table 5 Overview of timing opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism.

Timing #1	**Replace existing infrastructure that has a low remaining life-time**
Timing #2	Base construction planning on the program of requirements supplemented by prior experience.

The fourth observed priority heuristic (Priority #4) describes the way in sources of revenue is weighted. Similar to priority heuristic #2, decision makers searches for the timing of the impact of a measure on generating revenue and stop this search when the timing is determined. It is decided that measures that generate revenue during realization are preferred over measures that generate revenue during exploitation.

This heuristic shows a similar rational as priority heuristic #2, i.e. the net present value impact and (perceived) certainty of revenue result in prioritization of short-term over long-term revenue. Similar to priority heuristic #1, this heuristic reflects the emphasis on one-off payments rather than the quarterly net availability payments and hence relate to the timeliness element of the payment mechanism compliance with the availability requirements on a certain point in time. However, exceedance of the realization stage also results in availability penalties from the contractual availability date. As such, this heuristic also relates to the timeliness of the payment mechanism in the first quarters of the exploitation stage.

The remaining observed priority heuristics (#5 and #6) are not directly related to the payment mechanism. Priority heuristics #5 describes that the implied design and construction alternative embedded in the DBFM contract generally is preferred over other design and construction alternatives. Priority heuristic #6 describes that cost price – based on volumes, acreages and unit prices – and margins are primary indicators determining whether to further detail or include the measure in the bid.

Timing heuristics

In Table 5 an overview of the two observed timing opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project is included. The timing heuristics are used to schedule measures and actions and determine their sequence.

One of the observed timing opportunity-capturing heuristics relates to the payment mechanism (bold-faced in Table 5). The first observed priority heuristic (Timing #1) describes the timing of existing infrastructure replacement. For this purpose, the decision maker searches for two cues: (i) the physical condition of existing infrastructure and (ii) the maintenance history. When the remaining lif-time of the existing infrastructure is assed based on the physical condition and maintenance history, this search is stopped. The existing infrastructure is replaced when the assessment indicates that the remaining life-time is five years or less.

This heuristic relates clearly to the timeliness element of the payment mechanism; however, other elements relate to this heuristic as well. The rationale underlying this heuristic is that it is better to replace the existing infrastructure during realization when numerous exemptions on availability penalties apply.

The other observed timing heuristic (Timing #1) is not directly related to the payment mechanism as it describes the way in which the construction planning is construed based on the program of requirements – not reflecting the availability or performance requirements – and on experience in prior projects.

Table 6 Overview of the key figures and trivia of the A-Lanes A15 project.

Scope	Financials	Trivia
• Development of 37 km highway A15 (6-8 lanes); • Renewal of the Botlek Bridge (four lanes); • Renovation of the Thomassen Tunnel; • Infrastructure maintenance (existing and new-built).	• RWS estimated contract value: 1.5 billion Euros; • Two one-off payments: 250 and 250 million Euros; • Gross availability payment: 10.3 million Euros.	• Largest single-contract road infrastructure development project in the Netherlands; • Main transport route for hazardous materials from the Port of Rotterdam; • Winning contract awarded to four participating contractors.

4.1.2. A-Lanes A15[29]

Project context

A-Lanes won the estimated 1.5 billion Euro DBFM-contract for development of the A15 highway between the Maasvlakte and the Vaanplein junction and the Botlek Bridge. It is the largest project – in scope and estimated costs – for road infrastructure development tendered as a DBFM-contracted in the Netherlands.

The provincial road between the Maasvlakte and the Thomassen Tunnel is developed into a highway, rush hour lanes are added between Rozenburg and Spijkernisse and two lanes are added between Spijkernisse and the Vaanplein junction. Additionally, overpasses are created at the Vaanplein junction and the number of lanes in the Thomassen Tunnel is increased to six lanes, i.e. three in each direction. The contract scope includes refurbishment of the existing Thomassen Tunnel and a maintenance contract for 25 years after construction for the complete infrastructure system (roads, tunnels, bridges and overpasses).

The tender process was announced in 2008, contract was awarded in 2010 and construction started in 2011. In 2015, the construction was completed and the exploitation stage started.

Organization

A-Lanes A15 was created as commercial partnership between four parties: Ballast Nedam, John Laing, Strabag and Strukton. After contract awarding, these parties acquired equity shares in A-Lanes A15 which was from that moment on a limited company. ABN AMRO Bank, Fortis Bank, NIBC Bank, Société Generale, UniCredit and the European Investment Bank (EIB) provided additional funds up to 700 million Euros.

The equity holders acquired the right to execute project activities that related to their experience and knowledge. As a result, winning the tender bid resulted in both revenue from activities and profits from providing equity capital.

Contract

The general structure of the A-Lanes A15 DBFM contract is identical basic agreement discussed in Section 2.1. The payment mechanism includes both exemptions for major construction and

[29] More project information is available on http://www.rijkswaterstaat.nl/wegen/projectenoverzicht/a15-verbreden-maasvlakte-vaanplein (retrieved at November, 14 2015).

maintenance activities 'realization nights' (construction only) and 'maintenance weekends' (exploitation stage: once every five years; realization stage: maximum of 6).

The height of the unavailability penalty relates – in addition to the route affected – to the time slot in which the unavailability occurs. Two time slots are included in the contract: Time Window 1 (max. EUR 200.000 each quarter) and Time Window 2 (max. EUR 100.000 each quarter). During realization and at night (weekend: 22:00-6:00; workday: 23:00-6:00), the contractor is allowed to use Time Window 2. Time Window 1 applies during the realization stage in the day on workdays (5:00-23:00) and weekends (6:00-22:00) and during the full exploitation stage. However, the contractor is allowed to plan specific maintenance nights where Time Window 2 is applicable. The number of nights range from 24-40 each year. These specific provisions stimulate the contractor to create a reliable plan of construction and maintenance activities.

Moreover, in the tender the – and henceforth included in the contract – A-Lanes A15 estimated unavailability at the vehicle loss hour level rather than on the number of lane closures (or maintenance nights). These vehicle loss hours aim to limit traffic congestion and are primarily used in the MEAT-procedure. Nevertheless, exceedance of the estimation is eligible for performance.

General decision making process

Decision making in the early stage of the A-Lanes A15 project was exploratory, hesitant and uncertain. The tender manager had a strong technical background which was reflected in the decision making process. A relative large number of employees were involved in the early stage which had limited experience in earlier DBFM-type of projects. In addition, with Strabag as contractor with German origins, cultural and language barriers were present. The tender management team was small which allowed for short lines of communication.

Characterizing decision making within A-Lanes A15

Decision making within A-Lanes A15 was strongly technical-oriented and focussed on generating revenue while limiting tender costs. Decision makers relied on their technical training and experience – primarily in D&C settings – and followed the risks outlined in the Risk Management Plan. As a result, decision making process followed technical design and development. Tender management decomposed the project along the technical decomposition into major physical works requested by RWS which was then assigned to specific teams responsible for that specific part of the technical decomposition (e.g., a road design team, a tunnel installation design team, a maintenance organization development team). The activity of decomposing the work into physical works is generally referred to as the Work Breakdown Structure (WBS). The technical-orientation was further reflected in the decision separate responsibility of MEAT-eligible tender documents from engineers responsible for development of design documents.

The primary focus of decision making in the early stage of infrastructure development was to create insight in the costs as input for the BAFO. Activities involved creating budgets for each technical component and, to that end, detailing the design. Each technical component was detailed into volumes and acreages in order to determine the cost price. However, the contractual setting is complex. The Route Decision was used as a primary guideline and based on the Guidelines Design Highways while the program of requirements built on the New Design guideline for Highways. Moreover, availability requirements were included in an annex separate from the program of requirements. To deal with the complexity, an information manager was appointed and a single information database installed.

Main decision problems

The primary aim of decision making in the early stage of A-Lanes A15 project was to create a compliant design. To that end, decision problems on construction design, realization and maintenance were

Table 7 Overview of selection opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Increase MEAT-value by reducing the length of the offered recovery periods.**
Selection #2	**Accept the pre-defined optional risk on the condition of existing infrastructure.**
Selection #3	**Accelerate the construction planning.**

discussed. The decision makers put forward a number of decision problems, including the optional pre-defined risk for the condition of existing infrastructure. MEAT-value was to be obtained when the contractor accepts the risk that the infrastructure requires additional maintenance – or even replacement – within the contract period. In addition, the appointment of a single data manager responsible for information provisioning in the contract and the use of a single tender document as work and final product were mentioned as important decisions. In Appendix D.2, we included an overview of observed opportunity-capturing heuristics related to these decisions. In the next section, we discuss the heuristics related to the payment mechanism.

Decision making heuristics related to the payment mechanism

Based on interviews and document studies 13 opportunity-capturing heuristics were observed. In appendix D.2 an overview of these heuristics and their building blocks is provided; here we report only the heuristics. We first describe the heuristics with relation to the payment mechanism and highlight this relationship. Then, we discuss shortly why the remaining heuristics are not related to the payment mechanism.

Selection heuristics

In Table 7 an overview of the three observed selection opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project is included. The selection heuristics are used to determine which measures and alternatives to include in the final offer to RWS.

All three observed selection opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 7). The first observed selection heuristic (Selection #1) describes the way in which decision makers arrive at their offer of reduced length of the recovery period. Interviewee noted that minimization of the recovery period was preferred to obtain additional MEAT-value. To this end, the decision maker searches for the required capabilities of the maintenance organization for execution of required maintenance activities in a shorter recovery period. Moreover, a search for the main concerns of RWS underlying the formal risks outlined in the Risk Management Plan is executed. The search stopped when the organizational capabilities for organizing maintenance were evaluated and insight in RWS' concerns is created and reviewed with RWS. It is decided that the offered recovery period was shortened when the organization is able to execute the required maintenance activities within a shorter recovery period and RWS was willing to make a shorter recovery period MEAT-eligible. When either one of the conditions – i.e., sufficient organizational maintenance capabilities or RWS' willingness to make a shorter recovery period MEAT-eligible – was not met, the decision was made not to shorten the offered recovery period.

This heuristic relates to the payment mechanism with the emphasis on the maintainability and availability. As in the Coen Tunnel Company, decision makers were convinced that it is matter of organizing the maintenance activities. Moreover, the heuristic implies that winning the bid – with a focus on MEAT-value – was considered highly important. One of the decision makers noted that some of the people involved in the further project development – after contract awarding – had second thoughts as shorter recovery periods also had an impact on the reliability of the timely maintenance activities and hence on the reliability of the infrastructure.

The second observed selection heuristic (Selection #2) describes the way in which decision makers concluded that the pre-defined optional risk on the condition of existing infrastructure was accepted. Acceptation of the optional risk on the condition of existing infrastructure resulted in MEAT-value. However, additional information was sought as the risk included the risk of different conditions in reality than the condition reported by RWS. Two search cues were used: (i) the current condition of the existing infrastructure and (ii) the organization's capacities to execute required maintenance activities within 20 days after the contract start date.[30] The search was stopped when the organizational capabilities in organizing maintenance are evaluated and the condition of existing infrastructure is assessed. When the organization was able to organize the required maintenance activities on the existing infrastructure within 20 days after the contract start date, the pre-defined optional risk on the condition of existing infrastructure was accepted.

This heuristic relates to the payment mechanism both through maintainability and reliability of the infrastructure, reliability of the maintenance organization and the availability of the payment mechanism. Potential for non-compliance with performance and availability requirements, repeated failures on requirements and other maintenance, reliability and incentives embedded in the payment mechanism are weighed against the increased opportunity of winning the bid. Ultimately, the decision to accept the pre-defined optional risk on the condition of existing infrastructure showed that the latter was the primary focus of the decision makers.

The third observed selection heuristic (Selection #3) describes the way in which it was decided to accelerate the construction planning. First the organizational capabilities in executing the construction planning at a faster pace than specified in the concept DBFM contract was searched. This search stopped when these organizational capabilities were evaluated. It was decided that when the organization is able to execute the construction planning at a faster pace, the offered construction planning was accelerated. When the organization was unable to execute the construction planning at a faster pace, it was decided not to accelerate the construction planning.

Clearly, this heuristic relates to the timing element of the payment mechanism. Accelerated construction results in earlier conclusion of the realization stage of the project and hence earlier payment of the one-off payments. Hence, the heuristic reflects the emphasis in the early stage of project development on one-off payments rather than the quarterly net availability payments. However, exceedance of the realization stage also results in availability penalties from the contractual availability date. As a result, this heuristic relates to the timeliness element of the payment mechanism and focuses on compliance with the availability requirements on a certain point in time.

Procedural heuristics

In Table 8 an overview of the six observed procedural opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project is included. The procedural heuristics are used to determine action plans for project development and to detailed measures.

One of the observed procedural opportunity-capturing heuristics relates to the payment mechanism (bold-faced in Table 8). The first observed procedural heuristic (Procedural #1 describes the way in which construction planners are supported in detailing the construction planning. The cue searched for was a way to increase the reliability of the construction planning. The search is stopped when

[30] An exemption on availability penalties for maintenance activities on existing infrastructure is allowed in the payment mechanism during the first 20 days after the contract start date.

Table 8 Overview of procedural opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Procedural #1	**Provide payment-mechanism support to construction planners in detailing the construction planning.**
Procedural #2	The WBS is leading in determining the project activities.
Procedural #3	Separate development of tender documents from engineers responsible for development of design documents.
Procedural #4	Use a single database as the sole source of project information.
Procedural #5	Include managers with life-cycle experience in the project.
Procedural #6	Work in one document while developing MEAT-eligible measures.

current and required knowledge of construction planners on the payment mechanism is assessed. It was decided to support the construction planners in detailing the construction planning by personnel with payment mechanism knowledge when their knowledge on the payment mechanism did not meet the required knowledge.

Clearly, this heuristic relates to the payment mechanism. Providing assistance in construction planning reflects the emphasis on timing and availability ("on time available"). The support with payment mechanism knowledge was needed since the construction planners were largely unaware of the impact of construction activities at certain time slots on unavailability impact. Moreover, as MEAT-value was to be obtained by limiting the offered vehicle loss hours during construction,[31] integration of the payment mechanism and the underlying transport model in the construction planning was considered highly important. The support was also provided after contract awarding in the further detailing process. This relates to the performance penalties in the payment mechanism which penalize exceedance of vehicle loss hours during realization.

The remaining observed procedural heuristics (Procedural #2, #3, #4, #5 and #6) are not directly related to the payment mechanism. Procedural heuristic #2 describes which activities to execute and procedural heuristics #4 and #6 emphasized on centralizing information during tender activities. Procedural heuristic #3 and #5 describe which type of employee to include in the project and how to divide activities amongst personnel.

Priority heuristics

In Table 9 an overview of the two observed priority opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project is included. The priority heuristics are used to assign priorities to measures and actions. These priorities are used to decide which actions are detailed first and which measures are more likely to be included in the bid.

One of the observed priority opportunity-capturing heuristics relates to the payment mechanism (bold-faced in Table 9). The first observed priority heuristic (Priority #1) describes the way in which measures are prioritized based on an the importance of project objectives is determined. The decision makers first searches for RWS objectives and the objectives of the project organization and stops when the alignment between the measure at hand and RWS' objectives and the alignment with objectives of the project organization is evaluated. When the measure aligns with RWS' objectives, it is assigned

31 The Traffic Congestion Restriction Plan is one of the documents with which tendering contractors can gain MEAT-value.

Table 9 Overview of priority opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Focus on measures that align with RWS' project objectives rather than with the objectives of the tendering organization.**
Priority #2	Focus on measures with low cost prices and high levels of risk mitigation.

Table 10 Overview of timing opportunity-capturing heuristics used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Timing #1	**Determine the construction planning based on the WBS, contractual exemptions on availability penalties and time-slots.**
Timing #2	Validate interpretation of contract requirements after contract awarding.

a high priority of in detailing and inclusion in the final bid. Measures that align with the objectives of the project organization receive a low priority in detailing and inclusion in the final bid.

This heuristic relates strongly to the payment mechanism since the RWS' objectives are eminently explicated in the payment mechanism. Moreover as one decision maker noted "RWS values availability more than maintainability," the heuristic was used to prioritize elements within the payment mechanism.

The remaining observed priority heuristic (Priority #2) is not directly related to the payment mechanism as it describes that the cost price – not including availability levels – and the level of (physical) risk mitigation are important in the prioritization of measures to detail and include in the final bid.

Timing heuristics

In Table 10 an overview of the two observed timing opportunity-capturing heuristics used by decision makers in the Coen Tunnel Company project is included. The timing heuristics are used to schedule measures and actions and determine their sequence.

One of the observed timing opportunity-capturing heuristics relates to the payment mechanism (bold-faced in Table 10). The first observed priority heuristic (Timing #1) describes the of construction activities. The decision maker first searches for the timing and sequence of construction activities and stops searching when the WBS is constructed, contractual exemptions for availability penalties and time-slots are determined and the time-slots are determined. It is decided that construction activity planning is based on the WBS and contractual exemptions on availability penalties when the resulting period – allowed by these exemptions – is sufficient for the execution of construction activities. When the period is not sufficient, it is decided that the construction activity planning is based on the WBS and minimized unavailability penalties in the less penalized time slots.

This heuristic relates to the timeliness of the payment mechanism. The primary focus on contractual exemptions for availability penalties and secondary focus on time-slots indicates that the decision maker was aware of the time-dependent value of availability explicated in the payment mechanism. Moreover, this heuristic refers explicitly to the different Time Windows available for execution of construction activities.

The other observed timing heuristic (Timing #2) is not directly related to the payment mechanism as it describes the way in which the timing of contract validation is determined.

Table 11 Overview of the key figures and trivia of the IXAS Gaasperdammerweg project.

Scope	Financials	Trivia
• Development of the Gaasper bridge 10 km highway A5 (ten lanes); • Development of 3km land tunnel A9 (nine lanes); • Development of a city park on top of the tunnel; • Infrastructure maintenance (existing and new-built).	• RWS estimated contract value: 850 million Euros; • Two one-off payments: 140 and 10 million Euros; • Gross availability payment: 10.3 million Euros.	• Largest city park in Amsterdam; • Part of the SAAL projects aimed to increase availability on the Schiphol-Amsterdam-Almere route.

4.1.3. IXAS Gaasperdammerweg[32]

Project context[33]

The IXAS Zuid-Oost won the estimated 850 million euro DBFM-contract for development of the A9 Gaasperdammerweg between the Holendrecht junction and the Gaasper bridge, including the Holendrecht junction and the Gaasper bridge itself. This highway section was known as the Gaasperdammerweg prior to development of the current four lane highway and we refer to it as the A9 Gaasperdammerweg. The A9 Gaasperdammerweg is to be tunnelled between the junction and the bridge and covered with a city park. With the inclusion of a city park on top of the tunnel, RWS aims to improve the air quality and reduce noise pollution in the heavily populated area. The contract includes the a maintenance for 20 years after construction is completed.

The tender process was announced in 2012, the contract was awarded in 2014 and first construction activities started in 2015. In 2020, the major construction activities are expected to be completed after which the city park is installed. The project is the third part of the SAAL projects which aim to increase the accessibility and availability on the Schiphol-Amsterdam-Almere route.

The A9 is widened to eight lanes with a reversible lane. In addition, the A2 is widened with two lines to align on the reconstructed Holendrecht junction. The city park is placed on the roof of the tunnel and connects the neighbourhoods currently separated by the A9 Gaasperdammerweg.

Organization

The IXAS Zuid-Oost BV was created as commercial partnership between three contractors – Heijmans, Fluor and Ballast Nedam – and an infrastructure investor – 3i. After contract awarding, these parties acquired equity shares in the IXAS Zuid-Oost BV which was from that moment on a limited company. DZ BANK, ING, KBC, SMBC and Société Générale and the European Investment Bank (EIB) provided additional funds up to 960 million Euros. The project organization is currently known as IXAS Gaasperdammerweg.

The equity holders are also involved in the construction and maintenance activities. As a result, winning the tender bid resulted in both revenue from activities and profits from providing equity capital.

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[32] More project information is available on http://www.rijkswaterstaat.nl/wegen/projectenoverzicht/a9-holendrecht-diemen/ retrieved at November, 14 2015).

[33] On the Coen Tunnel Company website http://tweedecoentunnel.nl/ (retrieved at November, 13 2015), an excellent – Dutch – book on the project is provided.

However, participating companies agreed on the 'best-for-project' principal and explicitly consider contracting other companies when those can improve the quality of the project.

Contract

The general structure of the IXAS Gaasperdammerweg contract is identical to the basic agreement discussed in Section 2.1. However, the way in which availability penalties are determined is much more sophisticated. In the tender – and henceforth included in the contract – IXAS Gaasperdammerweg estimated unavailability at the vehicle loss hour level rather than on the number of lane closures (or maintenance nights). Moreover, different types of vehicle loss hours were distinguished: preventive and corrective. The preventive vehicle loss hours result from planned activities while he corrective vehicle loss hours result from unplanned activities, e.g. failures on availability requirements. Preventive vehicle loss hours result in lower fines (EUR 25/VHL) than preventive vehicle loss hours (EUR 25/VHL). As a result of the differentiation in types of vehicle loss hours, the IXAS Gaasperdammerweg payment mechanism put more emphasis on reliability of planning. Nearly[34] all unavailability is penalized for which contractors were required to include budget in their BAFO. Here, the MEAT procedure and payment mechanism closely align.

The height of the unavailability penalty relates – in addition to the route affected – to the time slot in which the unavailability occurs. For each day of the week and each time of the day a time slot is included in the contract (i.e. 168 time slots). However since the availability penalty is not primarily dependent on the lane section,[35] these slots are not assigned to monetary penalties but used to determine the multiplier for the vehicle loss hours.

General decision making process

Decision making in the early stage of the IXAS Gaasperdammerweg project was primarily directed by two tender managers who focussed on two specific fields of interest. One tender manager focussed on the tender organization (e.g., bid management), project finance (e.g., agreements with financiers and parent companies) and contract management while the other focussed on the technical aspects of the bid (e.g., design, construction planning and maintenance). Collaboration in an earlier tender process – SAA A1/A6; bid lost – was decisive in the composition of the early tender team and the composition of the consortium partners.

Characterizing decision making within IXAS Gaasperdammerweg

Decision making within IXAS Gaasperdammerweg was characterized by a technical-orientation, multi-disciplinarity, strongly risk-centred with an integral and traceable project management approach. During the full early stage of project development, decision makers relied strongly on information management practices which allowed them to identify main risks and their interrelations.

Naturally the project was driven by financial incentives to win the contract (revenue) with an attractive margin (profit). However, the decision makers took an risk-based approach. At the start of the project development, the decision makers examined the main risks in the project – "on which elements can you drain [financially]" as one decision maker noted – which related to securing financing from banks and to two types of unavailability penalties: not available and too late available. Risks defined in the Risk Management Plan where initially leading and the payment mechanism was "just one of the incentives."[36]

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34 Specific exemptions for availability penalties exist, e.g. for construction activities near the train and metro rails.

35 The unavailability penalty in the IXAS Gaapserdammerweg payment mechanism relies on the standardized vehicle loss hours for an affected route. Technically, the affected route section plays a role here the payment mechanism does not assign the penalty to the affected section but the affected route.

36 In addition, the payment mechanism was also considered 'too detailed and complex'.

The risk-based approach focused on traceability of (design) decisions and actions since "no tunnel has not been opened by failure to meet technical requirements" one decision maker noted. In order to "prevent people from thinking that they know what is right while they don't write nothing down," demonstration of compliance with the requirements received high priority. Moreover, there was a strong believe that "a tender is not won on a single golden element but on every element a little." To ensure traceability of decisions and actions and demonstrability of compliance with requirements, it was decided to strongly focus on information management. To that end, main (technical) decisions were identified for which a trade-off matrix was developed. In the trade-off matrix, different alternatives were listed and cost-information, compliance with requirements, risk-information and feasibility in time were added.

The trade-off matrices allowed decision makers to limit the influence of subjective (experience) judgement calls and gut feelings. However, experience and judgement calls were still valued and used to validate the result in the trade-off matrices. To this end, special attention was given to team composition as the IXAS Gaasperdammerweg project development was characterized by multiple decision makers as 'team work.' 'Teaming' was important for the multi-disciplinary approach. Hence, team were regularly evaluated on their composition of 'generalists', 'specialists' and 'criticasters'.

Compliance with requirements played an important role in the IXAS Gaasperdammerweg project not to demonstrate compliance but also as a frame of reference. The contractual requirements implicitly explicate a preferred – design and construction – alternative. However, as multiple decision makers noted "the contract is just a proposal," at least the project-specific technical requirements.[37] Based on the information in trade-off matrices, experience in prior projects and 'common sense', preferred alternatives were developed which not necessarily aligned with the formal requirements. The Dialogue with RWS was used to assess the feasibility of a change in requirements in order to align these with the measure.

Main decision problems

The primary aim of decision making in the early stage of IXAS Gaasperdammerweg project was to increase the demonstrability of compliance while offering an attractive, reliable price. To that end, decision problems on construction design, realization and maintenance were discussed. There was a strong belief that competitors were able to offer within the contractual bounds, technically identical solutions. For that reason, it was decided to rely heavily on know-how within the project organization. This allowed them to start the tender prior to the formal announcement of the tender process since no additional (external) information was required. This reliance on know-how within the tender organization is considered an important decision. In addition, a number of technical implementation alternatives were discussed. The chosen alternative is considered to have contributed to winning the tender. In Appendix D.3, we included an overview of observed opportunity-capturing heuristics related to these decisions. In the next section, we discuss the heuristics related to the payment mechanism.

Decision making heuristics related to the payment mechanism

Based on interviews and document studies 21 opportunity-capturing heuristics were observed. In appendix D.3 an overview of these heuristics and their building blocks is provided; here we report only the heuristics. We first describe the heuristics with relation to the payment mechanism and highlight this relationship. Then, we discuss shortly why the remaining heuristics are not related to the payment mechanism.

[37] Contractual requirements are primarily recorded in the program of requirements, availability requirements, performance requirements and in the management and output specifications.

Table 12 Overview of selection opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Select measures based on low direct and indirect costs, feasibility of the associated construction planning within the contractual deadlines and the likelihood of changing requirements to align with the measure.**
Selection #2	**Select measures with an acceptable level of residual risk on unavailability.**
Selection #3	Accept measures after contract awarding only when they align with the best and final offer.

Selection heuristics

In Table 12 an overview of the three observed selection opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project is included. The selection heuristics are used to determine which measures and alternatives to include in the final offer to RWS.

Two observed selection opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 12). The first observed selection heuristic (Selection #1) describes the way in which measures are selected based on the direct and indirect costs, feasibility of the associated construction planning within the contractual deadlines (e.g., the availability date) and the likelihood of changing requirements to the align with the measure. The decision makers searches for four cues: (i) direct cost (e.g., costs of construction and maintenance), (ii) indirect costs (e.g., potential availability and performance penalties), (iii) feasibility of the related planning and (iv) the likelihood that RWS is willing to change certain requirements in order to create alignment of with the measure at hand. As multiple decision makers noted, “the contract is a just proposal” and hence measures are not necessarily searched within the contract bounds. The search is stopped when the direct and indirect costs of the measure are determined and evaluated against the estimate of the budget, the feasibility of the construction planning is assessed based on the organizational capabilities in executing the required activities and RWS has indicated its willingness to change related non-compliant requirements. The measure is selected when the direct and indirect costs are equal to or lower than the available budget, the assessment of the construction planning and the organizational capabilities indicates that it is challenging but feasible and RWS is willing to change the requirements to align with the measure.

The integrated focus on all costs, feasibility of planning and contract requirements shows a clear relationship with the payment mechanism. Decision makers differ in their perspective on the most important decision criteria. As one decision maker noted “alignment with contract requirements, feasibility of the planning and the costs are equally important”. However, the heuristic indicates a primary focus on the realization stage of infrastructure development since timely delivery of the infrastructure is highly stimulated in tender win criteria. For that reason, the decision maker focuses with this heuristic on creating a low best and final offering to win the bid and execute the construction activities within contract dates for realization. This emphasis on timely construction is supported by priority heuristic #2 which indicates that there is a ranking in the criteria (discussed later).

The second observed selection heuristic (Selection #2) describes the way in which measures are selected based on the level of residual risk on unavailability after implementation of the risk measure. First, the risk appetite is searched for and when the risk appetite is established the search is stopped. The measure is selected when the residual risk on unavailability after implementation of the measure is smaller than the risk appetite and it is decided to reject the measure when the residual risk on unavailability after implementation of the measure is larger than the risk appetite.

This heuristic relates primarily to the payment mechanism through the reliability element and secondary through the availability element. Unavailability on during certain construction and maintenance activities is unavoidable; however, the heuristic indicates that the decision maker attempts to make a reliable estimate of the impact on unavailability and weighs the residual risk in selecting measures.

The remaining observed selection heuristic (Selection #3) is not directly related to the payment mechanism as it focuses on guarding the project scope after winning the bid. This is important as one decision maker noted, since in DBFM contracts the contractor has agreed a on performance-target with financers rather than a scope or revenue target.

Procedural heuristics

In Table 13 an overview of the ten observed procedural opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project is included. The procedural heuristics are used to determine action plans for project development and to detailed measures.

Six observed procedural opportunity-capturing heuristics relate to the payment mechanism (bold-faced in Table 13). The first observed procedural heuristic (Procedural #1) describes how the decision maker ensures demonstrability of compliance with requirements. As one decision maker noted “no tunnel has not been opened by failure to meet technical requirements.” Demonstrability of compliance with the requirements, in contrast, have caused serious delays.[38] First, the primary risk drivers for the project and the organizational capabilities to meet the requirements for successful project completion are searched. The search is stopped when the organizational capabilities are reflected on the project requirements to meet RWS’ requirements for successful project completion. It is decided that the organizational structure is adapted with a team solely responsible for continuously demonstration of compliance with requirements and information management and quality assessment practices (e.g., RAMS analysis and Systems Engineering) are implemented when the assessment of the alignment between the organizational capabilities to successfully complete the project in line with RWS' requirements indicates the risk of insufficient demonstrability.

The heuristics reflects the importance of not only complying with (availability) requirements but also being able to demonstrate compliance. Compliance is important for timely payment of the one-of payments, avoiding availability penalties but also for avoiding performance penalties (e.g., resulting from lack of process control or complying with performance requirements). Hence, this heuristic relates to the core of the payment mechanism since payments are only approved after demonstration of compliance. The latter is an explicit part of the performance penalty regimes related to requirements for performance measurement system.

The second observed procedural heuristic (Procedural #2) describes how the risk of unavailability penalties is estimated. The primary risk drivers for unavailability is the cue searched for in this heuristic and this search is stopped when linkages between the WBS and availability and performance penalties are established. The primary risk drivers considered in this heuristic are hence the risk on non-compliance with the availability and performance requirements linked to the technical decomposition. It is decided that the unavailability and performance penalties are estimated based on the WBS-linked failure modes when the associated requirements are related to the WBS. When the requirements are not related to the WBS, a residual risk on unavailability and performance penalties (e.g., a general risk provision) is estimated.

[38] Examples of delayed tunnel openings in the Netherlands are the North-South line in Amsterdam, the streetcar tunnel in The Hague and the Leidsche Rijntunnel in Utrecht.

Table 13 Overview of procedural opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Procedural #1	**Enable continuously demonstration of compliance with requirements to mitigate the top risk of unavailability after completing construction activities.**
Procedural #2	**Estimate the risk of unavailability penalties based on failure modes linked to availability and performance requirements.**
Procedural #3	**Increase objectivity and transparency of the decision making by clustering information related to direct and indirect costs, its timeliness and compliance with requirements in one single template.**
Procedural #4	**Appoint a single employee responsible for estimating the unavailability penalties resulting from traffic congestion mitigation measures.**
Procedural #5	**Use the payment mechanism only for estimation of unavailability penalties resulting from traffic congestion mitigation measures.**
Procedural #6	**Use the dialogue with RWS not only as a source of information or to validate the feasibility of measures but also to create opportunities to make measures compliant with requirements and to make requirements compliant with the measures.**
Procedural #7	Put emphasis on continuity of the team while providing with new perspectives.
Procedural #8	Obtain information on existing infrastructure from parent companies.
Procedural #9	Involve specialists with experience in prior projects ad hoc when additional information is needed.
Procedural #10	Generate new perspectives to increase the quality and reliability of measures and the final offer.

The heuristic clearly relates to the payment mechanism by means of availability and performance requirements. Moreover, the central role of risk in this heuristic and the close linkage with the payment mechanism shows the relation with the reliability element of the payment mechanism. Similarly as selection heuristic #2, the heuristic is used to assess residual risks of the non-compliance. However, here the scope is limited since the focus is on infrastructural elements rather than all potential risks in the project.

The third observed procedural heuristic (Procedural #3) describes how information relevant to main decisions is collected and documented. The search cue is a decision-aiding approach that limits reliance on experience judgement and gut feeling. The search is stopped when the decision making process is assessed on the reliance on judgement and gut feeling and insight is created in the number of information sources. When the assessment indicates that the decision making process is based on expert judgement and gut feeling or relevant decision information is scattered over several people and sources, it is decided to cluster decision information related to direct and indirect costs, its timeliness and compliance with requirements in a single template. Otherwise, the information is not centralized.

This heuristic describes the main process in which decisions in the IXAS Gaasperdammerweg project has taken place. In order to reduce expert judgement and – in conjunction with the emphasis of procedural heuristic #1 on demonstrability – to increase traceability of decisions, relevant information is centralized when these normally are stored in disparate locations. The main decision information highlighted in this heuristic includes the risk of non-compliance with requirements as an important decision criteria, indicating the relationship with the availability element of the payment mechanism.

The fourth observed procedural heuristic (Procedural #4) describes how the responsibility for estimating the unavailability penalties is assigned to project employees. The search cue is an approach to evaluate traffic congestion mitigation measures on their impact on availability penalties. The search was stopped when current and required knowledge of construction planners on the payment mechanism is assessed. When the knowledge of construction planners on the payment mechanism is insufficient, it was decided to appoint a single employee responsible for estimating the unavailability penalties resulting from traffic congestion mitigation measures. When the assessment indicates that construction planners are sufficiently knowledgeable, the construction planners are made responsible for evaluation of traffic congestion mitigation measures on the impact on availability penalties.

The heuristic relates to the way in which measures are reflected on the payment mechanism. It indicates that the availability incentive is integrated in the construction planning activities. The decision maker noted that “one person is making availability calculations all day long” which was to ensure minimization of availability penalties and making maximum use of the exemptions available during construction activities. It was decided that centralizing the analysis of the impact of availability on construction planning was also more efficient since the mechanism was considered a complex mechanism to work with.

The fifth observed procedural heuristic (Procedural #5) describes which measures are evaluated using the payment mechanism. The heuristic starts with a search for types of measures to be evaluated against the payment mechanism. The search is stopped when the main drivers for unavailability penalties are established. It is decided to evaluate a measure against the payment mechanism only when the measure is a traffic congestion mitigation measure.

Clearly, the heuristic relates to the payment mechanism as well as to the prior heuristic (Procedural #4). However, the focus of this heuristic – and Procedural #4 for that matter – is on MEAT-eligible traffic congestion mitigation measures during the realization. Moreover, the traffic congestion analysis are used to estimate the required vehicle loss hours. Exceedance of this estimation is eligible for performance penalties. Hence, the heuristic emphasizes on short-run measures which are MEAT-eligible and reliability of the vehicle loss hour budget. This shows that the heuristic is influenced by MEAT-incentives and the availability and reliability incentives in the payment mechanism.

The sixth observed procedural heuristic (Procedural #6) describes how the Dialogue with RWS is used for aligning the contractual requirements with the measure preferred by the payment mechanism. The decision maker searches for a way to align the preferred measure with the contract requirements and stopped searching when the preferred measure was evaluated on potential conflicts with contract requirements. When the preferred measure conflicts with one or more requirements, it was decided to use the Dialogue with RWS to create opportunities to make measures compliant with requirements and to make requirements compliant with the measures. When the preferred measure did not conflict with the requirements, it was decided that the Dialogue was used as a source of additional information and to validate the feasibility of measures.

The relation of this heuristic to the payment mechanism is concentrated on the compliance with requirements. However, the decision maker noted that the (concept) contract was considered a ‘proposal’ and in the discussion with RWS deviations appeared possible. In order to prevent unavailability penalties, this heuristic emphasizes a two-way alignment of requirement and measure.

The remaining procedural heuristics (Procedural #7 and #8) are not directly related to the payment mechanism. Procedural heuristic #7, #8 and #9 describe how to include new perspectives and information while procedural heuristic #10 describes how to create a qualitative and reliable offer.

Priority heuristics

In Table 14 an overview of the two observed priority opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project is included. The priority heuristics are used to assign

Table 14 Overview of priority opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Focus on measures that primarily align with availability requirements and secondary with performance requirements.**
Priority #2	**Focus on direct costs, timely and reliable execution of construction activities and the risk that RWS is unwilling to change conflicting requirements rather than indirect costs stemming from the payment mechanism.**
Priority #3	Focus on top level risks in determining the project activities.
Priority #4	Assess measures against the preferred alternative implied in the program of requirements.
Priority #5	Focus on the concerns of RWS underlying the formal risks outlined in the Risk Management Plan.

priorities to measures and actions. These priorities are used to decide which actions are detailed first and which measures are more likely to be included in the bid.

Two of the observed priority opportunity-capturing heuristics relates to the payment mechanism (bold-faced in Table 14). The first observed priority heuristic (Priority #1) describes how a decision maker weighs availability and performance requirements. First, the related availability and performance requirements are searched for. This search is stopped when the measure is reflected on the alignment with the availability and performance requirements. It is decided that when the measure aligns with the availability requirements it receives a high priority in detailing and inclusion in the final bid. Measures that align with performance requirements receive a lower priority than those that align with availability requirements.

The heuristic is related to the payment mechanism as it indicates that performance requirements are perceived less important than performance requirements. The later are primarily embedded in the performance penalties for lack of process control, inadequate maintenance actions and safety. Hence, the heuristics emphasizes on the incentive from availability penalties rather than performance penalties.

The second observed priority opportunity-capturing heuristic (Priority #2) describes direct costs, timeliness and reliability of construction activities, the risk that RWS is unwilling to change conflicting requirements and indirect costs stemming from the payment mechanism are weighted. Four cues are searched for: (i) direct cost (e.g., costs of construction and maintenance), (ii) indirect costs (e.g., potential availability and performance penalties), (iii) feasibility of the related planning and (iv) the likelihood that RWS is willing to change certain requirements in order to create alignment of with the measure at hand. When the direct costs of the measure are determined and evaluated against the available budget, the feasibility of the construction planning and RWS' willingness to change related non-compliant requirements is assessed, the search for cues is stopped. Everything equal, measures that result in lower indirect costs from unavailability penalties receive a low priority in detailing and inclusion in the final bid when they also result in higher direct costs, the assessment of the construction planning indicates that it is (likely) infeasible or RWS is unwillingness to change related non-compliant requirements

Clearly, this heuristic relates to the payment mechanism as it indicates that the decision maker prioritizes direct costs, reliable and timely execution of the construction planning and compliance with requirements over the potential for availability penalty. Nevertheless, the other elements – e.g., reliability of the planning of construction activities and compliance with requirements – are also related to payment mechanism; however, these emphasis on different points in time.

Table 15 *Overview of timing opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism*

Timing #1	Start the tender process with a small team of multi-disciplinarians and include mono-disciplinarians when the main project principles are established and approved by the tender board.
Timing #2	Start the project development before formal announcement of the tender process.
Timing #3	Start detailing the final offer when the condition of existing infrastructure, Route Decision requirements and permits are reviewed and top requirements are determined.

The other observed priority opportunity capturing heuristics (Priority #3-#5) are not directly related to the payment mechanism as these heuristics describe the focus on risks and the preferred alternative indicated by RWS.

Timing heuristics
In Table 15 an overview of the two observed timing opportunity-capturing heuristics used by decision makers in the IXAS Gaasperdammerweg project is included. The timing heuristics are used to schedule measures and actions and determine their sequence.

None of the observed timing opportunity-capturing heuristics relates to the payment mechanism.

4.2. CROSS-PROJECT ANALYSIS

The observations in the within-project descriptions allow us analyse decision maker's heuristics in different project settings. In line with the focal points, we discuss in this section the different decision making settings (i.e. project contexts and general decision making practices) and the reflect on the observed decision making heuristics related to the payment mechanism.

4.2.1. Context of the projects

In the within-project analysis, project contexts are described (e.g., project outline, key facts and figures), organization specifics and contractual deviations from the basic agreement outlined in Section 2.1. Here we discuss differences and similarities on these variables across projects.

Project overview
The projects are similar in that they involve realization and maintenance of Dutch highways and all projects include a different civil works (e.g. tunnels, bridges and overpasses) in the infrastructural system. Regarding the tunnels, these have different project-specific characteristics. The Second Coen Tunnel allows passage across the North Sea Channel while the Gaasperdammer Tunnel is a land tunnel. Moreover, the Thomassen Tunnel and Botlek Tunnel in the A-Lanes A15 project were pre-existing tunnels for which primarily maintenance activities are required.

All projects include responsibilities for long-term maintenance activities. The Coen Tunnel Company and A-Lanes A15 accepted the risk for the existing condition of the infrastructure and were hence from the contract start date on eligible for availability penalties resulting from poor road conditions. IXAS Gaapserdammerweg accepted limited responsibility and obtained waivers for several existing sections of the road infrastructure.

Organizations
When we consider the financial and organizational similarities and differences, we found great similarities in the number of financing banks and gross availability payment. The one-off payments vary for each project which results from the project-specific differences in the realization stage (e.g.,

Table 16 General overview of the different project characteristics | [A] Project includes refurbishment of an existing tunnel.

	Coen Tunnel Company	**A-Lanes A15**	**IXAS Gaasperdammerweg**
Main road section	10 km A5: 4 lanes Tunnels: 9 lanes	37 km A15: 6 lanes	10 km A9: 10 lanes Tunnel: 9 lanes
Tunnel construction	Yes[A]	No[A]	Yes
Length realization stage	8 years	5 years	6 years (estimated)
Maintenance contract (existing and new-built)	24 years	25 years	20 years
Estimated project value	1.2 billion Euros	1.5 billion	850 million Euros
One-off payment(s)	100 million Euros	250 and 250 million Euros	140 and 10 million Euros
Gross Availability Payment	9.7 million Euros	10.3 million Euros	10.3 million Euros
Consortium	7 contractors	4 contractors	3 contractors and 1 investor
Financiers	6 banks and consortium partners	6 banks and consortium partners	6 banks and consortium partners

the A-Lanes A15 project involves development of a larger road section and includes the realization of a bridge). Other differences include the composition of the consortia. As one of the first DBFM-contracted projects, the Coen Tunnel Company included multiple contractors for the different disciplines. A-Lanes A15 and IXAS Zuid-Oost BV consist of a limited – respectively four and three – number of main contractors which were supported by specialistic subcontractors. Moreover, IXAS Zuid-Oost BV included an infrastructure investor. As a result of the large reliance on subcontractors, A-Lanes A15 – and to a lesser extent IXAS Zuid-Oost – had more complex organizational structure with multiple interfaces to other organizations.

Coen Tunnel Company and A-Lanes A15 started the tender process with a relatively large team (magnitude: 50 employees) whereas IXAS Gaasperdammerweg started the tender process with a smaller team (i.e., 15 employees). Moreover, the IXAS Gaasperdammerweg organization was assembled early on prior to the formal announcement of the tender process.

Contracts

The different contracts followed in general the structure of the basic agreement outlined in Section 2.1. However, the payment mechanism differs across the projects on three main elements: penalization of exceedance of the estimated vehicle loss hours during construction, exemptions for availability penalties and the way in which value is linked to availability.

The first difference relates to the estimated vehicle loss hours during construction. In the tender process organizations submitted an estimation of the vehicle loss hours during the construction stage. These estimations were recorded in the DBFM contract and penalized. However, exceedances of the estimated vehicle loss hours for Coen Tunnel Company project are only penalized with availability penalties whereas A-Lanes A15 and IXAS Gaasperdammerweg were penalized with both availability and performance penalties. As a result, the contracts in the A-Lanes A15 and IXAS Gaasperdammerweg projects put stronger emphasis on reliability of construction planning than the contract in the Coen Tunnel Company project.

The second difference relates to the exemptions on availability penalties recorded in the contract. The Coen Tunnel Company has the access to 'maintenance nights' throughout the contract duration in which unavailability is not penalized. For the realization stage, the A-Lanes A15 project provides similar arrangements while in the exploitation stage the contractor may request certain nights in which unavailability is less severely penalized. The IXAS Gaasperdammerweg contract has a different approach. Here the contractor is required to make a budget for construction and maintenance unavailability and include this in the offer. A distinction is made between preventive and corrective unavailability. The preventive – or planned – unavailability is less severely penalized and is available from the 'vehicle loss hour'-budget. As a result, the IXAS Gaasperdammerweg contract has limited exemptions for unavailability which puts an emphasis on the availability incentive.

Closely related to these vehicle loss hour budgets is the way in which value is assigned to unavailability. In the Coen Tunnel Company and A-Lanes A15 contract, unavailability was valued based on the route section affected and timing of unavailability. The IXAS Gaapserdammerweg contract in contrast links value to unavailability on the number of vehicle loss hours. The calculation of the vehicle loss hours is also based on the timing and route section affected, however at a larger detail. Moreover, the linkage to vehicle loss hours stimulates the contractor to value every hour lost rather than each section affected. As a result, the IXAS Gaasperdammerweg contract puts here a stronger emphasis on the availability incentive.

In conclusion, it can be stated that the projects are similar in complex road infrastructure development environment and that the organizational structures differ in that the A-Lanes A15 and IXAS Gaasperdammerweg have more interfaces to other organizations. Moreover the contract settings are in general similar but the A-Lanes A15 and IXAS Gaasperdammerweg contracts emphasize more on reliability of construction planning. Moreover, the IXAS Gaasperdammerweg contract puts a stronger emphasis on the availability incentive.

4.2.2. General decision making environment

A reflection on the observed decision making processes demonstrates a number of characteristics found across projects, various project-specific characteristics and developments over the projects that reflect the decision making environment, i.e. the ecological rationality of decision making in the early stage of Dutch DBFM-contracted road infrastructure development. We discuss this ecological rationality in this section.

Characteristics across projects

The decision making process in the early stage of all projects was primarily led by the technically-oriented tender managers which relied on personnel with experience in prior projects. The technical orientation and reliance on experience was important for all projects. The tender and project managers all have a strong technical background and the activity breakdown in order to win the tender and develop the project was also guided by the technical orientation, i.e. the work breakdown structure (WBS) was a primary guideline in determining which activities when to execute. Moreover, decision makers relied on their – and others' – experience in prior projects.

The aim of the early stage was similar in al projects: winning the bid and subsequently successful completion of the project realization. To that end, the decision making process emphasized on creating the winning bid and a reliable price. RWS' objectives were important guidelines for creating the winning bid. Here the MEAT-procedure provided with important incentives to minimize the BAFO and increase the possibilities in winning the bid. Especially the predefined risks in the Risk Management Plan played an important role as the decision makers focused on these risks to obtain the MEAT-value. These risks were primarily approached with the technical orientation of the tender team (i.e. WBS-based). Moreover, the risks embedded in existing infrastructure received attention by decision makers in all projects.

After winning the bid, the decision making process was primarily focused on the construction activities. Realization of the project received priority over the exploitation stage and was more important than other activities stemming from the life-cycle approach (e.g., organizing maintenance and monitoring continuous compliance).

Project specific characteristics

Naturally – as the first RWS-originated DBFM-contracted road infrastructure development project – the Coen Tunnel Company was characterized by newness and inexperience with the maintenance component recorded in the contract. As a result, decision makers relied heavily on their experience in earlier D&C projects. To a lesser extent, this D&C-reliance was also observed in the A-Lanes A15 decision making process. Moreover, the decision making process in the reliance on gut feeling was stronger in the Coen Tunnel Company while in the A-Lanes A15 project implementation of information management practices started. The focus on information management was an important element of the IXAS Gaapserdammerweg decision making process. Two other important elements in the IXAS Gaapserdammerweg project are the focus on project-risks rather than technical risks and the multidisciplinary team in the early stage of the project. These elements had an high impact on the decision making process in the IXAS Gaasperdammerweg project; however, these element also demonstrate progress across the observed DBFM-contracted projects.

Development over projects

The observed decision making processes relate to different points in time. The tender for the Coen Tunnel Company project was announced in 2005 followed by the A-Lanes A15 project in 2008 and the IXAS Gaasperdammerweg in 2012. Since the Coen Tunnel Company project, different studies and reviews provided with recommendations for next projects. Moreover, the decision making processes rely strongly on experience which is transferred from one project to the following. As a result, we have observed four developments in the decision making process since the Coen Tunnel Company project.

The first development relates to the emphasis in technical development of the project from a focus on detailing to information management and demonstrability. This development is best described as the emergence of 'integrated thinking.' This focus aims to approach the project development as a whole rather than along the technical disciplines. Therefore additional emphasis is laid in the IXAS Gaapserdammerweg on demonstrability of requirements and information practices[39] whereas in the Coen Tunnel Company project, the tender manager had an important role in assigning tasks to various technical disciplines for detailing while safe-guarding the integrity and completeness of the bid and project development. This is important for the integration with the payment mechanism as the incentives in the payment mechanism are not necessarily confined within the technical disciplines: availability requirements are valid for the construction and maintenance organizations as well as for the tunnel installations as the road surface.

The second development relates to the project risk approach. Decision making in all projects concentrate at technical risks; however, in the later projects – A-Lanes A15 and IXAS Gaasperdammerweg – additional emphasis was laid on project risks which include both technical risks – e.g., not meeting technical requirements – and other risks, i.e. risks of not meeting project objectives. Rather than a primary technical risk focus, with this new emphasis the decision making process also assessed other types of project risks. This development closely relates to the third development concerning the objective-orientation. Since the Coen Tunnel Company project, decision makers have put more emphasis on objectives from the own project organization. As a result, decision makers consider more explicitly objectives which are their own, i.e. self-defined and for their own benefit

[39] The attention for information practices were also observed in the A-Lanes A15 project.

rather than RWS-defined or defined by the parent company and primarily for RWS's and the parent companies' benefit.

The fourth development relates to the reliance on experience and other sources of information. Whereas in the Coen Tunnel Company project the decision making process was surrounded by reliance on experience in prior projects, in later projects the reliance shifted more and more to objectively based information which is validated by expert judgement. As the Coen Tunnel Company project was the first Dutch DBFM-contracted road infrastructure development by RWS, a large reliance on experience was unavoidable; however, standardized methods – e.g., risk analysis and project control – were available in other industries (e.g., gas and oil) which could provide at least with an additional perspective next to the experience-based perspective.

In conclusion, it can be stated that the ecological rationality of decision making is similar across projects in their technical orientation, leadership from the tender manager, focus on RWS objectives, winning the bid and increasing the reliability of the price and in the focus on construction activities after awarding of the contract. Differences in the ecological rationality primarily relate to developments over the projects. These developments include the emergence of 'integrated thinking', a different perspective on risks and objectives and increased emphasis on objective decision information.

4.2.3. The adaptive toolbox and payment mechanism

We characterized decision making in the early stage of DBFM-contracted road infrastructure development as an adaptive toolbox with opportunity-capturing heuristics. An adaptive toolbox consists of heuristics that result in swift decision making and require low levels of cognitive processing (i.e. 'fast and frugal'), are adapted to their decision making environment (i.e. ecological rational) and of which the deployment is coordinated by a importance weighing of conflicting motivations and goals (Gerd Gigerenzer & Selten, 2002, p. 2).

The decision making environment is technical-orientated, shaped by leadership from the tender manager, focused on RWS objectives, winning the bid and increasing the reliability of the price and in the focus on construction activities after awarding of the contract. Moreover, compliance and demonstrability of compliance and widening the scope of risks and objectives under consideration are gain increasing prevalence.

When we reflect on the heuristics observed we consider four types in the adaptive toolbox for a decision maker in DBFM-contracted road infrastructure development: heuristics specifying how (i) to obtain relevant decision information, (ii) to process decision information, (iii) to prioritize decision information and (iv) to convert decision information into action. We included an overview of the heuristics in 17 and discuss these later on in this section. First, it is important to note that this typology is just one of possible typologies; however, it does fit well with an important aspect of this research: making implicit reasoning processes explicit. Moreover, the developments in decision making processes discussed earlier show that making use of objective information and objectifying the decision making is an important topic for practitioners. A final argument is that the early stage of DBFM-contracted road infrastructure development is not concerned with realizing physical infrastructure; rather the early stage is information-based and involves interpretation of norms, contract requirements and recording interpretations in the final bid.

Heuristics related to obtaining decision information give insight in the places from which decision makers obtain their information. In line with the ecological rationality, the heuristics relate to including

Table 17 Typology and examples of heuristics in the adaptive toolbox for a decision maker in DBFM-contracted road infrastructure development

Obtaining information

- Include managers with life-cycle experience in the project.
- Obtain information on existing infrastructure from parent companies.
- Generate new perspectives to increase the quality and reliability of measures and the final offer.
- Start the tender process with a small team of multi-disciplinairians and include mono-disciplinairians when the main project principles are established and approved by the tender board.
- Assess measures against the preferred alternative implied in the program of requirements.

Processing information

- Provide payment-mechanism support to construction planners in detailing the construction planning.
- Work in one document while developing MEAT-eligible measures.
- Validate interpretation of contract requirements after contract awarding.
- Enable continuously demonstration of compliance with requirements to mitigate the top risk of unavailability after completing construction activities.
- Increase objectivity and transparency of the decision making by clustering information related to direct and indirect costs, its timeliness and compliance with requirements in one single template.
- Appoint a single employee responsible for estimating the unavailability penalties resulting from traffic congestion mitigation measures.
- Implement the Systems Engineering Approach.

Prioritizing information

- Focus on measures that align with RWS' project objectives rather than with the objectives of the tendering organization.
- Focus on measures with low cost prices and high levels of risk mitigation.
- The WBS is leading in determining the project activities.
- Determine the construction planning based on the WBS, contractual exemptions on availability penalties and time-slots.
- Focus on the revenue from realization rather than maintenance of the infrastructure.

Converting decision information into action

- Increase MEAT-value by minimization of the offered recovery periods.
- Accept the pre-defined optional risk on the condition of existing infrastructure.
- Accelerate the construction planning.
- Select measures based on low direct and indirect costs, feasibility of the associated construction planning within the contractual deadlines and the likelihood of changing requirements to the align with the measure.
- Select measures with an acceptable level of residual risk.
- Accept measures after contract awarding only when they align with the best and final offer.
- Increase MEAT-value by minimization of the offered number of 'maintenance nights'.
- Reduce uncertainty by creating frequent 'life buoys' with budgets for maximum availability over the life-cycle'.
- Replace existing infrastructure that has a low remaining life-time.

(technical) experience from prior projects as an important information source. Moreover, these heuristics moderate team composition to stimulate new perspectives and inclusion of specific knowledge into the project. Contractual requirements are also an important source of information but heuristics specifically related to contractual requirements mainly specify how to process information in an assessment against the requirements. This indicates that decision makers use contractual requirements as a 'benchmark', i.e. as weighing criteria in the judgement of different measures. The absence of heuristics related to obtaining information from contractual requirements may indicate

that these are not 'top of mind'; however, the presence in heuristics related to processing and prioritizing information demonstrate that this is not the case. Rather, the contractual requirements seem 'internalized' and as a result not explicated by decision makers in describing their decision making practices.

This is an important notion since it signifies that the adaptive toolbox of decision makers in DBFM-contracted road infrastructure development not fully include the sources of information and methods to obtain information. The lack of awareness is reflected in the absence of heuristics related to obtaining information specifying to which information to extract from the MEAT-procedure and payment mechanism.

Heuristics related to processing decision information reflect how information is stored, managed and 'digested' by the project organization. This type of heuristics indicates that decision makers act along the technical disciplines, although heuristics to create alignment between different disciplines are also part of this typology. Information management practices – e.g., appointing information managers and providing support for specific information – are also reflected in these heuristics. Moreover, these heuristics describe how the quality of information (validation), the demonstrability of compliance with requirements and objectivity of information is improved.

In the information processing typology, heuristics are related to the payment mechanism in various ways, mainly through requirements which are specific conditions for payment. However, these heuristics often centralized information processing related to the payment mechanism outside the technical disciplines while the adaptive toolbox of decision makers in DBFM-contracted road infrastructure development is highly technical-oriented along the WBS. This reflects a lower priority of requirements stemming from the payment mechanism relative to technical requirements.

The prioritizing decision information typology of heuristics in the adaptive toolbox of decision makers in the early stage of DBFM-contracted road infrastructure development reflect the weighing of different pieces of decision information. These heuristics prioritize measures aligning with RWS objectives and preferences (e.g., implied alternative in the contract), resulting in revenue from realization, maximizing use of contractual exemptions, minimizing direct costs and activities related to WBS over other alternatives. This is the class of heuristics of the adaptive toolbox in which the payment mechanism plays an important role. As discussed earlier, the adaptive toolbox arranges weighing against the (availability) requirements in the judgement of different measures. However, timeliness – i.e., chiefly the availability date – and direct costs are considered far more important than any other piece of information.

The final type of heuristics in the in the adaptive toolbox of decision makers in the early stage of DBFM-contracted road infrastructure development reflect the way in which information is converted into action. Similar as the selection heuristics in Bingham and Eisenhardt's (2011) opportunity-catpuring heuristics these heuristics reflect which measures to include in the final offer or bid. These heuristic focus on various aspects of road infrastructure development, including the organization's capabilities, MEAT procedure, construction planning and the condition of existing infrastructure. As discussed, the elements of the payment mechanism are reflected in these heuristics, e.g., availability, timing, maintenance and reliability. Safety, however, is not 'top off mind' which we further discuss in a later section.

The typology discussed above is closely related to opportunity-capturing heuristics. One major difference exist: our analysis shows that the toolbox of decision makers in DBFM-contracted road infrastructure development contains a limited number of heuristics related to timing; rather, the adaptive toolbox contains various heuristics related to obtaining information from experience, i.e. including personnel in the project with specific experience in prior projects. This conclusion agrees with the experience-based nature of decision making in infrastructure development.

Hence, the decision making practices of a decision maker in DBFM-contracted road infrastructure development can be described as an information-centered adaptive toolbox with heuristics related to obtaining information, information processing, prioritizing information and converting information into action.

4.2.4. Decision making practices and the payment mechanism

Cross-project comparison of the observed heuristics related to the payment mechanism is a fruitless endeavour since the heuristics depend strongly on the reasoning process of the decision maker from which these are derived. Therefore, we reflect on the body of heuristics – the decision making practices – related to the payment mechanism as a whole and the cues and decision criteria embedded in the heuristics.

We included an overview of the search cues and decision criteria embedded in the building blocks of the opportunity-capturing heuristics related to the payment mechanism in Appendix E. The cues give insight in the way in which decision makers refer to the payment mechanism in their search for information on the decision problem at hand. The decision criteria give insight in the way in which the payment mechanism is used as a decisive factor for the decision. In order to assess the extent to which the payment mechanism is incorporated in the decision making in the early stage of Dutch DBFM-contracted road infrastructure development, we analyse different cues and decision criteria related to main incentives in the payment mechanism. These insights allow us to answer Research Question 5, i.e. discuss the relationship between decision rules used in early stages of DBFM-contracted road infrastructure development.

RESEARCH QUESTION 5
How is the payment mechanism related to the decision making practices used in early stages of DBFM-contracted road infrastructure development?

We reflect on the main incentives in the payment mechanism identified earlier (see Section 2.1.4 and Figure 9, p. 19) and indicate relationships between the incentives, cues and decision criteria.

Availability

Three availability incentives were identified earlier: compliance with availability requirements, minimizing lane closures and minimizing the impact of lane closures on important routes and route sections. All these incentives are reflected in the observed heuristics and indicate that unavailability is a relevant decision criterion for decision making practices in the early stage of Dutch DBFM-infrastructure development.

Compliance with availability requirements is reflected in many heuristics. We found four dimensions: compliance itself, arrangements for non-compliance, demonstration of compliance and creating compliance. First, compliance itself is reflected in the heuristics used to meet the requirements. These heuristics describe how decision makers used requirements as a basis for decisions on which measures to include and which to detail. Second, heuristics were observed that aim not only to comply with the requirements but also with the main concerns underlying the requirements. Heuristics related to arrangements for non-compliance highlighted how insight in unavailability penalties over the life-cycle was generated and which provisions (budgets) to include in the final offer. Third, heuristics related to demonstration of compliance highlighted the way in which decision makers focus on information management practices and the traceability of requirements to decisions (e.g., on inclusion of specific measures). Fourth, we observed heuristics with which decision makers aim to align measures with requirements by establishing RWS' willingness to change the requirements.

The incentives to minimize lane closures and minimize the impact on important routes and route sections was primarily reflected in heuristics describing how and when to plan construction activities. Time Windows, attention for recovery periods and attention for maintenance nights were observed. Moreover, the use of the exemptions for availability penalties were found. In situations where lane closures were unavoidable, heuristics related to traffic congestion mitigation measures were used. Here, the opportunity to obtain MEAT-value for the BAFO played an important role as well.

In addition to the three incentives described earlier, we found that decision makers were focussed on the timeliness of unavailability, i.e. decision makers emphasized on preventing unavailability in the realization rather than the exploitation stage. We discuss the timeliness element of the payment mechanism in a later paragraph.

Safety

Two safety incentives were identified in our analysis of the payment mechanism: prevention of injuries, fatalities and unsafe situations and adequate analysis, documentation and communication before execution of activities. Although various heuristics describe a risk-based approach to infrastructure development, these heuristics do not directly relate to the safety element of the payment mechanism. Rather these heuristics aim to estimate the risk on unavailability and provisions for unavailability to include in the bid. Moreover, an heuristics was observed which prioritizes availability requirements over performance requirements which supports the primary focus on availability over safety incentives.[40]

Maintenance and reliability

Multiple incentives were identified related to the maintenance and reliability element of the payment mechanism: compliance with performance and other requirements, prevention of repeated failures on requirements, adequate maturity of the project organization, reliability of measurement information, preventive (planned) actions over corrective (unscheduled) actions, timely execution of maintenance activities within recovery period, repeated non-occurrence of performance penalties and project realization within agreed vehicle loss hours. Four out of eight of these incentives are reflected in the observed heuristics.

Compliance with performance and other requirements is reflected in similar heuristics as described with the incentive for compliance with availability requirements with similar dimensions: compliance itself, arrangements for non-compliance, demonstration of compliance and creating compliance. However, a difference exists in the prioritization of availability requirements, i.e. one heuristic indicates that compliance with performance requirements is less important than compliance with availability requirements.

Multiple observed heuristics relate to the incentive for adequate maturity of the project organization. These heuristics describe the way in which the ability – or maturity – of the project organization is

[40] This perspective is reflected by multiple decision makers. As one noted "RWS values availability over anything else."

assessed in order to limit recovery periods, maintenance nights, the construction planning, accept additional risk and obtain additional MEAT-value.

The incentive to prioritize preventive (planned) actions over corrective (unscheduled) actions is reflected not directly reflected in the heuristics. However, the large body of heuristics related to unavailability assessments indicate that decision makers are engaged in the planned actions. Their involvement with unscheduled actions is not reflected in our observed heuristics.

Specific heuristics were observed that precisely relate to the incentive for timely execution of maintenance activities within recovery period. Here, the decision maker evaluated the organizational capabilities to the timely – i.e., within the recovery period and within 'maintenance nights' – execute maintenance activities in order to decide whether to reduce the recovery period and 'maintenance nights' offered in the final offer in order to obtain additional MEAT-value.

The incentives for prevention of repeated failures on requirements, reliability of measurement information and repeated non-occurrence of performance penalties are not reflected in the observed decision making practices. Similarly, the incentive for project realization within the agreed vehicle loss hours was not reflected in the heuristics. Rather decision makers focussed on the available exemptions for unavailability and less expensive time slots (Time Windows).

Timeliness

We highlighted the influential mediating factor of timeliness for the other incentives in the payment mechanism earlier and found evidence in the observed heuristics. For example, multiple heuristics prioritize earlier execution of measures, i.e. in the realization stage rather than the exploitation stage. Moreover, the heuristic describing how to develop the construction planning indicates that decision makers are aware of the value attributed to time (e.g., Time Windows, 'maintenance nights'). Moreover, these incentives are used as decision criteria in the heuristics.[41]

4.3. CONCLUSION CASE STUDIES

In the case study, we observed and analysed the project context, general decision making process and decision making practices of seven decision makers in three Dutch DBFM-road infrastructure development projects. For each project we analysed the project context, general decision making process and heuristics related to the payment mechanism.

We found that the decision making process in the early stage of Dutch DBFM-contracted road infrastructure development projects is primarily led by the technically-oriented tender managers who relied on experience in prior projects. The main aim of the early stage was to win the bid and subsequently successful completion of the project realization stage. The MEAT-procedure was considered highly important for decisions as decision makers focused their efforts on developing risk mitigation measures for risks defined by RWS.

The sequentiality of the projects was reflected in four developments in the decision making process since the Coen Tunnel Company project. First, the technical perspective in the decision making process shifted from a focus on detailing to information management, demonstrability and 'integrated thinking'. Second, the risk approach in the decision making process shifted from a technical, WBS-based focus on risks to project risks. Third, the focus on objectives shifted from RWS objectives to

[41] The focus on timeliness is even reflected in one of the project principles of IXAS Gaasperdammerweg which states that the activities with an impact on the availability should be 'short and intense.'

project objectives. Fourth, the reliance on experience in the decision making process decreased and inclusion of objectively based information validated by expert judgement emerged.

We described the decision making practices of a decision maker in DBFM-contracted road infrastructure development as an information-centered adaptive toolbox with heuristics related to obtaining information, information processing, prioritizing information and converting information into action. This information-centered characterization is closely related to the opportunity-capturing adaptive toolbox with the main difference that we identified a class of heuristics related to obtaining information rather than timing of actions. However, an information-centered characterization fits better with the nature of the early stage of DBFM-contracted road infrastructure development.

In answering Research Question 4, we observed 51 opportunity-capturing heuristics: 9 selection heuristics, 22 procedural heuristics, 13 priority heuristics and 7 timing heuristics. In total, 24 opportunity-capturing heuristics related to the payment mechanism and 27 opportunity-capturing heuristics were not directly related to the payment mechanism. We included all opportunity-capturing heuristics and their building blocks in Appendix D.

In answering Research Question 5 – "how is the payment mechanism related to the decision making practices used in early stages of DBFM-contracted road infrastructure development?" – we highlighted the cues and decision criteria embedded in the observed opportunity-capturing heuristics related to the payment mechanism (see Appendix E). We found that indeed these cues and decision indeed relate to the payment mechanism.

The three availability incentives – compliance with availability requirements, minimizing lane closures and minimizing the impact of lane closures on important routes and route sections – were all reflected in the observed heuristics where compliance with the requirements was the most prominent incentive. None of the safety incentives – prevention of injuries, fatalities and unsafe situations and adequate analysis, documentation and communication before execution of activities – were reflected in the observed heuristics. Half of the maintenance and reliability incentives were reflected in the observed heuristics: compliance with performance and other requirements, adequate maturity of the project organization, prioritization of preventive (planned) actions over corrective (unscheduled) actions, timely execution of maintenance activities within recovery period. The incentives for prevention of repeated failures on requirements, reliability of measurement information and repeated non-occurrence of performance penalties are not reflected in the observed decision making practices. Similarly, the incentive for project realization within the agreed vehicle loss hours was not reflected in the heuristics. The mediating effect of timeliness was reflected in multiple observed heuristics through prioritization of earlier execution of measures, certain Time Windows and maintenance nights.

In conclusion, we found that the availability and the mediating timeliness incentives from the payment mechanism are strongly reflected in the observed heuristics, we found reference to half of the reliability and maintenance incentives and no evidence for a relationship between the observed heuristics and safety incentives in the payment mechanism.

In the next chapter, we discuss these results in more detail and reflect their implications for further research and practitioners.

5. DISCUSSION AND CONCLUSION

The aim of this study is to shed light on the extent to which elements of the payment mechanism are integrated with the decision making practices of decision makers in early stages of Dutch DBFM-contracted road infrastructure development. To this end, we assessed the characterized the payment mechanism and the decision making process and developed a theoretical lens with which we observed decision makers and their decision making practices in three Dutch DBFM-contracted road infrastructure development projects. In this chapter, we conclude this study. First, we present the main findings where we reflect on the Research Questions and Central Research Question. Then we discuss the results, highlight the theoretical relevance and consider the limitations. We suggests topics for further research, reflect on the practical implications provide practical recommendations.

5.1. MAIN RESULTS

In this study, we shed light on the extent to which elements of the payment mechanism are integrated with the decision making practices of decision makers in early stages of Dutch DBFM-contracted road infrastructure development.

CENTRAL RESEARCH QUESTION
To which extent are elements of the payment mechanism integrated in the decision making practices in early stages of Dutch DBFM-contracted infrastructure development?

To this end, we formulated six Research Questions as a guidance throughout the research project:

Theoretical perspective

1. What are the elements in which the payment mechanism in Dutch DBFM contracts for road infrastructure development may be decomposed?
2. How is the decision making process in the early stage of infrastructure development characterized?
3. How can elements of the payment mechanism in Dutch DBFM contracts relate to the decision making process in early stages of infrastructure development?

Observation of decision making practices

4. Which decision making practices are used in early stages of DBFM-contracted road infrastructure development?
5. How is the payment mechanism related to decision making practices used in DBFM-contracted road infrastructure development?

We used these Research Questions to answer and the **Central Research Question** and conclude that the availability incentives and timeliness incentive is fully integrated in the decision making practices in early stages of Dutch DBFM-contracted road infrastructure development. We have found evidence for 50 per cent of the maintenance and reliability incentives embedded in the decision making practices and safety incentives were not reflected in the observed decision making practices.

5.1.1. Theoretical perspective

The main aim of the literature review was to develop a theoretical perspective – or lens – through which we observe decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development and the way these relate to the payment mechanism. We described the early stage in Dutch DBFM-contracted road infrastructure development which is largely consumed by the tender process. We highlighted two main incentive regimes for contractor's decision making in the tender process – the MEAT-procedure and the payment mechanism – and concluded that the incentives in the MEAT-procedure are similar to the incentives in the payment mechanism in that they aim for availability during the realization and exploitation stage. However, there is a difference in timelines of the incentive regimes. The incentives in the MEAT-procedure aim moderate the probability of winning the contract while the incentives in the payment mechanism influence the revenue generated from the contract, if won.

We analysed standard structure of Dutch DBFM contracts and described different elements of the payment mechanism. We found that the payment mechanism provides with a collaboration mechanism with which RWS awards the contractor full reimbursement for the services when no penalties for unavailability or underperformance are imposed. Its primary emphasis is to enforce conduct according to the contractual requirements. This conduct is imposed with financial incentives including the one-off payments, gross availability payment and availability and performance penalties. We discussed these financial incentives – one-off payments, gross availability payment, availability penalties and performance penalties – and described the conditions for the associated payments. Categorization of these non-financial incentives may lead to different decompositions; however, in line with common practice and RWS aims we classified five non-financial incentives: four main non-financial incentives are distinguished: availability of the infrastructure, safety of road users, swiftness and quality of maintenance activities, reliability of the infrastructure and maintenance organization. In addition, timeliness was identified as a mediating factor since the severity of penalties in the payment mechanism depends on the timing. This led to our conclusion that the payment mechanism in Dutch DBFM contracts is best characterized as an incentive framework for contractors to deliver and maintain reliable, safe and available infrastructure on time.

We reviewed relevant literature on decision making and reasoning and construed a theoretical lens on decision making in infrastructure development. As starting point, we focussed on the extensive field of academic research in decision making primarily building on classic economic theories and more recently on behavioural science. We discussed the elements of decision making – problem formulation, identification of dissolution strategies and selection of the preferred strategy – and highlighted the main assumptions underlying the economic perspective on decision making: rationality, complete information and infinitely sensitivity of the decision maker. Following the seminal works from Morgenstern (1944), Savage (1954) and Tversky and Kahneman (1974, 1981) that loosened various assumptions underlying the economic perspectives and gave way for different perspective on decision making and the underlying reasoning process, we highlighted different perspectives on human reasoning.

Human reasoning is limited by their computational capacities, time and knowledge (Gerd Gigerenzer & Gaissmaier, 2011). Moreover, in many situations the optimal strategy is not only unknown but unknowable. In these situations, humans are unable to consider all possible strategies and outcomes and arrive at conclusions that satisfy rather than optimize their preferences (Simon, 1978, 1990). Gigerenzer and Todd (1999) argues that the decision making process based on this satisficing reasoning model consists of fast and frugal heuristics with three building blocks that guide the search for pieces of decision information, indicate when the search for information is stopped and specify how the final decision is reached. This decision making process is supported by recognition and social cognitive capabilities and allows decision makers to make fast and frugal decisions.

The literature review provided with reports of the use of fast and frugal heuristics for decisions in various fields, including in construction projects (Morren, 2014). Decision making in the early stage of construction projects is complex and based on uncertainty and ambiguous and conflicting objectives. Moreover, decision makers in construction are faced with a plethora of – sometimes unreliable –

information (Bagies & Fortune, 2006; Bakht & El-diraby, 2015). As a result of their limited information processing capability, decision makers in construction focus on pattern recognition rather deep reasoning, rely on intuition derived from a mixture of gut feelings, experience and guesses, make subjective assessments and decide on partial cues (Ahmad, 1990; Chua & Li, 2000; Deng, 1994; Fayek et al., 1999; Moselhi et al., 1991). Hence, we found that the decision making process in the early stage of infrastructure development is best described with the fast and frugal heuristic-based decision making process. In this process, decision makers have an adaptive toolbox at their disposal with cognitive capacities and fast and frugal, ecological rational heuristics. The toolbox is adaptive and the heuristics are ecological rational as the heuristics are context-dependently deployed and developed (Gerd Gigerenzer & Gaissmaier, 2011, p. 456).

Morren (2014) showed that the adaptive toolbox in construction projects consists of Bingham and Eisenhardt's (2014) four classes of opportunity-capturing heuristics: selection, procedural, priority and timing. These heuristics support decision makers to allocate scarce resources to an advantageous set of opportunities, provide rules of thumb to detail resource allocation and allow decision makers to organize their actions efficiently and effectively. We followed Morren (2014) perspective on decision making in construction and concluded that the decision making process in the early stage of infrastructure development is best characterized as an adaptive toolbox with opportunity-capturing heuristics that are ecological rational and supported by recognition and social cognitive capabilities.

We produced a theoretical lens on the relationship between the payment mechanism and the decision making process in the early stage of infrastructure development. The payment mechanism may provide contractors with cues and decision criteria to reflect their decisions on the impact on the impact according to the payment mechanism. These cues and decision criteria can be embedded in the opportunity-capturing heuristics which are construed of search, stopping and decision rules – i.e., the building blocks – and guide the search for pieces of decision information, indicate when the search for information is stopped and specify how the final decision is reached.

We concluded that the payment mechanism in Dutch DBFM contracts can provide with cues – e.g., incentives – and decision criteria – e.g., the impact on payments – for the search, stopping and decision rules embedded in the decision maker's adaptive toolbox with opportunity-capturing heuristics and hence relate to the decision making process in early stages of infrastructure development.

5.1.2. Observation of decision making practices

In order to create insight in decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development –specifically the decision making practices related to the payment mechanism – we used the theoretical lens developed to answer Research Question 3 to observe decision making practices in the field. To this end we analysed documents and interviewed (semi-structured) seven decision makers in three different DBFM-contracted road infrastructure development projects: Coen Tunnel Company, A-Lanes A15 and IXAS Gaasperdammerweg. We centred our observations on three focal points: (i) developing a general understanding of the decision making practices, (ii) developing a specific understanding of decision making practices and (iii) developing insight in the role of specific elements of the payment mechanism. The collected data was analysed in two steps: within-project and cross-project analysis. Although we focused on the decision making practices of individual decision makers, we reported the practices at the project-level in order to ensure anonymity of decision makers involved and better frame the decision making practices within their ecological rationality.

We observed the general project decision making process and different opportunity-capturing heuristics and their building blocks. We observed 51 opportunity-capturing heuristics: 9 selection heuristics, 22 procedural heuristics, 13 priority heuristics and 7 timing heuristics. In total, 24 opportunity-capturing heuristics related to the payment mechanism and 27 opportunity-capturing heuristics were not directly related to the payment mechanism. In Appendix D we included an overview of all observed opportunity-capturing heuristics and their building blocks.

We found that the ecological rationality of decision making practices in the early stage of Dutch DBFM-contracted road infrastructure development projects is primarily characterized by technically-oriented leadership relying on experience in prior projects. The main aim of the early stage was to win the bid and subsequently successful completion of the project realization stage. The MEAT-procedure was considered highly important for decisions as decision makers focused their efforts on developing risk mitigation measures for risks defined by RWS.

The sequentiality of the projects was reflected in four developments in the decision making process since the Coen Tunnel Company project. First, the technical perspective in the decision making process shifted from a focus on detailing to information management, demonstrability and 'integrated thinking'. Second, the risk approach in the decision making process shifted from a technical, WBS-based focus on risks to project risks. Third, the focus on objectives shifted from RWS objectives to project objectives. Fourth, the reliance on experience in the decision making process decreased and inclusion of objectively based information validated by expert judgement emerged.

Decision making in the early stage of DBFM-contracted road infrastructure development is not concerned with realizing physical infrastructure; rather the early stage is information-based and involves interpretation of norms, contract requirements and recording interpretations in the final bid. As a result, decision making in the early stage is information-centred and can be described as an information-centered adaptive toolbox with heuristics related to obtaining information, information processing, prioritizing information and converting information into action.

We highlighted the cues and decision criteria embedded in the observed opportunity-capturing heuristics related to the payment mechanism (see Appendix E). We found that indeed these cues and decision criteria relate to the payment mechanism; however not for all incentives. All availability incentives – compliance with availability requirements, minimizing lane closures and minimizing the impact of lane closures on important routes and route sections – were reflected in the observed heuristics where compliance with the requirements was the most prominent incentive. Four dimensions of compliance with requirements were established: compliance itself, arrangements for non-compliance, demonstration of compliance and creating compliance. No evidence was found for the relation between the safety incentives – prevention of injuries, fatalities and unsafe situations and adequate analysis, documentation and communication before execution of activities – and observed heuristics. Four maintenance and reliability incentives were reflected in the observed heuristics: compliance with performance and other requirements, adequate maturity of the project organization, prioritization of preventive (planned) actions over corrective (unscheduled) actions, timely execution of maintenance activities within recovery period. The incentives for prevention of repeated failures on requirements, reliability of measurement information, repeated non-occurrence of performance penalties and project realization within the agreed vehicle loss hours were not reflected in the decision making practices. The mediating effect of timeliness was reflected in multiple observed heuristics through prioritization of earlier execution of maintenance and traffic congestion mitigation measures, certain Time Windows and emphasis on the available maintenance nights and recovery periods.

5.2. DISCUSSION AND THEORETICAL RELEVANCE

The primary motive for this study was the lack of clarity in the extent to which decision makers in early stages of Dutch DBFM-contracted road infrastructure development integrate elements in their decision making practices. In the main results, we reported the insights created to clarify the integration between decision making practices and the payment mechanism. Here reflect on these results, discuss the theoretical relevance and highlight limitations and directions for further research.

5.2.1. Discussion of main results

The results indicate that decision makers primarily focus on availability incentives and in particular compliance with requirements. The focus on requirements closely aligns with the technical orientation of the decision making process in which the decisions were made. Engineers are requirement-oriented as they are traditionally trained to develop infrastructure based on requirements. Moreover, the focus on availability incentives is certified by the client-focus we observed in the decision making practices.

Timeliness proved an important mediating factor for availability. Many, if not all, decision makers were closely aware of the importance of time in the payment mechanism and especially its effect on the availability incentive. As we noted earlier, this is a logical consequence of the operationalization of availability and availability penalties as quarters of lane closure or vehicle hours lost.

The emphasis of decision makers on timely availability in the early stage of DBFM-contracted road infrastructure development reflects not only the influence of the payment mechanism. As we noted earlier, during the tender process there are two incentive regimes for contractors which both emphasize creating availability and timeliness. The simultaneous existence of two incentive regimes has an important implication for inference from this research, i.e. our results have limited inferential power over the relationship between payment mechanism and decision making practices as we cannot assign specific payment mechanism incentives exclusively to decision making practices. The limited inferential power follows naturally from our objective at the integration of payment mechanism incentives in decision makers reasoning: we observed decision making practices and payment mechanism incentives imbedded in these practices rather than payment mechanism incentives and their impact on decision making.

The limited integration of maintenance and reliability incentives in decision making practices indicates that in the early stage of infrastructure development maintenance and reliability receive limited attention. When we reflect on the specific incentives which have not been found in the decision making practices, we find that these incentives stimulate performance after the realization stage and are largely related to the way in which maintenance in the exploitation stage is organized. As several decision makers noted, maintenance was primarily regarded as a matter of organizing which could take place at a later stage in time. However, one incentive which was not observed related to the realization stage, i.e. project realization within the agreed vehicle loss hours were not reflected in the decision making practices. The rationale for the absence of this incentive in the observed heuristics is unclear but may relate to the fact that exceedance of the agreed vehicle loss hours is already penalized with availability penalties.

Interestingly we found evidence for integration of safety incentives in decision making practices. Multiple decision makers noted that safety is important; however, in the observed heuristics these were not reflected. Three motives for the lack of safety incentives are considered. First, with our observation protocol we focused on main decisions in the early stage of DBFM-contracted road infrastructure. This gave insight in different decision making practices related to the main goals, i.e. the opportunity-capturing heuristics to create the winning bid; however, other aspects of may have remained underexposed. Second, the safety incentive is primarily embedded in the availability requirement. Hence, decision makers may consider the safety aspects covered when they focus primarily on the availability incentives. Third, similar to the rational for the reliability and maintenance incentives, safety may have been considered a matter of organizing which received only attention when safety issues became apparent – e.g. during realization or maintenance – and not in the early stage of development.

The analysis of the payment mechanism indicated a hierarchy of the main incentives. Maintenance and reliability of the infrastructure and maintenance activities are considered preconditions for safety and availability, i.e. on the long-term without proper reliable, maintenance unavailability is likely to occur. We found evidence some evidence supporting this view in the prioritization of availability over other main incentives observed in various heuristics; however, we cannot infer a hierarchy in the payment mechanism from these observations. We observed the way in which decision makers used the payment mechanism; inferences on a hierarchy at least require us to examine the reverse relationship, i.e. how incentives stimulate decision makers behaviour.

With our theoretical lens we took the perspective that decision makers searched for cues in the incentives of the payment mechanism which they weigh against the decision criteria reflected in impact on payments related to these incentives. However, our results indicate that decision makers also search for the financial incentives and decide on non-financial incentives.

An interesting contradiction emerged in our findings. On the one hand, the decision makers are highly technical-oriented on technical specifications and requirements whilst on the other hand the payment mechanism – strongly relying on technical specification and requirements – is not fully integrated in their decision making practices. This is especially curious as all elements in the payment mechanism were considered – although with different priorities – important. Indeed, from a traditional, rational perspective decision makers might be considered 'irrational' or the statement that all elements in the payment mechanism are important might be considered false. Absence of decision criteria that were first considered may indicate a "form of bounded rationality, but may also simply point to an unstructured way of working" (Heerkens, 2003, p. 178) and although we were unable to clarify this contradiction, the most plausible explanation lies in the coexistence of two incentive frameworks of which the incentives for the MEAT-procedure clearly were considered more important than the incentives of the payment mechanism.

5.2.2. Theoretical relevance

In the literature review, we found a large academic field emphasizing the ambiguous, complex nature of decision making in construction (Bagies & Fortune, 2006; Bakht & El-diraby, 2015). We found evidence for this in the ambivalent objectives in the early stage of DBFM-contracted road infrastructure development. For example, contractors are on the one hand stimulated to accept additional risks – e.g., on the condition of existing infrastructure – in order to obtain additional MEAT-value and increase the probability of winning the contract while on the other hand, contractors are stimulated to increase the reliability of the infrastructure. In addition, Ahmad (1990, p. 565) noted that decision makers in construction relied on "intuition derived from a mixture of gut feelings, experience and guesses" (Ahmad, 1990, p. 565). We provide with evidence for this view in Dutch DBFM-contracted road infrastructure development as we found that the decision making process in was primarily led by technology-oriented managers who relied on experience in prior projects. Moreover, the observed decision making practices relied largely on estimations and judgement calls. However, as the developments over the projects indicate, a shift towards objectifying the decision making practices is ongoing. With this research we contributed to that by applying the adaptive toolbox concept and making implicit heuristics explicit.

We provide with contributions to the academic field in various other ways. First, we developed a theoretical lens which deviates from the traditional (descriptive) perspective on decision making. Although we noted that on several aspects the decision making perspectives are similar and not all observed heuristics were based on ‘fast and frugal’ reasoning, our approach allowed to capture a wider range of reasoning processes rather than the standard ‘maximizer’ assumption underlying the traditional perspective on decision making. Moreover, the adaptive toolbox approach allowed us to capture a wide variety of different decision making *practices* while traditional approaches generally consider decision making as a coherent general-purpose decision making *process* (Gerd Gigerenzer & Selten, 2002, p. 2). With this approach we contribute to the need for concrete context-dependent knowledge on decision making practices advanced by Flyvbjerg (2006, p. 224). Nevertheless, we must note that further research into the context-dependency and a comparison of differences and similarities of the decision making perspectives is needed.

Second, DBFM incentive regimes are generally evaluated at project levels (Rijkswaterstaat, 2014b). We provided with insights in the impact of incentive regimes at the individual reasoning level. This micro-level perspective on the decision making provides with nuanced insights on the impact of payment mechanisms in Dutch DBFM-contracted road infrastructure development. We found that decision makers not necessarily base their decisions on the payment mechanism itself but their interpretation of the objective of the project principal. This finding supports previous research on opportunistic behaviour in the DBFM-contracted road infrastructure development (Krstulovic, 2014).

Second, the setting of the observed decision making practices was to a large extent similar in that the decision making context were Dutch DBFM-contracted projects for road infrastructure development which were led by engineering-oriented managers who relied on experience in prior projects. Moreover, decision making in all projects focused on RWS objectives and delineated the activities to undertake from a technical orientation. As a result, we can conclude that the ecological rationality in all projects was similar. We extended the notion of ecological rationality from notion to environments confined by the contract setting.

Third, we further the findings of Morren (2014) who described the adaptive toolbox for the bid-no bid decision making in construction. We extended this view towards the decision making after the decision to bid has been made and found similarities and differences between the types of the heuristics in the adaptive toolbox. The adaptive toolboxes are similar in that both focus on opportunity-capturing with procedural, priority and selection heuristics. The main difference is the existence of heuristics related to obtaining information rather than heuristics related to timing of actions. This difference is defendable as the research by Morren (2014) concerns internal processes of business units within a single contracting firm in their decision whether to bid where the current study focuses on the decision making for project development – i.e., development of the project organization and the deliverable of that organization – for large, complex projects. These project organizations – or consortia – constitute of different participating contractors and require therefore information from outside the project organization, e.g., from parent organizations. Moreover, rather than an intercompany considerations, our study provides insights with inter-, intra- and extra-company considerations for developing a bid in a competitive setting. To this end, alignment with specifications from the project principal and validation of interpretations of the specifications with the project principal is crucial. This requires decision makers in these projects to develop and deploy specific heuristics in their adaptive toolbox related to obtaining information.

The ecological rationality of the adaptive toolbox is not only different with respect to the width of applicability, i.e. decision making within the organization versus decision making between the consortia partners and the project principal governed by different legal frameworks (e.g., the Tender Guidelines with the MEAT-procedure and DBFM contract with the payment mechanism). Difference also exists in scope due to a different unit of analysis. The adaptive toolbox approach on decision making relies strongly on the ‘fast and frugal’ perspective on reasoning. To this end, Morren (2014) framed the decision making practices of *business units* while the the current study focused on decision making practices of *decision makers*. While both business units and decision makers are influenced by procedures, business units itself do not have the ability to reason to a decision. As a result, the heuristics described by Morren (2014) may primarily reflect the way in which decisions are 'ought to be taken' within the business units, rather than the reasoning process followed within the business units. However, we must note that the current research is also limited in that respect as we reconstructed past decision making practices which required the interviewed decision makers to some extent to rationalize their decision making practices. Further research on the level of an individual decision maker with field observations may bridge both approaches.

5.2.3. Limitations and further research

In this study, we selected a limited number of decision makers to study their decision making practices in-depth. We then reflected on the complete body of heuristics related to the payment mechanism as a whole and the cues and decision criteria embedded in the heuristics. As a result, the results have limited inferential power over the relationship between payment mechanism and decision making practices. This limits our ability to generalize our findings over all decision making practitioners in road infrastructure development. As we noted earlies this limited inferential power follows naturally our focus on the payment mechanism incentives imbedded in the decision making practices. Nevertheless, extending this research into a broader framework that allows for generalization may increase the relevance of our findings as it provides with insight in best practices.

In addition to generalization, we also highlight the opportunity to focus in further research more on specific decisions. Various aspects play a role in large, complex DBFM-contracted road infrastructure projects. An in-depth analysis of several specific important decisions the way in which decision makers arrived at these decisions, what information was gathered and how this information was evaluated provides with a thorough understanding of decisions in DBFM practices. To this end, we suggest a focus on construction planning and existing infrastructure.

We specifically focussed on reasoning processes of individual decision makers. However, decision making in these large projects is rarely the responsibility for individuals. Rather decision making processes takes place in tender boards and management teams. A wide field of academic research emphasize the differences between individual and group decision making. Our research is limited in that these differences are not included; studies into the group reasoning processes may provide relevant new insights in decision making practices in the early stage of DBFM-contracted road infrastructure development.

An important direction for future research is the analysis of the interrelations of the co-existing incentive regimes with decision making practices in infrastructure tender processes. As we highlighted, these incentives do not necessarily align. Insight in the interrelations allows RWS to improve their control over the infrastructure projects. Another direction for further research is the focus on tender board. As we focussed on the early stage of infrastructure development which is largely consumed by the tender process, most decisions are effectuated in the tender board. Insight in their reasoning process provides with valuable insight for practitioners and RWS and allows them to improve decision making and the incentive regimes.

In this research we have not reflected on the cognitive capacities supported the decision making process as it was out of our research scope. In contrast to general belief, Gigerenzer (2008, p. 21) argues that decision makers with higher cognitive capabilities select different heuristics. Inclusion of cognitive capacities in future research on decision making in infrastructure development may improve our understanding of the cognitive capacities required for heuristic-based decision making.

5.3. PRACTICAL RELEVANCE AND RECOMMENDATIONS

The objective of this research was to contribute to better control over project performance in early stages of Dutch DBFM-contracted road infrastructure development. The payment mechanism is an important performance control mechanism in DBFM-contracted projects and hence insight in how this mechanism is used provides with insight in to increase project control. Moreover, RWS is aiming to increase its use of DBFMs while only recently the first DBFM contracts entered the exploitation stage. Hence, only few project evaluations are available while these focus primarily on the DBFM-contract as procurement instrument. Our study enables RWS broaden their evaluations and include insights in the way incentives in the payments are used in practice. These insights can improve future tender processes and current contract management activities.

We developed three categories of recommendations to improve the payment mechanism and decision making practices in Dutch DBFM-contracted road infrastructure development. First, the results show that safety incentives are not ‘top of mind’ in decision making practices in the early stage of DBFM-contracted road infrastructure development. Different heuristics describe the way in which risks are considered in the decision making; however, these risks relate to ‘physical risks’, i.e. risks of the infrastructure being non-compliant with the requirements. We recommend practitioners better integrate safety consideration in their decision making practices in two ways: first, practitioners should identify a set of safety risks (e.g., risk on fatalities, accidents and unsafe situations) and for all other risks emerging from risk analyses reflect on the potential influence on these safety risks. With this approach practitioners can integrate ‘safety thinking’ in their decision making practices based on a *risk impact* analysis. In many risk analysis templates and automated software programs this impact analysis is already available; as decision making in construction is largely experience-bases the important next step is to develop a heuristic for the adaptive toolbox and in this way implement the safety-focus in the decision making practices. A second approach can borrow from the trade-off matrices used in the IXAS Gaasperdammerweg. These trade-off matrices provide an excellent template for information management related to specific decision making practices. By specifically including safety risks in this template, safety considerations receive attention for every major decision made.

We suggest that practitioners refrain from monetizing safety risks – and for that matter other risks as well – since this reduces the objectivity of the decision information (e.g., the main objective of the use of trade-off matrices). We stress that both approaches – extending risk analysis to their impact on safety risks and inclusion of safety risks in trade-of matrices – are non-exclusive. Rather, these approaches are complementary: the impact analysis may provide with the decision information needed for the trade-off matrices.

Second, we showed that contractors currently are guided by two incentive mechanisms: the MEAT-procedure and the payment mechanism. In practice, the incentives from the MEAT-procedure receive considerably more attention from practitioners in order to increase the probability of winning the bid. This leads to a strong emphasis on timely execution of the realization stage which conflicts with the life-cycle approach of DBFM-contracted road infrastructure development. We recommend RWS to further integration these incentive mechanisms to reduce complexity and advance unambiguous stimuli to contractors. The ideal situation is obtained when the MEAT-procedure is integral part of the payment mechanism as this eliminates any conflicting requirements and creates unambiguity. To this end, a two step-approach is recommended: (i) for the short-term we strongly recommend RWS to include criteria in the MEAT-procedure that relate to measures focussed on long-term– i.e., during the exploitation stage – condition of the infrastructure; (ii) for the long-term integration we suggest that RWS is performs an analysis of the objectives of both incentive regimes, develop related incentives and analyse their impact on decision making practices. It is essential for the first step that RWS communicate their intention with the rationale and enforce compliance since contractors focus on their interpretation of criteria and requirements rather than the criteria and requirements themselves. For the second step, this study may provide a good starting point.

Third, we highlighted four developments in decision making practices across projects: (i) the shift from attention for details, to information management, demonstrability and ‘integrated thinking’, (ii) the shift from technical risks to inclusion of project risks, (iii) the shift from RWS objectives to project objectives and (iv) the shift from reliance on experience to inclusion of objectively based information validated by expert judgement. We strongly recommend to continue on this route as it furthers project control in large DBFM-contracted road infrastructure development projects for both RWS and contractors.

Continuous demonstrability of compliance provide practitioners with insight in their own performance. This insight allows contractors to pro-actively communicate over potential compliance issues and may result in a more lenient attitude towards potential issues of non-compliance. For instance, all DBFM contracts include provisions for cases of compensation and force majeure. The ability to continuously demonstrate compliance allows decision makers to more clearly substantiate incidents in as a force majeure or case of compensation. Furthermore, continuous demonstrability aligns with the system-based contract management approach deployed by RWS in which the responsibility for demonstrability of compliance is transferred from RWS to the contractor.

In conjunction with the recommendation for integration of safety consideration in decision making practices, a broader perspective on project objectives and risks rather than technical risks and RWS objectives allows practitioners to manage the impact of risks on the project organization’s objectives. Naturally, these include financial objectives but may also relate to reputation issues – e.g., unsafe construction practices – of the project organization and the parent company. As such, this provides a first step towards enterprise risk management. For the interested reader, Morren (2014) provide excellent recommendations for inclusion of enterprise risk management in decision making practices.

It is important that tender boards are involved in the early decision making process rather than responsible for making the final decision. Earlier and frequent involvement not only creates a support base for decisions, members of tender boards also can use their expertise to provide input to and validate the decision information (e.g., in the trade-off matrices).

DBFM-contracted road infrastructure development relies heavily on experience which is embedded in employees. This may provide an advantage for project organizations with ‘the best people’; however, it is not durable since employees may retire or switch jobs and relevant experience-based knowledge gets lost. A shift from reliance on experience to inclusion of objectively based information validated by expert judgement may counter this risk. Moreover, the adaptive toolbox of decision makers in DBFM-contracted road infrastructure development is information-centred; therefore, recording information in a structured way may relieve decision makers from the need to remember many important facets of the project development.

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APPENDICES

A. OBSERVATION SCHEME

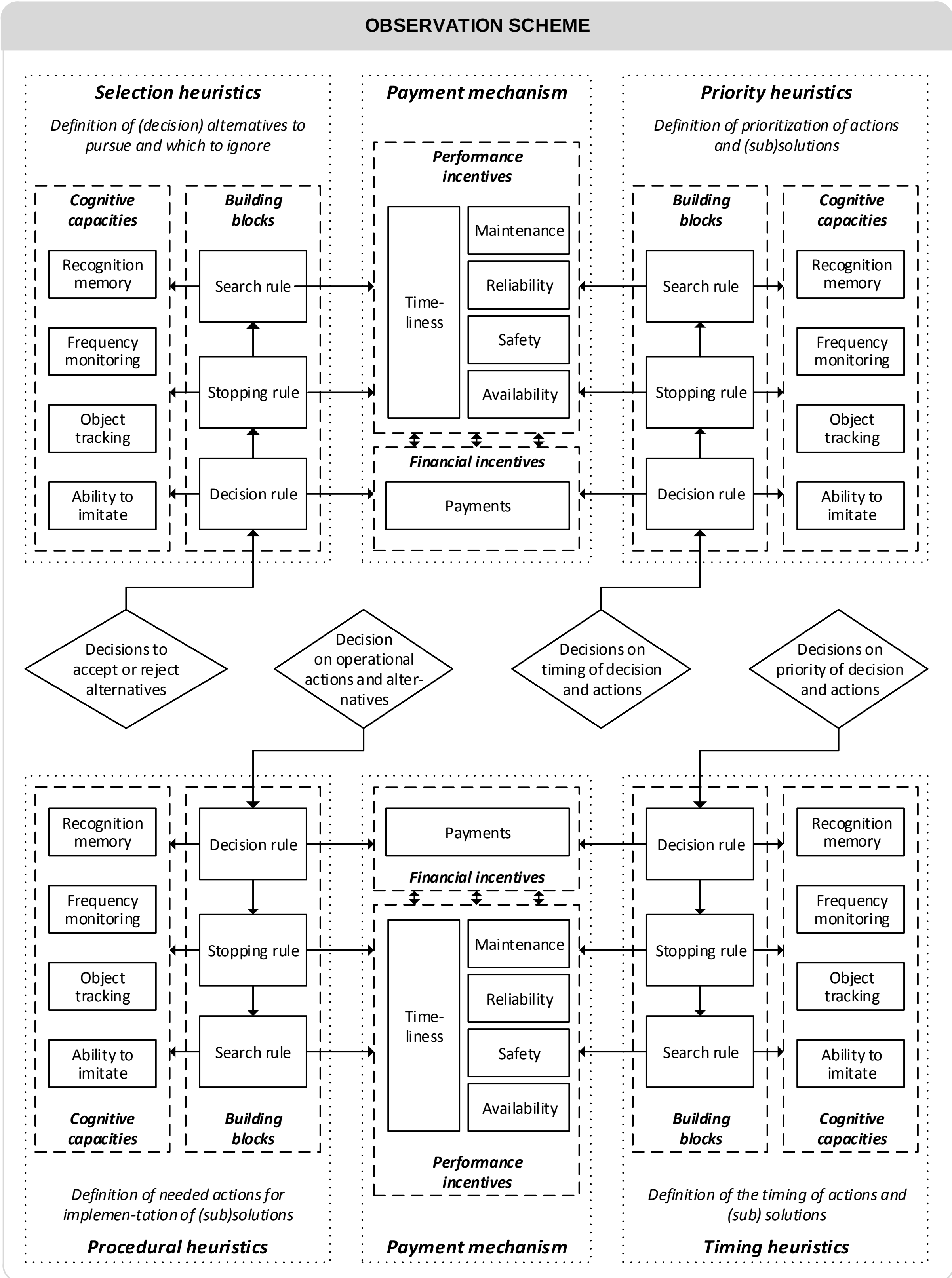

Figure 19 Detailed observation scheme developed from the theoretical lens developed in Chapter 2.

B. DUTCH DBFM-CONTRACTED ROAD INFRASTRUCTURE DEVELOPMENT PROJECTS

An overview of all Dutch DBFM-contracted road infrastructure development projects currently in preparation, tender stage, realisation or exploitation are included in Table 18.

Table 18 DBFM contract-based infrastructure developments in the Netherlands (Rijkswaterstaat, 2015b).

Project	Realisation		Status
	Start	Completion	
Haak om Leeuwarden (N31)	2004	2007	Exploitation
Second Coen Tunnel and Westrandweg	**2009**	**2013**	**Exploitation**
Utrecht-Lunetten-Veenendaal (A12)	2010	2013	Exploitation
Widening Maasvlakte – Vaanplein (A15)	**2011**	**2015**	**Realisation**
Assen-Zuidbroek (N33)	2013	2014	Exploitation
Diemen – Almere Havendreef (A1/A6)	2014	2020	Realisation
Widening Veenendaal - Ede – Grijsoord (A12)	2015	2016	Realisation
Lock Limmel (Meuse)	2015	2018	Realisation
Varsseveld-Enschede (N18)	2015	2018	Tendering
Holendrecht – Diemen (Gaasperdammerweg; A9)	**2015**	**2020**	**Realisation**
Utrecht-junction Eemnes-Amersfoort (A27/A1)	2016	2018	Tendering
Sea lock IJmond	2016	2019	Tendering
Lock Eefde	2016	2020	Preparation
Accessibility of Arnhem and Nijmegen (Via15)	2016	2019/2021	Preparation
Third Beatrix lock	2017	2020	Tendering
New highway Rotterdam (A13/A16/A20)	2017	2021	Preparation
Afsluitdijk	2017	2021	Preparation
Blankenburg link road (A15/A20)	2017	2022	Preparation
Almere Havendreef - Almere Buiten-Oost (A6)	2017	2020/2022	Preparation
Badhoevedorp - Holendrecht (Amstelveen; A9)	2019	2024/2026	Preparation

B.1. PROJECT SELECTION

Three inclusion criteria were defined to select projects for our case study (see Section 3.3):

- The project is concerned with the development of road infrastructure in The Netherlands with use of a DBFM contract;
- The project has left the tender stage which allows us to study decision making practices used in the complete tender stage and in the first design activities;
- The project data and interviewees must be accessible for the researcher.

Based on these criteria three projects were selected (see Table 18; bold lines):

- Development of the Second Coen Tunnel and Westrandweg by project organization Coen Tunnel Company;
- Widening of the A15 between Maasvlakte and Vaanplein by project organization A-Lanes A15; and

- Tunneling of the A9 Gaasperdammerweg between Holendrecht and Diemen by project organization IXAS.

B.2. DATA COLLECTION

The observation scheme in Figure 19 (Appendix A) is the basis for the case study. We primarily obtain our data from semi-structured interviews with decision makers (see Appendix C.4). Secondary data sources included DBFM Agreements, Tender Guidelines and additional information provided by the interviewees.

C. CASE STUDY INTERVIEWS

C.1. SELECTION OF INTERVIEWEES

For each project identified in Appendix A, a number of key decision making roles during the tender and early design stages were identified based on the associated responsibility for:

- The complete project [end-responsibility]
- Engineering
- Life-cycle integration and optimization
- Maintenance

In addition, interviewees were selected based on their availability and familiarity with the case study projects that could provide with more background information. In Appendix C.4 an overview of interviewees is provided.

C.2. INVITATION TO THE INTERVIEWS

Interviewees are selected based on their involvement with the identified projects, availability and accessibility by Oxand employees (see Appendix A). The invitation bellow was sent out in Dutch and accompanied and sent by contact persons within Oxand. On request, the research motive, objective and approach (Chapter 1) were made available.

Subject: Besluitvorming in vroege stadia (tender) van DBFM weginfrastructuur ontwikkeling

<<Salutation>>,

<<Person-specific preliminaries>>.

Introduction
In conclusion of my master studies in Business Administration at the University of Twente, I conduct at Oxand – formerly known as Iter Fidelis – a research project on the role of the payment mechanism in the early stage of decision-making in DBFM road infrastructure development. I am primarily concerned with the period following the decision to participate in the tender but before completion of the preliminary design. Given your extensive experience in the <<Project involved in>>, I would like to ask you some questions about the early stage of DBFM projects and how you make decisions at this stage.

I am very flexible in the time-space continuum and hope to be allowed to be allowed to make use of one and a half hours of your time in the period from October 19 to November 13.

About the research
With this research, I aim to create an overview of the way in which important decisions in the early stage of DBFM projects are made. I primarily focus on the way in which managers arrive at their decisions and which decision rules they use. Examples of questions which I would like to discuss, are:

- how do you select solutions to design, construction, and maintenance challenges?
- when is a solution ‘good enough’ and when is more information required?
- what do you consider decisive criteria to accept or reject a solution?

I have a special interest in the role of the payment mechanism in these decisions: how important do you consider various elements of the payment mechanism – e.g., recovery periods and process control – in trade-offs and decisions in the early stage of a road infrastructure project?

Objective

The aim of this research is **not** to judge the decision making process in DBFM projects. This study focuses on describing implicit assumptions and decision rules (rules of thumb) in early stages of DBFM projects. With this insight I aim to achieve two objectives: on the one hand, I focus on recommendations for RWS which allows them to design payment mechanisms that better align with decision making practices. On the other hand, I focus on expressing explicitly the way in which managers arrive at their decisions in the early stage of DBFM road infrastructure development projects. I gladly share the results with you.

About myself

My name is Martijn Driesprong (27) and after my Bachelor Civil Engineering at the University of Twente I studied at the same university the masters Financial Engineering & Management [completed] and Business Administration. This study into decision making in DBFMs in combination with the payment mechanism provides with an ideal combination of my fields of interest: large infrastructure projects, financial incentive structures and complex decision making.

<<greetings and contact information>>

C.3. INTERVIEW STRUCTURE AND QUESTIONS

Interviews were held in Dutch at the work place of the interviewees. Interviews had a duration of approximately 1.5 hours and followed a generic structure of three parts:

1. *Familiarization with the research topic, project and main decisions;*
2. *Specific discussions on decisions and decision rules;*
3. *Specific role of the payment mechanism in decision making practices.*

All interviews were taped for reference during case study analysis in order to limit ambiguities in interpretation. Questions were intentionally formulated as open but specific questions in order to create a large focussed set of data for our analysis. Moreover, interviewees were invited to speak openly over their factual decision making practices and refrain from judgements. This approach was chosen to minimize ex-post rationalization of decision making and maximize insight in reasoning processes. In addition to the general questions bellow, we discussed various project-specific considerations in-depth which allowed the interviewer to increase robustness of inferences about the heuristics used.

C.3.1. Introduction

The main topic of this interview is the way in which you make decisions in the early stage of DBFM-contracted road infrastructure development. I would like to primarily focus on the tender stage of <<specific project>>; however, feel free to include other experiences with early stages of DBFM-contracted road infrastructure development project. Please be so kind to indicate when you refer to other projects.

We have reserved <<person-specific; 1-1.5 hours >> for this interview which consists of three parts and is structured as followed. The first part is explorative in nature for which I developed a number of questions about the general project description and an overview of decision making in the early stages of the project development. The objective of this first part is to familiarize myself with the project and identify key decisions in these early stages.[42] A selection of these decisions form the basis – e.g., concrete examples of decisions – for the second part of the interview.

The second part of the interview is designed to discuss the way in which you make decisions in detail. We specifically discuss the way in which you arrived at the key decisions. I gladly invite you to take me along in the steps taken and share your considerations.

In the third part we focus more specifically on the decisive criteria, i.e., the 'rules of thumb', criteria and questions that were most important to the decision. To this aid, I composed a (limited) list of potential factors which I like to discuss with you.

C.3.2. Interview questions

Part 1: General project description and overview of decision making in the early stage of the <<project name>> project

This part discusses four questions to characterize decision making practices and its environment in early stages of DBFM-contracted road infrastructure development.

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[42] Note for thesis: These decisions are most likely to be categorized as having an impact on the design, construction or maintenance or a combination of these categories. We use additional, persistent questions – not reported in this interview structure – to uncover this type of information and report these in the findings from the case study.

1.1 In which stages would you subdivide the early stage – after the decision to tender, before the delivery of the preliminary design – of the project?
   - o Why is the early stage of the project subdivided in these elements and in this sequence?

1.2 Which keywords would you use to describe the way in which decisions were made in the early stage of the project?

1.3 When you consider all decisions made in the early stage of the project, which five to ten decisions would you consider most important?
   - o Why do you consider these decisions most influential for the project?

Various representations of decision making exist. One general three-step representation of the way in which decision makers arrive at their decisions is shown in the figure.

[see figure included bellow this section]

1.4 Does this representation align with the way in which you arrive at your decisions?
   - o Why does it (not) align with your decision making practices?
   - o What are the distinct differences and similarities?
   - o Can you provide with an example in which you went through these three steps?

All three steps require pieces of information (cues) that express a certain characteristic searched (e.g., characteristics of a design solution). In the second part of this interview, we discuss these cues into more detail.

Part 2: Specific decision making practices and the way the interviewee arrived at the most important decisions

This part focusses on specific decision making practices and criteria used. The most important decisions identified earlier are used as 'talking pieces' and concrete examples to elucidate the way the interviewee arrived at the most important decisions. We put emphasis on obtaining insight in the criteria used for the decisions.

The early stage of DBFM-contracted road infrastructure development is focussed on capturing an opportunity, i.e. winning the bid. Stated as a decision problem one might describe the overall objective of these early stages as "how do we put together a winning bid?" With the following questions we discuss four elements which play a role in winning the bid:

- *decision making to select (sub)solutions (which we refer to as alternatives);*
- *decision making on processes and actions to transfer the alternatives into specific actions;*
- *decision making on prioritization of alternatives and actions;*
- *decision making on the timeliness of alternatives and actions.*

The following questions focus on the way in which you select or reject alternatives to 'win the bid'. In general, and for the most important decisions identified earlier.

2.1 For which cues do you search when you select potential alternatives to decision problems?
   - o At which places do you search – or who do you consult – for these cues?
   - o What questions do you ask yourself – and others – to obtain a rough insight in potential alternatives?

2.2 How do you determine that you have collected sufficient cues – and alternatives – for the decision problem?

2.3 When you have collected sufficient alternatives, what are the criteria on which you evaluate them?
   - o What are the decisive criteria for acceptation or rejection of an alternative?
   - o What are the minimum conditions which the alternative needs to fulfil?

2.4 Is the payment mechanism – or parts thereof – explicitly used in the process of selection or rejection of these alternatives?
   - o Why do you think it is (not) important to use the payment mechanism for these decisions?
   - o Is the payment mechanism – or parts thereof – explicitly made available to all involved in the process of selection or rejection of an alternative?

Often decision makers require some level of detailing of the alternatives before a decision is made to accept or reject it. Also when an alternative is selected it needs further detailing. The following questions concern the detailing process of alternatives into actions or (generic) action plans and the associated prioritization.

2.5 How are alternatives detailed into action plans?

2.6 Are there (standard) methods used to select and detail the alternatives into action plans and, if so:
   - o Which methods were used?
   - o How did you acquire these methods?

2.7 What elements of the alternatives are detailed and which not?
   - o Why is there a difference in the level of detailing?

2.8 Which alternative was detailed first and why?

Part 3: Decision making practices and the payment mechanism

This part focusses on specific elements of the payment mechanism to obtain insights in which it played a role in decision making practices. The most important decisions identified earlier are used as 'talking pieces' and concrete examples to elucidate the way the interviewee arrived at the most important decisions. We put emphasis on obtaining insight in criteria used for the decisions related to the payment mechanism.

Regarding the way at which you arrived at the main decisions in early stages of DBFM-contracted road infrastructure development identified earlier:

3.1 What were the most decisive criteria?
   - o How would you rank these criteria?

3.2 What was the role of the contract requirements?
   - o Which (type of) requirements do you consider most important and why?

3.3 What was the role of RAMS-aspects?
   - o Which aspect do you consider most important and why?

3.4 Was timing or timeliness of actions an important consideration for these decisions?
   - o Why was timing or timeliness (not) an important consideration?

3.5 What was the role of the payment mechanism?

3.6 What was the impact of potential availability penalties?
   - o How did you determine this impact?

- o To which extent [level of detail] is the impact of potential availability penalties analysed?

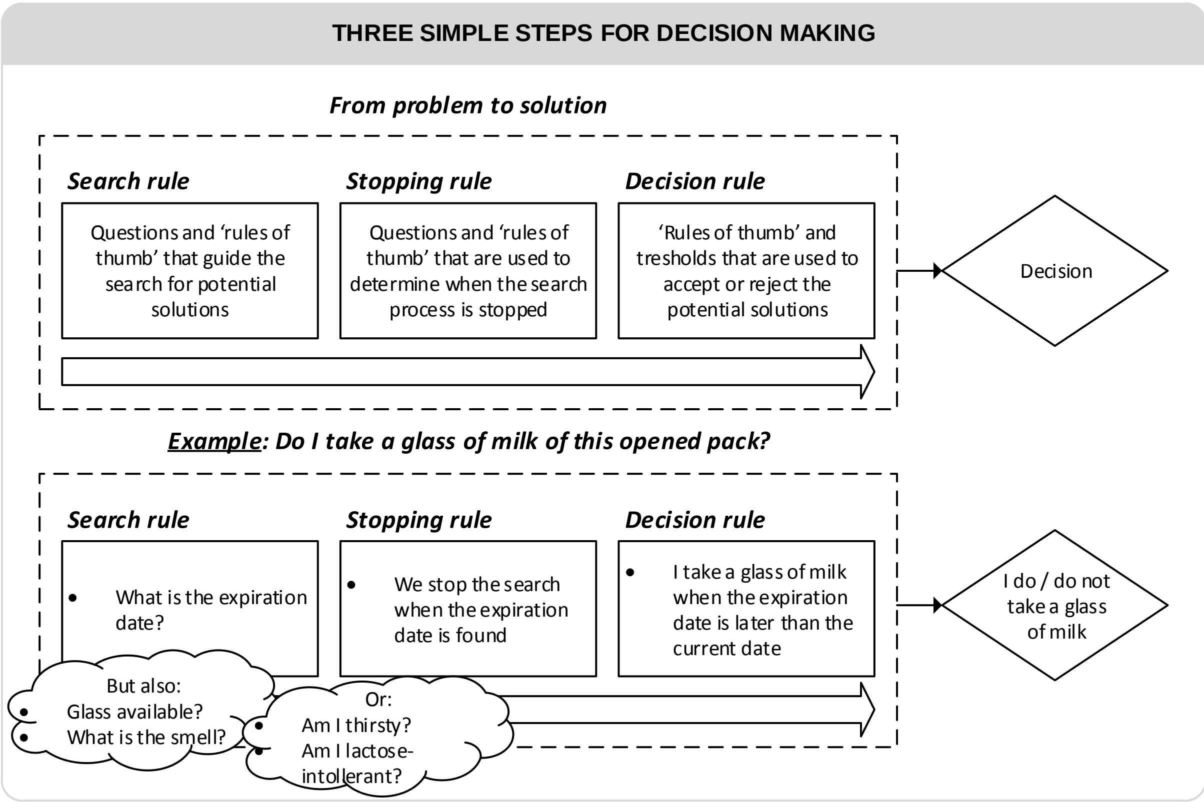
3.7 What was the impact of potential performance penalties?

- o How did you determine this impact?
- o To which extent [level of detail] is the impact of potential performance penalties analysed?

3.8 Which decision was influenced most by the payment mechanism and why?

3.9 In general, how important do you consider the payment mechanism for decision making in early stage of DBFM-contracted road infrastructure development?

[End of interview]



C.4. LIST OF INTERVIEWED PERSONS

Coen Tunnel Company			
Interviewee	**Involvement**	**Time**	**Date**
C.1	Management and technical	1.5h	03-11-2015
C.2	Management and technical	2.0h	02-11-2015

A-Lanes A15			
Interviewee	**Involvement**	**Time**	**Date**
A.1	Management and technical	1.5h	30-10-2015
A.2	Technical	2.0h	19-10-2015

IXAS Gaasperdammerweg			
Interviewee	**Involvement**	**Time**	**Date**
I.1	Management and technical	1.0h	23-10-2015
I.2	Management and technical	1.5h	04-11-2015
I.3	Management	1.0h	04-11-2015

D. OBSERVED DECISION MAKING HEURISTICS

D.1. COEN TUNNEL COMPANY

Table 19 Overview of selection opportunity-capturing heuristics and their building blocks used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Increase MEAT-value by minimization of the offered number of 'maintenance nights'.**
Search rule	What are the capabilities of our organization to organize required maintenance activities in the minimum number of maintenance nights specified in the MEAT-procedure?
Stopping rule	When the organizational capabilities in organizing maintenance is evaluated.
Decision rule	• Minimize the number of offered maintenance nights when the organization is able to organize the required maintenance activities within the minimized number of maintenance nights; • Do not minimize the number of offered maintenance nights when the organization is unable to organize the required maintenance activities within the minimized number of maintenance nights.
Selection #2	**Reduce uncertainty by creating frequent 'life buoys' with budgets for maximum availability over the life-cycle'.**
Search rule	What is the likely frequency of availability penalties over the life-cycle?
Stopping rule	When the tender manager is convinced that the frequency is defendable to the tender board.
Decision rule	• Include budgets for full unavailability penalties once in the five years when the tender manager is convinced that this frequency defendable to the tender board; • Adjust budgets for frequent full unavailability penalties when the tender manager is not convinced that this frequency defendable to the tender board.
Selection #3	Include measures in the bid that eliminate the concerns of RWS underlying the formal risks outlined in the Risk Management Plan.
Search rule	What are the concerns of RWS underlying the formal risks outlined in the Risk Management Plan?
Stopping rule	When insight in RWS' main concerns is created and reviewed with RWS during the Dialogue.
Decision rule	• Include measures in the bid that eliminate concerns underlying the risks identified in the Risk Management Plan when insight in RWS' concerns is established, the measures eliminate the concerns and are recorded in the Tender Guidelines as eligible for MEAT-treatment; • Convince RWS to make measures MEAT-eligible that eliminate their concerns when insight in RWS' concerns is established, the measures eliminate the concerns but proposed measures are not rewarded with MEAT-value in the Tender Guidelines.

Table 20 Overview of procedural opportunity-capturing heuristics and their building blocks used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism; italic-faced only marginally.

Procedural #1	**Use a FMECA analysis on WBS-based availability requirement categories to determine the technical components for which risk mitigation measures are to be developed.**
Search rule	• What is the relationship between the availability requirement and the WBS? • What is the Risk Priority Number of the availability requirement category as determined by the FMECA?
Stopping rule	When the relationship between the availability requirement and the WBS is established, the requirements are categorized across the WBS and an FMECA analysis on these categories is executed.
Decision rule	• Risk mitigation measures are developed for a technical component of the infrastructure when the associated availability requirement categories have been assigned a high Risk Priority Number; • Risk mitigation measures are not developed for a technical component of the infrastructure when the associated availability requirement categories have been assigned a low Risk Priority Number.
<u>*Procedural #2*</u>	*Include personnel with physical risk knowledge and life-cycle analysis to create insights in the risk of unavailability penalties.*
Search rule	Which persons has life-cycle analysis experience and physical asset knowledge?
Stopping rule	When people in parent or other companies with experience in life-cycle analysis of physical assets are found.
Decision rule	• Include employees from the parent companies with physical risk knowledge and experience in life-cycle analysis in the project when these are available in the parent companies; • Hire consultants with physical risk knowledge and experience in life-cycle analysis in the project when these are not available in the parent companies.
Procedural #3	Include managers with D&C engineering experience in the project.
Search rule	What type of project experience do managers in parent companies have?
Stopping rule	When insight in the type of project experience in the parent companies is established.
Decision rule	• Include managers from the parent company in the project when the manager has experience in previous D&C engineering project(s); • Do not include managers from the parent company in the project when the manager has no experience in previous D&C engineering project(s).
Procedural #4	Implement the Systems Engineering Approach.
Search rule	What are the requirements related to project control?
Stopping rule	When the requirements related to project control are evaluated.
Decision rule	• Implement the Systems Engineering approach when requirements related to project control require implementation of Systems Engineering; • Implement project controls similar to those used in previous projects when requirements related to project control do not require implementation of Systems Engineering.
Procedural #5	Rely on prior experience of parent company in detailing maintenance budgets.
Search rule	What prior experience is there within parent companies with maintenance budgets?
Stopping rule	When parent companies are evaluated on their prior experience with detailing maintenance budgets.

Decision rule	• Use knowledge and experience of parent company to detail maintenance budgets when the knowledge and experience is present in one of the parent companies; • Use knowledge and experience of a consultant firm to detail maintenance budgets when the knowledge and experience is not present within a parent company.
Procedural #6	The WBS is leading in determining the project activities.
Search rule	Which activities do we need to undertake to win the tender?
Stopping rule	When the main activities to develop technical elements of the infrastructure (WBS) are determined.
Decision rule	• Execute activities that are needed to develop technical elements of the infrastructure; • Do not execute activities that do not relate to the WBS of the to develop infrastructure.

Table 21 Overview of priority opportunity-capturing heuristics and their building blocks used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Compliance with requirements related to the realization stage is more important that compliance with requirements related to the exploitation stage.**
Search rule	What is the relationship between the requirement and the project stage?
Stopping rule	When the relationship between the requirement and the project stage is established.
Decision rule	• Requirements that relate to the realization stage are used as primary reference for detailing of measures; • Requirements that do not relate to the realization stage are not used as primary reference for detailing of measures.
Priority #2	**Focus with measures and alternatives on preventing unavailability in the short-run rather than preventing unavailability on the long-run.**
Search rule	When does the measures and alternatives prevent unavailability?
Stopping rule	When the timing of the impact of the measure or alternative on preventing unavailability is determined.
Decision rule	• Measures that prevent unavailability in the realization stage receive high priority in detailing and inclusion in the final bid; • Measures that prevent unavailability in the exploitation stage receive low priority in detailing and inclusion in the final bid.
Priority #3	**Use the availability requirements as a guide rather than take them literally in the development of measures and alternatives.**
Search rule	What is RWS' intention of the availability requirement?
Stopping rule	When an interpretation of RWSs intention with the availability requirement is established.
Decision rule	• Availability requirements with an interpretation that closely resembles the contractual formulation are used as primary reference for detailing of measures; • Availability requirements with an interpretation that does not closely resemble the contractual formulation are not used as primary reference for detailing of measures.
Priority #4	**Focus on the revenue from realization rather than maintenance of the infrastructure.**
Search rule	When does the measure generate revenue?
Stopping rule	When the timing of the impact of the measure or alternative on generating revenue is determined.

Decision rule	• Measures and alternatives that result in revenue in the realization stage receive high priority in detailing and inclusion in the final bid; • Measures and alternatives that result in revenue in the exploitation stage receive low priority in detailing and inclusion in the final bid.
Priority #5	Make trade-offs against the preferred alternative implied in the in program of requirements.
Search rule	What is the preferred design and construction alternative?
Stopping rule	When an interpretation of the preferred alternative is construed from the contract and this interpretation is reviewed with RWS.
Decision rule	• Assess all alternatives against the preferred alternative of RWS and assign high priorities to measures are in line with the preferred alternative. • Deviate from the preferred alternative only when this results in a higher BAFO.
Priority #6	Focus on the cost price and margin in determining measures to include in the bid.
Search rule	What are the volumes, acreages and unit prices for the measure?
Stopping rule	When the volumes, acreages and unit prices for the measure are estimated and a cost price is computed.
Decision rule	• Measures that result in low cost prices receive high priority in detailing and inclusion in the final bid; • Measures that result in high cost prices receive low priority in detailing and inclusion in the final bid.

Table 22 Overview of timing opportunity-capturing heuristics and their building blocks used by decision makers in the Coen Tunnel Company project. Bold-faced heuristics relate to the payment mechanism

Timing #1	**Replace existing infrastructure that has a low remaining life-time**
Search rule	What is the physical condition and maintenance history of existing infrastructure?
Stopping rule	When an assessment of the remaining life-time of the infrastructure based on the current physical condition and maintenance history is made.
Decision rule	• Existing infrastructure is replaced when the assessment indicates that the remaining life-time is five years or less; • Existing infrastructure is not replaced when the assessment indicates that the remaining life-time is more than five years.
Timing #2	Base construction planning on the program of requirements supplemented by prior experience.
Search rule	When and in which sequence do we need to plan the construction activities?
Stopping rule	When prior experience with construction planning is reflected and program of requirements is evaluated on conditions for the construction planning.
Decision rule	• Plan construction activities based on conditions laid out in the program of requirements supplemented with experience in prior projects, when the program of requirements specifies conditions for construction activities; • Plan construction activities based on experience in prior projects, when the program of requirements does not specify conditions for construction activities

D.2. A-LANES A15

Table 23 Overview of selection opportunity-capturing heuristics and their building blocks used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Increase MEAT-value by reducing the length of the offered recovery periods.**
Search rule	• Is our organization able to create a maintenance organization able to execute maintenance activities in a shorter recovery periods than specified in (concept) DBFM contract? • What are the concerns of RWS underlying the formal risks outlined in the Risk Management Plan?
Stopping rule	When the organizational capabilities in organizing maintenance is evaluated, insight in RWS' concerns is created and reviewed with RWS.
Decision rule	• Shorten the offered recovery periods when the organization is able to organize the required maintenance activities within a shorter recovery period and RWS is willing to make a shorter recovery period MEAT-eligible; • Do not shorten the offered recovery period when the organization is unable to organize the required maintenance activities within a shorter recovery period or RWS is unwilling to make a shorter recovery period MEAT-eligible.
Selection #2	**Accept the pre-defined optional risk on the condition of existing infrastructure.**
Search rule	• What is the current condition of the existing infrastructure? • Is our organization able to create a maintenance organization able to execute required maintenance activities on the existing infrastructure within 20 days after the contract start date?
Stopping rule	When the organizational capabilities in organizing maintenance is evaluated and the condition of existing infrastructure is assessed.
Decision rule	• Accept the pre-defined optional risk on the condition of existing infrastructure when the organization is able to organize required maintenance activities on the existing infrastructure within 20 days after contract start date; • Reject the pre-defined optional risk on the condition of existing infrastructure when the organization is unable to organize required maintenance activities on the existing infrastructure within 20 days after contract start date.
Selection #3	**Accelerate the construction planning.**
Search rule	Is our organization able to execute the construction planning at a faster pace than specified in (concept) DBFM contract?
Stopping rule	When the organizational capabilities in executing the construction activities in a higher pace are evaluated.
Decision rule	• Accelerate the offered construction planning when the organization is able to execute the construction planning at a faster pace; • Do not accelerate the offered construction planning when the organization is unable to execute the construction planning at a faster pace.

Table 24 Overview of procedural opportunity-capturing heuristics and their building blocks used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Procedural #1	The WBS is leading in determining the project activities.
Search rule	• Which activities do we need to undertake to win the tender?

Stopping rule	When the main activities to develop technical elements of the infrastructure are determined.
Decision rule	• Execute activities that relate to the WBS; • Do not execute activities that do not relate to the WBS.
Procedural #2	Separate development of tender documents from engineers responsible for development of design documents.
Search rule	To whom do we assign responsibility for development of tender documents?
Stopping rule	When the main tasks of project personnel are reflected on the activities needed to develop tender documents.
Decision rule	• Assign the responsibility for the development of design documents to engineers; • Assign the responsibility for development of tender documents not to engineers.
Procedural #3	Use a single database as the sole source of project information.
Search rule	How do we document and track the requirements within the organization?
Stopping rule	When the information need of various disciplines is assessed.
Decision rule	• Use a single database as the sole database when different disciplines require the same information; • Use decentralized (multiple) data sources when different disciplines require different types of information.
Procedural #4	**Provide payment-mechanism support to construction planners in detailing the construction planning.**
Search rule	How do we increase the reliability of the construction planning?
Stopping rule	When current and required knowledge of construction planners on the payment mechanism is assessed.
Decision rule	• Construction planners are supported in detailing the construction planning by personnel with payment mechanism knowledge when the knowledge of construction planners on the payment mechanism is insufficient; • Construction planners detail the construction planning when their knowledge of the payment mechanism is sufficient.
Procedural #5	Include managers with life-cycle experience in the project.
Search rule	What type of project experience do managers in parent companies have?
Stopping rule	When insight in the type of project experience in the parent companies is established.
Decision rule	• Include managers from the parent company in the project when the manager has experience in previous life-cycle project(s); • Do not include managers from the parent company in the project when the manager has no in previous life-cycle project(s).
Procedural #6	Work in one document while developing MEAT-eligible measures.
Search rule	How can we increase coherence between different elements of the tender documents?
Stopping rule	When an assessment is made of increased coherence by working in the one document.
Decision rule	• Work in one document while developing MEAT-eligible measures when the assessment indicates that coherence is increased by working in one document; • Work in separate documents while developing MEAT-eligible measures when the assessment indicates that coherence is not increased by working in one document.

Table 25 Overview of priority opportunity-capturing heuristics and their building blocks used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Focus on measures that align with RWS' project objectives rather than with the objectives of the tendering organization.**
Search rule	• What are RWS' objectives for the project? • What are the objectives of the project organization?
Stopping rule	When the alignment between the measure and RWS' objectives and the objectives of the project organization is evaluated.
Decision rule	• Measures that align with RWS' objectives receive high priority in detailing and inclusion in the final bid; • Measures that align with the objectives of the project organization receive low priority in detailing and inclusion in the final bid.
Priority #2	Focus on measures with low cost prices and high levels of risk mitigation.
Search rule	• What are the volumes, acreages and unit prices for the measure? • What is the risk mitigation level of the measure.
Stopping rule	When the volumes, acreages and unit prices for the measure are estimated and a cost price is computed and the decrease in FMECA, RAMS or FTA-based Risk Priority Number is determined.
Decision rule	• Measures that result in low cost prices and high risk mitigation measures receive high priority in detailing and inclusion in the final bid; • Measures that result in high cost prices or low risk mitigation measures receive low priority in detailing and inclusion in the final bid.

Table 26 Overview of timing opportunity-capturing heuristics and their building blocks used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism

Timing #1	**Determine the construction planning based on the WBS, contractual exemptions on availability penalties and time-slots.**
Search rule	When and in which sequence do we need to plan the construction activities?
Stopping rule	When a WBS is constructed, the contractual exemptions for availability penalties and time-slots are determined.
Decision rule	• Plan construction activities based on the WBS and contractual exemptions on availability penalties when the resulting period is sufficient for execution of construction activities; • Plan construction activities based on the WBS and minimized unavailability penalties in the less penalized time slots when the period covered by contractual exemptions on availability penalties is insufficient for execution of construction activities.
Timing #2	Validate interpretation of contract requirements after contract awarding.
Search rule	What is RWS' intention of the requirement?
Stopping rule	When an interpretation of RWS' intention with the availability requirement is established and the criticality of the requirement for obtaining MEAT-value is assessed.
Decision rule	• Validate interpretation of contract requirements before contract awarding when the requirement is critical for obtaining MEAT-value and the interpretation does not closely resembles the contractual formulation; • Validate interpretation of contract requirements after contract awarding when the requirement is not critical for obtaining MEAT-value.

D.3. IXAS GAASPERDAMMERWEG

Table 27 Overview of selection opportunity-capturing heuristics and their building blocks used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Selection #1	**Select measures based on low direct and indirect costs, feasibility of the associated construction planning within the contractual deadlines and the likelihood of changing requirements to align with the measure.**
Search rule	• What are the direct costs of the measure? • What are the indirect costs related to the measure? • Is the construction planning feasible within the contractual deadlines? • What is the likelihood that RWS is willing to change requirements to the align with the measure?
Stopping rule	When the direct and indirect costs of the measure are determined and evaluated against the available budget, the feasibility of the construction planning is assessed based on the organizational capabilities in executing the required activities and RWS has indicated its willingness to change related non-compliant requirements?
Decision rule	• Select the measure when the direct and indirect costs are equal to or lower than the available budget, the assessment of the construction planning indicates that it is challenging but feasible and RWS is willing to change the requirements to align with the measure; • Reject the measure when the direct and indirect costs are higher than the available budget, the assessment of the construction planning indicates that it infeasible or RWS is unwilling to change the requirements to align with the measure.
Selection #2	**Select measures with an acceptable level of residual risk on unavailability.**
Search rule	What is an acceptable level of residual risk on unavailability?
Stopping rule	When the risk appetite is determined.
Decision rule	• Select the measure when the level of residual risk on unavailability is smaller than the risk appetite; • Reject the measure when the level of residual risk on unavailability is higher than the risk appetite.
Selection #3	Accept measures after contract awarding only when they align with the best and final offer.
Search rule	What is the contract scope?
Stopping rule	When the alignment between the measure and the best and final offer is determined.
Decision rule	• Accept the measure after contract awarding when the measure aligns with the best and final offer; • Reject the measure after contract awarding when the measure is out of scope of the best and final offer.

Table 28 Overview of procedural opportunity-capturing heuristics and their building blocks used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Procedural #1	**Enable continuously demonstration of compliance with requirements to mitigate the top risk of unavailability after completing construction activities.**
Search rule	• What are the primary drivers for project risk? • What are the capabilities of our organization to meet RWS' requirements for successful project completion?

Stopping rule	When the organizational capabilities are reflected on the project requirements to meet RWS' requirements for successful project completion.
Decision rule	• Include a team in the project organization responsible for continuously demonstration of compliance with requirements and implement information management and quality assessment practices including RAMS analysis and Systems Engineering when the assessment of the alignment between the organizational capabilities to successfully complete the project in line with RWS' requirements indicates the risk of insufficient demonstrability. • Do not change the organizational structure and enforce new information management and quality assessment methods when the organizational capabilities to successfully complete the project in line with RWS' requirements indicates the risk of sufficient demonstrability.
Procedural #2	**Estimate the risk of expected unavailability penalties based on failure modes linked to availability and performance requirements.**
Search rule	What are the primary drivers for unavailability penalties?
Stopping rule	When the linkage between the WBS and availability and performance requirements is established.
Decision rule	• Estimate unavailability and performance penalties based on the WBS-linked failure modes when availability and performance requirements are related to the WBS; • Estimate the residual risk on unavailability and performance penalties when availability and performance requirements are not related to the WBS.
Procedural #3	**Increase objectivity and transparency of the decision making by clustering information related to direct and indirect costs, its timeliness and compliance with requirements in one single template.**
Search rule	How can I limit the reliance on experience judgement and gut feeling in the decision making process?
Stopping rule	When the decision making process is assessed on the reliance on expert judgement and gut feeling and insight is created in the number of information sources.
Decision rule	• Cluster decision information related to direct and indirect costs, its timeliness and compliance with requirements in one single template when the decision making process is based on expert judgement and gut feeling or the information is scattered over several people and sources. • Do not centralize decision information when the decision making process is based on objective information and the information is sourced from a select number of sources and people.
Procedural #4	**Appoint a single employee responsible for estimating the unavailability penalties resulting from traffic congestion mitigation measures.**
Search rule	How can we evaluate our traffic congestion mitigation measures on availability penalties?
Stopping rule	When current and required knowledge of construction planners on the payment mechanism is assessed.
Decision rule	• Appoint a single employee responsible for estimating the unavailability penalties resulting from traffic congestion mitigation measures when the knowledge of construction planners on the payment mechanism is insufficient; • Assign responsibility for estimating the unavailability penalties resulting from traffic congestion mitigation measures to construction planners when the knowledge of construction planners on the payment mechanism is sufficient.
Procedural #5	**Use the payment mechanism only for estimation of unavailability penalties resulting from traffic congestion mitigation measures.**

Search rule	Which types of measures are evaluated against the payment mechanism?
Stopping rule	When the main drivers for unavailability penalties are established.
Decision rule	• Estimate unavailability penalties for measures when the measure is a traffic congestion mitigation measure; • Do not estimate unavailability penalties for measures when the measure is not a traffic congestion mitigation measure.
Procedural #6	**Use the dialogue with RWS not only as a source of information or to validate the feasibility of measures but also to create opportunities to make measures compliant with requirements and to make requirements compliant with the measures.**
Search rule	How can we align our preferred measure with the contract requirements?
Stopping rule	When the preferred measure is evaluated on potential conflicting requirements.
Decision rule	• Use the dialogue with RWS to create opportunities to make measures compliant with requirements and to make requirements compliant with the measures when the preferred measure conflicts with one or more requirements; • Use the dialogue with RWS as a source of additional information and to validate the feasibility of measures when the preferred measure does not conflict with the requirements.
Procedural #7	Put emphasis on continuity of the team while providing with new perspectives.
Search rule	What is the right balance of visionary, generalist and criticaster roles in the project team?
Stopping rule	When the team composition and task is reflected on the need for new perspectives.
Decision rule	• Include new employees in the project when new perspectives are required; • Do not include new employees in the project when new perspectives are not required.
Procedural #8	Obtain information on existing infrastructure from parent companies.
Search rule	How can I obtain more information on the condition of existing infrastructure?
Stopping rule	When parent companies' prior involvement with the development or maintenance of the existing infrastructure is evaluated.
Decision rule	• Obtain information on existing infrastructure from parent companies when parent companies have been involved in the development or maintenance of the existing infrastructure; • Use (visual) inspections when parent companies have not been involved in the development or maintenance of the existing infrastructure.
Procedural #9	Involve specialists with experience in prior projects ad hoc when additional information is needed.
Search rule	How can I organize information provision to the tender organization without increasing the team size?
Stopping rule	When the frequency of requiring specialistic knowledge is determined.
Decision rule	• Involve specialists on an ad hoc basis with the project when required information is specialistic and one-off; • Add specialists to the project permanently when the required information is not one-off.
Procedural #10	Generate new perspectives to increase the quality and reliability of measures and the final offer.
Search rule	• How can I assess the quality of the measures? • How can I improve the reliability of the cost and risk estimates underlying the measures and final offer?

Stopping rule	When quality control and assurance practices in the parent company are reviewed.
Decision rule	• Arrange for external reviews and benchmarks, use scenarios thinking, include criticasters in the team and reflect with individual intuitive preferences when these practices have proven to improve quality control and assurance in parent companies; • Do not arrange for external reviews and benchmarks, use scenarios thinking, include criticasters in the team and reflect with individual intuitive preferences when these practices have not proven to improve quality control and assurance in parent companies;

Table 29 Overview of priority opportunity-capturing heuristics and their building blocks used by decision makers in the IXAS Gaasperdammerweg project. Bold-faced heuristics relate to the payment mechanism.

Priority #1	**Focus on measures that primarily align with availability requirements and secondary with performance requirements.**
Search rule	What are related availability and performance requirements?
Stopping rule	When the alignment between the measure and availability and performance requirements is determined.
Decision rule	• Measures that align with availability requirements receive high priority in detailing and inclusion in the final bid; • Measures that align with performance requirements receive lower priority than those that align with availability requirements in detailing and inclusion in the final bid.
Priority #2	**Focus on direct costs, timely and reliable execution of construction activities and the risk that RWS is unwilling to change conflicting requirements rather than indirect costs stemming from the payment mechanism.**
Search rule	• What are the direct costs of the measure? • What are the indirect costs related to the measure? • Is the construction planning feasible within the contractual deadlines? • What is the likelihood that RWS is willing to change requirements to the align with the measure?
Stopping rule	When the direct costs of the measure are determined and evaluated against the available budget, the feasibility of the construction planning and RWS' willingness to change related non-compliant requirements is assessed.
Decision rule	• Measures receive higher priority when the direct costs are lower than the current budget estimates, the assessment of the construction planning indicates that it is feasible and RWS is willingness to change related non-compliant requirements; • Measures receive a lower priority when the indirect costs from unavailability penalties are lower than any other measure but direct costs are higher than the current budget estimates, the assessment of the construction planning indicates that it is infeasible or RWS is unwillingness to change related non-compliant requirements.
Priority #3	Focus on top level risks in determining the project activities.
Search rule	What are the primary drivers for project risk?
Stopping rule	When the RMPO and RMP are reviewed.
Decision rule	• Measures receive high priority in detailing and inclusion in the final bid when the risks mitigated by the measure are included in the RMPO or RMP; • Measures receive lower priority in detailing and inclusion in the final bid when the risks mitigated by the measure are not included in the RMPO or RMP.

Priority #4	Assess measures against the preferred alternative implied in the program of requirements.
Search rule	What is the preferred design and construction alternative?
Stopping rule	When an interpretation of the preferred alternative is construed from the contract and this interpretation is reviewed with RWS.
Decision rule	• Measures receive high priority in detailing and inclusion in the final bid when the measure aligns with the preferred alternative of RWS; • Measures receive low priority in detailing and inclusion in the final bid when the measure deviates from the preferred alternative of RWS.
Priority #5	Focus on the concerns of RWS underlying the formal risks outlined in the Risk Management Plan.
Search rule	What are the concerns of RWS underlying the formal risks outlined in the Risk Management Plan?
Stopping rule	When insight in RWS' main concerns is created and reviewed with RWS during the Dialogue.
Decision rule	• Measures receive high priority in detailing and inclusion in the final bid when the risks mitigate RWS' concerns underlying the formal risks outlined in the Risk Management Plan; • Measures receive low priority in detailing and inclusion in the final bid when the risks do not mitigate RWS' concerns underlying the formal risks outlined in the Risk Management Plan.

Table 30 Overview of timing opportunity-capturing heuristics and their building blocks used by decision makers in the A-Lanes A15 project. Bold-faced heuristics relate to the payment mechanism

Timing #1	Start the tender process with a small team of multi-disciplinarians and include mono-disciplinarians when the main project principles are established and approved by the tender board.
Search rule	What are the leading project principles?
Stopping rule	When the leading project principles are established.
Decision rule	• Include mono-disciplinarians when the main project principles are established and approved by the tender board; • Do not include mono-disciplinarians when the main project principles are not established and approved by the tender board.
Timing #2	Start the project development before formal announcement of the tender process.
Search rule	What know-how and project-specific information is required to determine a general project outline?
Stopping rule	When know-how and project-specific information required to determine a general project outline is evaluated.
Decision rule	• Start the project development before formal announcement of the tender when the general outline of the project can be determined with know-how; • Do not start the project development before formal announcement of the tender when determination of the general outline of the project requires project-specific information.
Timing #3	Start detailing the final offer when the condition of existing infrastructure, Route Decision requirements and permits are reviewed and top requirements are determined.
Search rule	At what moment in time do we start detailing the final offers?
Stopping rule	When the contract scope is established.

Decision rule	• Start detailing measures for the final offer when the condition of existing infrastructure, Route Decision requirements and permits are reviewed and top requirements are determined; • Do not start detailing measures for the final offer when the condition of existing infrastructure, Route Decision requirements and permits are not reviewed and top requirements are not determined.

E. CUES AND DECISION CRITERIA

Table 31 Cues embedded in the search rules of observed opportunity-capturing heuristics related to the payment mechanism. The lasts column refers to the heuristic (C: Coen Tunnel Company; A: A-Lanes A15; I: IXAS Gaasperdammerweg)

Cues		
Priority opportunity-capturing heuristics		
Relationship requirements and project stage	Availability; timeliness	C #1
Timing unavailability prevention	Availability; timeliness	C #2
Intention RWS	Availability	C #3
Timing revenue generation	Availability; timeliness	C #4
Project objectives RWS; Project objectives project organization.	Reliability; availability; maintenance; timeliness	A #1
Relationship measure with availability requirements; Relationship measure with performance requirements.	Maintenance; availability	I #1
• Direct costs; • Indirect costs; • Feasibility construction planning within contractual deadlines; • RWS' willingness to change requirements.	Availability; maintenance; reliability	I #2
Procedural opportunity-capturing heuristics		
• Relationship availability requirements and WBS; • Categorization availability requirements; • Risk Priority Number of the availability requirement category.	Maintenance; reliability; timeliness	C #1
Methods to increase the reliability of the construction planning.	Availability	A #1
• Primary project risk drivers; • Capabilities organization to meet RWS' requirements.	Availability; reliability; timeliness	I #1
Primary unavailability penalty drivers.	Availability; maintenance; reliability	I #2
Reliance on experience judgement and gut feeling.	Availability; reliability	I #3
Ways to evaluate traffic congestion mitigation measures on availability penalties.	Availability	I #4
Types of measures.	Availability	I #5
Ways to align the preferred measure with the contract requirements.	Availability; timeliness	I #6
Selection opportunity-capturing heuristics		
• Project organization's maintenance capabilities; • MEAT-value minimization maintenance nights.	Maintenance; reliability; timeliness	C #1
Estimated frequency of availability penalties.	Availability	C #2

Ability to organize a capable maintenance organization.	Availability	A #1
Ability to create a maintenance organization able to execute required maintenance activities within 20 days after the contract start date.	Maintenance; reliability	A #2
Ability to execute the construction planning at a faster pace than specified in the (concept) DBFM contract.	Timing	A #3
• Direct costs; • Indirect costs; • Feasibility construction planning within contractual deadlines; • RWS' willingness to change requirements.	Availability; timeliness	I #1
Acceptable level of residual risk on unavailability.	Reliability; availability	I #2
Timing opportunity-capturing heuristics		
Sequence and timing of the construction planning.	Availability; timeliness	A #1

Table 32 Decision criteria embedded in the decision rules of observed opportunity-capturing heuristics related to the payment mechanism. The lasts column refers to the heuristic (C: Coen Tunnel Company; A: A-Lanes A15; I: IXAS Gaasperdammerweg)

Decision criteria		
Selection opportunity-capturing heuristics		
Ability to organize required maintenance activities within the minimized number of maintenance nights.	Maintenance; reliability; timeliness	C #1
Conviction tender manager defendability estimated frequency of availability penalties.	Availability	C #2
Ability to create a maintenance organization able to execute maintenance activities in a shorter recovery period	Availability	A #1
Ability to create a maintenance organization able to execute required maintenance activities within 20 days after the contract start date.	Maintenance; reliability	A #2
Ability to execute the construction planning at a faster pace than specified in the (concept) DBFM contract.	Timeliness	A #3
• Sufficiency of budget; and • Feasibility of construction planning within deadlines; • RWS' willingness to change requirements.	Availability; timeliness	I #1
Proportion risk appetite and residual risk .	Reliability; availability	I #2
Procedural opportunity-capturing heuristics		
Risk Priority Number of the availability requirement category.	Maintenance; reliability; timeliness	C #1
Sufficiency knowledge construction planners on the payment mechanism.	Availability	A #1
Sufficiency organizational capabilities to demonstrate compliance with RWS requirements.	Availability; reliability; timeliness	I #1
Relationship WBS with type of requirement.	Availability; maintenance; reliability	I #2
• Basis for decision making; and Disparity of information sources.	Availability; reliability	I #3
Sufficiency of knowledge on the payment mechanism.	Availability	I #4
Type of measure is a traffic congestion mitigation measure.	Availability	I #5
Conflict with one or more requirements.	Availability; timeliness	I #6
Priority opportunity-capturing heuristics		
Relationship requirements to realization stage.	Availability; timeliness	C #1
Project stage in which unavailability is prevented.	Availability; timeliness	C #2
Resemblance contractual formulation and interpretation RWS' intention.	Availability	C #3
Project stage in which revenue is generated.	Availability; timeliness	C #4
Ownership project objective with which the measure aligns.	Reliability; availability;	A #1

	maintenance; timeliness	
Alignment with type of requirement.	Maintenance; availability	I #1
• Sufficiency of budget; and • Feasibility of construction planning within contract deadlines; • RWS' willingness to change requirements; • Indirect costs from unavailability.	Availability; maintenance; reliability	I #2
Timing opportunity-capturing heuristics		
Sufficiency of contractual exemptions for execution of construction activities.	Availability; timeliness	A #1