Project-financed Infrastructure: a Systematic Approach to Evaluating Project Complexity From a Lenders’ Perspective

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Project-financed Infrastructure: a Systematic Approach to Evaluating Project Complexity From a Lenders’ Perspective

By

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Graduation Thesis Report

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my curiosity of knowing more about them than what technical drawings may convey. Exploring the multidisciplinary
crossroads of engineering and management, I have learned that understanding the perspectives of different
stakeholders is of pivotal importance for planning projects at both strategic and operational level.

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projects, which helped me set a course for the final steps of my CME journey. Inspired by an internship at a financial
institution, I found the interfaces between engineering and finance disciplines in project-financed infrastructure
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I hope you will enjoy reading this report!
Nejc Švent
Summary

Introduction and problem statement

The planning, implementation and operation of large infrastructure projects brings together a range of stakeholders with variously aligned interests and risk perceptions. Public-private partnerships (PPPs) are becoming an attractive delivery model for such projects. In such partnerships with characteristic risk allocation patterns and project financing arrangements, lenders are vital stakeholders. Lenders have a unique risk exposure that highly depends, ceteris paribus, on the borrower’s successful construction and uninterrupted operation of the infrastructure asset concerned. Lenders’ risk analyses therefore need to understand a project’s technical substance as a basis for appraising the quality of borrower’s plans and making decisions on conditions of financing. This need makes an interesting interface of disciplines, where engineering and finance worlds must meet and work together. A common practice is that lenders’ risk analyses are supported by specialised engineers who carry out technical due diligence (TDD) by analysing a project’s technical features and appraising the associated project risks. Previous research had highlighted a lack of research on streamlining risk analyses in PPPs, and better tailoring due diligence attention to the complexity of projects. As much as academic research has focused on the lenders’ perspective, limited attention has been given to project risks related to project-specific technical features, important factor in the lenders’ risk perception. These features are often related to project complexity, a concept extensively researched in the domain of project management but less understood from the perspectives of lenders as specific stakeholders. This thesis explores the lenders’ perspective of project complexity and aspires to improve the cross-disciplinary collaboration of engineering and finance experts, specifically in the domain of lenders’ TDD. A systematic approach is established that supports complexity evaluation by engineers in a manner that efficiently informs lenders’ risk analyses and eventually the decision-making on project finance loans. The addressed research question is:

*In what ways can a systematic project complexity evaluation in technical due diligence contribute to supporting lenders’ decision-making on project finance loans?*

To answer the main research question, four sub-questions have been formulated and addressed in sequential order. First, the role of complexity has been explored in the context of lenders’ risk-based decision-making. Second, a systematic approach is proposed for evaluating project complexity in the realm of lenders’ TDD. Third, the TDDs of case study projects have been revisited to measure their complexity based on inputs from finance and engineering professionals. Fourth, interviews with lenders have been carried out to discuss the implications of complexity evaluated through the proposed systematic approach and how its better mutual understanding can enhance existing practices.

A specific perspective of project complexity

Project complexity had been extensively studied in the domain of project management, and various definitions and characterisations had been elaborated. For a project’s internal stakeholders, complexity evaluation posits an aid to adapt early project planning and management, for which complexity is seen as having both positive and negative impacts. While influencing factors of project complexity have been said to differ per specific stakeholder perspective in each project type, empirical research had mainly focused on the perspective of project managers. However, lenders are a specific stakeholder with a different view of project complexity. In this context, lenders are (i) **external to a project** and thus have limited control over its planning, as they only get involved in late stages, (ii) **distinctly risk-averse** and thus predominantly consider negative impacts of project complexity, and they (iii) **adopt a legalistic view** with the project’s specific contractual arrangements shaping their risk perception. These differences may have led to observed **inefficiencies in communicating a project’s complexity** from a lenders’ perspective in collaboration between engineering and finance professionals in TDD.

A desk review of the context of lenders’ risk-based decision-making found that throughout the project’s lifetime, the lenders’ perspective of project complexity is related to the project-specific risk character at a high level. This perspective of project complexity mainly considers a project’s engineering and managerial features, for an understanding of which lenders’ risk analyses generally rely on TDD performed by engineers. Representing an important element of credit risk assessment, the understanding of a project’s complexity may directly influence an infrastructure project’s affordability. Therefore, for project complexity evaluation in TDD supporting lenders’ risk analyses, a clearly defined and mutually understood definition of project complexity must be operationalised. The role of project complexity in TDD was found to be related to the nature and amount of project-specific
It is recommended to compare, discuss and align the involved finance and technical views between the involved experts, for which the BWM method needed. The complexity had previously been arbitrarily assessed by experts participating in a lenders' due diligence process. Best-specific complexities should be emphasised for appropriately informing lenders’ risk analyses and managing. Focus on the manageability of specific complexities and the parties’ risk management capacity.

Engineers’ individual views of the proposed systematic approach, its potential complexity elements identified in a desk study were used to define a hierarchical complexity evaluation model. The top-level complexity factors reflect the top-down view of lenders in credit risk analysis models. The underlying detailed-level complexity indicators comprehensively cover project-specific engineering and management features enabling engineers’ bottom-up complexity evaluation. Second, the relative importance of complexity indicators in the considered project type must be determined by experts participating in a lenders’ due diligence process. Best-Worst Method (BWM) is applied to transpose detailed-level complexity scores to a higher-level overview of a project’s complexity, while also reflecting different individual views of the experts. Third, through a consistent qualitative complexity scoring system, project complexity must be quantified based on inputs of engineers carrying out a TDD analysis.

The proposed approach was applied by revisiting the TDD stage of two explanatory case study projects and obtaining inputs from finance and engineering experts. The results confirmed the need for a clearer and more nuanced systematic complexity evaluation. The case studies pointed at the presence of different individual concerns and preferences as to the importance of various complexity indicators, even among experts involved in the same project’s due diligence. This further highlighted the need for communication and collaboration in evaluating a project’s complexity. While the studied projects’ complexity had previously been arbitrarily assessed based on project types or rather general beliefs, the systematic approach helped expose a specific project’s complex aspects and show that more differentiation between projects per level of complexity is indeed needed. The systematisation of complexity evaluation therefore enables improved communication between engineering and finance experts in TDD. Importantly, however, the evaluation exercise itself should be assisted by reciprocal communication of individual views between the involved experts, for which the BWM-based component of the proposed approach provides a useful platform.

Conclusion
This study confirmed that an absence of a systematic project complexity evaluation can give rise to conflicting perceptions about a project’s inherent risk character. It was shown that the proposed systematic approach to complexity evaluation can act as a needed nexus between engineering and finance expertise. If applied at an early phase of lenders’ due diligence, the approach can facilitate communication and collaboration, complementing the existing practices and methodologies by establishing a common understanding of a project’s substance. Through critically considering different experts’ views enabled by a BWM-based analysis, an enriched understanding of project complexity can be gained. The proposed systematic approach can therefore help streamline the identification, evaluation and management of risks and eventually contribute to more informed lenders’ decision-making.

Recommendations
The study’s findings and positive conclusions lead to the following recommendations to engineers supporting lenders’ risk analyses:

**Take a clear stance on a project’s complexity and be aware of the lenders’ specific perspective** – While engineers’ focus on detailed technical risks is ultimately needed in supporting lenders’ risk analyses, a clear stance on a specific project’s overall complexity from a technical perspective is an important starting point.

**Apply the proposed approach facilitating communication and collaboration in early TDD** – As a central component of the proposed systematic approach, it is recommended to compare, discuss and align the involved finance and engineering experts’ individual views, ideally prior to detailed due diligence.

**Focus on the manageability of specific complexities and the parties’ risk management capacity** – Manageability of specific complexities should be emphasised for appropriately informing lenders’ risk analyses and ultimate decision-making.
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1 Introduction
The planning, implementation and operation of large infrastructure projects brings together a range of stakeholders with variously aligned interests and risk perceptions. Large infrastructure construction projects come at a high cost forming a hurdle for project owners planning and implementing infrastructure development visions. There are various ways of securing financing for a project, and different sources of finance can be thought of. Inevitably, most large infrastructure projects involve borrowing funds. This makes lenders an important stakeholder in the construction project lifecycle. This thesis explores the perspective of lenders in project-financed infrastructure, and focuses on exploring projects’ technical features seen as complexities potentially giving rise to the risk perceived by the project’s debt providers. As explained in the following sections, lenders’ risk exposure in project-financed infrastructure highly depends, ceteris paribus, on the borrower’s successful delivery and uninterrupted operation of the infrastructure asset concerned. Lenders’ risk analyses therefore need to understand a project’s complexity as a basis for appraising the quality of borrower’s plans and making decisions on conditions of the potential financing agreement. In this process, finance experts are supported by engineers specialised as lenders’ technical advisers (LTAs) who carry out technical due diligence (TDD), a thorough expert analysis of a project’s technical features and associated project risks. Therefore, the focal point of this thesis is the process of TDD carried out by engineers, whose expertise is essential in ensuring lenders’ thorough understanding of the project’s technical aspects relevant in lenders’ risk analyses and decision processes.

1.1 Introduction to the research subject
For complex infrastructure projects with long construction periods and operational life, project finance is increasingly considered a preferred financing arrangement. Project finance (PF) is a method of financing projects defined by Yescombe (2014, p. 1) as “raising long-term debt financing for major projects [...] based on lending against the cash flow generated by the project alone”. To enable this, PF’s key characteristic is the establishment of an ad hoc entity – the project company, also called special purpose vehicle (SPV) – whose sole undertaking is the realisation of the project agreed with its client in the project agreement.

The interest in PF has increased in parallel to the growing market for public-private partnerships (Yescombe, 2007), or PPPs, that expanded globally since the late 1990s (IPFA, 2016) as a model for attracting private finance to public infrastructure projects. The financing of PPPs is based largely on the PF structure (Cruz & Sarmento, 2017) and the two notions are often used interchangeably due to the complementarity of the underlying concepts. In PPPs, PF is used because it facilitates favourable allocation of risks (Brealey et al., 1996) among the different stakeholders who have a largely shared fundamental interest in successfully delivering the project (Demirag et al., 2011).

Notwithstanding its common association to PPP infrastructure projects, which are the focus of this study, project finance must be understood more broadly – as a financing method that can be contrasted to the more traditional corporate finance in that it (i) includes the establishment of a highly-leveraged SPV and (ii) provides very limited guarantees from SPV’s equity providers (also called sponsors) to lenders seeking security of their loans (Steffen, 2018; Esty, 2004). In distinct contrast to corporate finance where lenders can have recourse against a borrower’s existing assets in case of default in loan repayment, PF lenders mainly rely on the promise of future cash flows from the successfully constructed and operated project itself. This is because the only existing asset an SPV, as a borrower, holds at loan approval is the project agreement according to which any remuneration is largely dependent on its successful construction and uninterrupted operation of the infrastructure project concerned. This positions lenders as a stakeholder with a pronounced interest for adequate planning, successful realisation and efficient operation of the project itself.

1.1.1 Lenders’ due diligence
It follows from the above that from loan approval until eventual debt repayment, PF lenders must carefully scrutinize a project to identify and manage any downside risks that could affect the SPV’s cash flows and, in turn, reduce its ability to repay the loan (IPFA, 2016, Yescombe, 2014; Rajgor, 2011). To do so, lenders’ risk analysis and decision-making relies on various external advisers providing specialised due diligence services – these may include technical, legal, financial and insurance advisers (Yescombe, 2014).
This study focuses on the realm of lenders’ TDD carried out by independent engineers acting as lenders’ technical advisers (LTA). An LTA is appointed by one of the shortlisted bidders at the beginning of its final dialogue with the contracting authority. TDD often takes place in parallel with the bidding consortium’s final bid preparation activities, negotiations with the contracting authority, and lenders’ risk analyses. In the TDD process, LTAs play an important advisory role through ensuring that the prospective lenders’ interests and requirements are understood and properly taken into account by the borrower, and independently examining lenders’ exposure to risks related to the technical aspects of the borrower’s offer to the contracting authority. LTAs therefore act as a link between the borrower’s project management team and finance experts (e.g. credit risk analysts at financial institutions) to support the assessment of a project’s readiness for securing favourable financing conditions through robust risk mitigation (Gatti, 2018; Yescombe, 2007).

Figure 1 outlines the process of TDD as organised by Mott MacDonald as one of the leading engineering firms involved in infrastructure projects as LTA. Parallel processes can be observed of (i) final stages of a typical PPP procurement procedure, (ii) bidders’ final offer preparation and (iii) lenders’ TDD carried out by LTAs ahead of the project’s financial close. As shown in the figure, initial TDD analysis takes place in parallel to the bidder’s second-stage dialogue with the contracting authority, which culminates in the bidder’s submission of the best and final offer (‘BAFO’). Before submission to the contracting authority, lenders perform due diligence on this final offer to confirm their commitment to financing the bidder’s delivery of the contractual obligations. The contracting authority carrying out the procurement process then selects the preferred bidder who establishes an SPV, following which the contractual close (‘CC’ in Figure 1) can take place where the final project agreement between the contracting authority and the SPV is signed. Finally, financial close of the agreement between the SPV and its lenders takes place.

TDD analyses are generally concluded prior to financial close, after which lenders’ scrutiny over the project continues through construction and operation monitoring – with a focus on any risks identified during the due diligence phase. The expertise of LTAs in the due diligence phase, while essential for supporting creditworthiness at the outset (Gatti, 2018), therefore also has a bearing on facilitating the longer-term success of a PF infrastructure projects.

Figure 1: Organisation of LTAs’ TDD process in context of PPP procurement (Source: internal Mott MacDonald NL B.V.; used with permission)
1.1.2 Literature review

Existing research covering project-financed engineering projects has focused predominantly on public-private partnerships for infrastructure projects. As mentioned in the introduction, PF is the most common financing scheme of PPPs that are based on integrated contracts between a contracting authority and an SPV, also referred to as build-operate-transfer (BOT) or design, build, finance, maintain and operate (DBFMO) contracts (Brealey et al., 1996; Cruz & Sarmento, 2017; Yescombe, 2014 & 2007).

Academic studies from the points of views of different actors involved in PF infrastructure projects can be distinguished: most commonly addressed are the perspectives of project owners/contracting authorities (e.g. Greve et al., 2018; Liu et al., 2016; Osei-Kyei & Chan, 2015; Zhang, 2005) and of equity sponsors (e.g. Alavipour & Arditi, 2018; Cruz & Sarmento, 2017; Schaufelberger & Wipadapisut, 2003). It has been emphasized by various authors (e.g. Hodge & Greve, 2018; Alavipour & Arditi, 2018; Cruz & Sarmento, 2017) that existing research on the lenders’ perspective is relatively limited.

PF lenders may include commercial banks, bond investors and other senior debt providers, and are one of the key stakeholders in PPP projects having a distinct perception of risks compared to other players involved (Yescombe, 2018; Demirag, 2012; Grimsey & Lewis, 2002). PF structures are characterized by the establishment of an SPV which reduces its financing costs by using high debt-to-equity ratios. This inevitably transfers a majority of the SPV’s risk to its lenders. Lenders can only rely on future cash flows from the fully operational asset to get their loan repaid, which is dependent on substantial success of the project. Limited return on debt investment, however, makes lenders the most risk-averse participant in PPPs (Demirag, 2011) and all risks they bear are downside risks (Grimsey & Lewis, 2002). To grant loans on affordable conditions, they therefore look to the project company to contractually isolate itself from even unlikely risks (Yescombe, 2018) by transferring them to its sub-contractors (see Figure 2). Therefore, the perceptions of lenders may differ from those of other key PPP players due to the wide range of risks they need to assess and mitigate in structuring a PF deal.

Risks taken into consideration by PF lenders culminate in an assessment of overall credit risk. Credit risk has been broadly divided into project risks, macro-economic risks, and regulatory/political risks (Yescombe, 2014). Credit risk can be generally seen as the likelihood of borrower’s failure to repay its loan: project risks stem from the project itself and the immediate (economic) environment in which it is positioned; macro-economic risks relate to the wider economic context indirectly affecting the project; political risks concern the repercussions of political and regulatory dynamics (Yescombe, 2014). Macro-economic, regulatory and political risks that lenders consider in PF projects are rather extensively covered in academic literature (Dorobantu & Müllner, 2017; Osei-Kyei & Chan, 2015; Hainz & Kleimeier, 2012). By contrast, the lenders’ perspective of project risks is less well elaborated in the existing studies.

Figure 2: Typical organisational structure and related risk transfer paths in project-financed (PPP) infrastructure projects.
Though they are often the immediate cause of cost and time overruns in construction projects, lenders consider these risks easier to manage through contractual allocation to the parties best able to manage them (Yescombe, 2014; Demirag et al., 2012; Rajgor, 2011).

As indicated in the introduction, a thorough overview and analysis of the technical sources of project risk is at the core of the practice of lenders’ TDD carried out by lenders’ independent engineers before financial close. The role of technical advisers in TDD was summarised by Gatti (2018, p. 122) as “critical analysis of all technical aspects of the deal, with reference to project, contractual and financial data that are usually already quite well defined [at the time of lenders’ due diligence]”. The general scope of TDD entails (Gatti, 2018) checking the completeness of documentation, adequacy of technologies, maintenance requirements, vulnerability to harmful events, environmental impacts, financial assumptions, schedule robustness and organizational issues. In summary, a wide range of project’s technical aspects must be considered by engineers providing support to lenders’ risk evaluation and decision-making in the due diligence phase.

In academic research addressing debt-financing of PPP infrastructure, projects’ technical features seen by lenders as complexities potentially giving rise to credit risk are not discussed thoroughly. A model, by Kong et al. (2008), to quantify the lenders’ default risk exposure in project finance loans is based on credit ratings, market data and financial information as the required inputs; a project’s technical aspects are not explained or used as a variable. In a study addressing PF loan pricing specifically for infrastructure projects, Cruz & Sarmento (2017) related project value, complexity and uncertainty to increased cost of project finance loans in highway projects. However, project-specific technical features considered in the analysis were immensely simplified – especially project complexity which was only related to the length of the highway section built. This is an oversimplification as previously shown by e.g. Bosch-Rekveldt et al. (2011) who have characterised project complexity as a very multi-faceted phenomenon. They also argued that project size was not necessarily a direct contributor to complexity, though it had traditionally been widely considered a central complexity indicator. Based on inputs of Indian lending institutions, Laishram & Kalidindi (2009) presented a model to assess desirability of projects from a debt-financing perspective (DRAT) aimed at supporting the SPV’s project preparation activities for tolled road PPP projects. While the model entails a variety of parameters including some high-level technological, construction and operational aspects, it provides merely a high-level overview of considerations possibly important to lenders’ decision-making.

Showing that a very wide range of risks is important to the financiers of PPP projects, Demirag et al. (2011) emphasised that the design- and development-related risks were perceived particularly important to lenders before a project’s financial close and during construction. An ensuing study (Demirag et al., 2012) explored how and why risks in PPPs are allocated among various PPP stakeholders including senior debt providers, the lenders’ main goal being to transfer project risks away from equity partners (preferably pass them on to the contractors in particular) and minimise their loan’s exposure to any construction or performance risk. This underlines the need for careful assessment of the nature and severity of project-specific risks and any mitigations that are in place in the PPP structure, which then facilitates appropriate risk allocation as the central concern for lenders.

In summary, lenders’ perspective on project-specific technical features that give rise to credit risk have received limited attention in academic research. Project risks are generally less studied than other categories of the overarching credit risk, such as financial, regulatory and political risks. Project risks may be seen as an important component of credit risk for several reasons. First, lenders’ risk exposure is greatest during construction and early operational phases due to the abundance of technical risks and absence of project revenues. Second, a thorough understanding of projects’ technical risks is essential in enabling their appropriate allocation and mitigation with a view to fully appraising the overall credit risk. Third, assessing the projects’ exposure to their inherent risk is at the centre of attention of lenders’ TDD carried out by independent engineers acting as lenders’ technical advisers (LTAs), and best practice must be set for appropriately supporting the lenders’ risk assessment and decision-making on loans.

1.2 Problem statement

As discussed above, the lenders’ risk exposure in PF infrastructure is highly dependent the risks of the project itself. In the context of lenders’ risk assessments, it is important to recognise that a borrower is as good as the project it represents (Pantelias & Roumboutsos, 2015). The lack of studies on project-specific technical features that give rise
to an infrastructure project’s credit risk signals a limited understanding of the lenders’ perspective of project complexity. The importance of multidisciplinary collaboration between engineering and finance professionals in TDD of project-financed infrastructure necessitates a better understanding and methodical evaluation of technical sources of project complexity from the perspective of lenders’ risk evaluation and decision-making. While trivialising a project’s complexity could put the capital at greater risk, overstating it could unjustly increase the cost of debt financing. In both cases, the total cost of infrastructure development could escalate either directly or indirectly. Through better understanding between engineering and finance disciplines as to a project’s complexity, better infrastructure can be planned and delivered (Figure 3).

Project finance has traditionally been used for highly complex projects (Gatti, 2018), but it has been argued that this financing technique needs to become more supportive of less complex projects on the rise recently for example in renewable energy projects (Steffen, 2018). In this respect, a good understanding is needed of project complexity perceived by lenders. This is relevant in the realm of TDD supporting lenders’ risk analyses and decision-making on project finance loans, as it could enable to focus detailed due diligence and subsequent construction and operations monitoring to a project’s key complexities perceived by lenders’ risk analyses. In this respect, a systematic approach for complexity evaluation applied in TDD may help streamline the risk analyses in finance and engineering.

Figure 3: Relevance of studying the lenders’ perspective
1.3  Research gap

A recent bibliometric review of studies on PPPs by Cui et al. (2018) identifies six knowledge gaps and related research directions in which further research should orient. Notably relevant for the realm of lenders’ TDD as the focus of this thesis is the suggested research direction aimed at streamlining the identification and evaluation of risks, improving risk management and proposing feasible decision methods. Cui et al. (2018) additionally reiterated that sustainability performance of projects must be ensured throughout the PPP project lifecycle (Shen et al., 2016), to which end more studies should be devoted with sufficient attention to detail.

At a more applied level, these views appear shared by Steffen (2018) having studied the importance of project finance for renewable energy projects. The results of the study implied a need to structure due diligence criteria and develop systematic tools that could standardise the approach to PF due diligence. As highlighted by the author, this is needed to facilitate the creation of a project-finance lending environment that is more supportive of smaller and less complex projects observed to have been on the rise recently. The fact that lenders’ decisions are backed by careful scrutiny including TDD of a project is often portrayed as beneficial to the overall sustainability of large infrastructure projects (Yescombe, 2014; HM Treasury, 2010) but can have considerable scheduling and budgetary implications for the overall project due to the time- and resource-intensity of such procedures. The transaction costs and the complexity of project financing itself may become an entry barrier for smaller and/or less complex projects. This further marks the need for setting best practice for TDD through developing feasible complexity evaluation methods related to lenders’ risk analyses and decision models. Therefore, the research direction proposed by Cui et al. (2018) also applies to the domain of TDD, the lenders’ risk analyses, and lenders’ decision-making these ultimately support.

A growing body of research on construction project complexity from a project management perspective has discussed complexity definitions, compiled extensive lists of complexity indicators and proposed tools to facilitate the appraisal of project complexity (e.g. Qazi et al., 2016; Nguyen et al., 2015; Lu et al. 2015; Bosch-Rekvedt et al., 2011); no studies appear to have focused on the lenders’ perspective and the particular realm of TDD (see 2.1). Exploring the implications of systematically evaluating project complexity arising from the project’s technical aspects perceived as giving rise to credit risk could therefore help address the research gap indicated by Steffen (2018) and represent a step into the research direction defined by Cui et al. (2018).

1.4  Research objective

Following from the above scientific research gap, the research objective for this study is:

Contribute to improving the process of lenders’ technical due diligence in project-financed infrastructure by proposing a systematic approach facilitating engineers’ effective evaluation and efficient communication of infrastructure projects’ complexity in support of lenders’ risk analyses and eventual decisions on project finance loans.

Fulfilling the above research objective may additionally represent a step taken towards achieving higher-level objectives from the following perspectives

- **Scientific perspective**
  By exploring the lenders’ perspective of project complexity and providing insight into a specific stakeholder’s views in infrastructure development, expand the existing academic body of knowledge on engineering and management of large infrastructure projects.

- **Organizational perspective**
  By exploring the lenders’ perspective of project complexity to streamline the process of collaboration between engineers and finance experts, contribute to defining best practice in the field of TDD supporting lenders’ risk analyses.

- **Sectoral perspective**
  By clarifying and improving a part of the decision process on project-finance loans for construction projects, help the key stakeholders in construction industry to plan and deliver better projects from the perspective of bankability.
- **Societal perspective**

By enhancing the effectiveness and efficiency of TDD as a means of controlling projects’ overall quality, help reduce the societal cost of infrastructure development.

1.5 **Research question**

In order to address the research objective, the following research question is formulated:

**RQ: In what ways can a systematic project complexity evaluation in technical due diligence contribute to supporting lenders’ decision-making on project finance loans?**

To answer the above research question, a set of sub-questions shall be answered in the following order:

**SQ1. What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on project finance loans?**

**SQ2. In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?**

**SQ3. How can the systematic approach to complexity evaluation be applied in technical due diligence?**

**SQ4. In what way does the applied systematic approach to complexity evaluation contribute to the process of technical due diligence and support lenders’ decision-making?**

1.6 **Research approach**

This section presents the systematic research approach applied in this study. The approach is divided into four phases corresponding to the four research sub-questions defined above. First, the meaning and role of project complexity in the context of decision-making on project finance loans is explored, pointing to the practical relevance of the research problem and setting the direction for proposing a systematic approach to complexity evaluation in lenders’ technical due diligence. Second, a systematic bottom-up approach for evaluating project complexity in the process of TDD is specified. Third, the complexity of two case study projects is measured by applying the proposed approach. Fourth, the implications of a project’s complexity for lenders’ decision-making are discussed and the findings are validated by project finance practitioners which provides insight of the merit of systematic complexity evaluation in the context of lenders’ decision-making. The research approach is schematically illustrated in Figure 4. The four main phases of the research approach are explained in more detail in the sections below.

1.6.1 **Exploring the lenders’ perspective of project complexity**

In the first phase of the research, an exploratory research sub-question (SQ1) is answered:

**SQ1. What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on project finance loans?**

To provide an answer to the above question, the theoretical and practical characterisations of project complexity are explored in a desk research of academic and practical literature, which is carried out in three steps. First, the concept of project complexity is explored based on its characterisations in academic literature (2.1). Second, the practice of TDD carried out by LTAs is reviewed (2.2) based on past projects’ TDD reports and additional insights from exploratory interviews with LTAs. Third, the broader context of lenders’ risk-based decision-making is explored to illustrate the lenders’ project risk perception and gain insight on the meaning of project complexity from a lenders’ perspective (2.3). Based on this specific perspective, projects’ technical features representing complexity elements relevant in the practice of lenders’ TDD can be identified from academic and practice-based literature (2.4). Following the above steps, the first sub-question can be answered by discussing the specific role of project complexity in TDD as governed by its wider context of lenders’ decision-making. Insights from practice help expose the practical relevance of the research problem and set the preconditions for specifying a systematic project complexity evaluation approach as the main objective of this study.
RQ: In what ways can a systematic project complexity evaluation in technical due diligence contribute to supporting lenders’ decision-making on project finance loans?

SQ1: What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on PF loans?

- Desk research
  - Academic literature
  - TDD document analysis
  - Credit risk analysis models
  - Exploratory interviews (LTAs)

- Lenders’ view of project complexity
- Role and elements of complexity in TDD
- Project complexity in literature

SQ2: In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?

- Hierarchical model for complexity evaluation
  - Literature review
  - Literature review, document analysis
  - Expert inputs (LTAs)

- MCDM for determining importance
  - Qualitative system for measuring complexity
  - Proposed approach

Proposed approach to complexity evaluation

- Expert inputs (LTAs, credit risk analysts)
- Expert inputs (LTAs)
- Rank importance of factors & indicators
  - Evaluate complexity at indicator level
  - Determine weights using BWM
  - Detailed complexity quantification

SQ3: How can the systematic approach to complexity evaluation be applied in technical due diligence?

- Case study project (2x)
  - Approach application (2x)

- Expert inputs (LTAs, credit risk analysts)
- Project’s complexity profile (2x)

SQ4: In what ways does the applied approach contribute to the process of technical due diligence and support lenders’ decision-making?

- Interviews with finance professionals
  - Independent validation interview (LTA)

- Implications, clarification and validation

Figure 4: Overview of the research approach
1.6.2 Specifying a systematic approach for complexity evaluation

In the second phase, the second sub-question is answered by specifying a method to evaluate the complexity of projects from the lenders’ perspective.

**SQ2. In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?**

Taking into account the lenders’ specific perspective of project complexity and the observed need for its clearer evaluation by lenders’ engineers, this step starts by explaining the complexity evaluation challenge and defining the practical requirements for systematising the approach to complexity evaluation in technical due diligence. The relevant high-level complexity factors and detailed-level complexity indicators are discussed and structured into a hierarchical model that may be used for complexity evaluation. Next, a method is elaborated that enables an analysis and quantification of the relative importance of detailed-level complexity indicators included a considered model. A qualitative complexity scoring system discussed for detailed-level complexity indicators to enable quantification of a project’s complexity. To answer SQ2 of the research question, the way in which project complexity can be systematically evaluated in technical due diligence is explained, as well as presenting the series of steps to be taken in its application in this study.

1.6.3 Case study application

The application of the approach specified in the previous phase is illustrated by evaluating the complexity of two case study projects. The addressed research sub-question is SQ3:

**SQ3. How can the systematic approach to complexity evaluation be applied in technical due diligence?**

In this step, the complexity of two explanatory case study projects is measured by applying the specified systematic approach. The early TDD phase is revisited for the two case study projects. First, a document review of the projects’ background information that had been available before detailed due diligence is carried out, providing a basis for assessing the complexity of each project. Based on the inputs of each project’s LTAs and finance experts involved at the time of TDD, the importance of complexity indicators is analysed using a questionnaire survey. Based on inputs solicited through semi-structured interviews with LTAs, the proposed approach is applied to explore the case study projects’ complexity from the lenders’ perspective. Two real-life, ongoing projects are revisited in this way, enabling a discussion of their overall complexity profiles, while empirical observations from the approach application provide input for answering this research sub-question.

1.6.4 Clarification and validation interviews

Finally, validation of this study’s findings follows the test application of the specified approach, aiming to answer the final research sub-question:

**SQ4. In what way does the applied approach contribute to the process of technical due diligence and support lenders’ decision-making?**

To expose the ways in which systematic complexity evaluation in technical due diligence could contribute to supporting lenders’ decision-making, several interviews are conducted that provide a degree of research validation and an answer to the final research sub-question. The first set of interviews are held with finance experts representing lenders in the revisited case study projects. These interviews are carried out to clarify the observed inputs, discuss the results of systematic evaluation, and explore the implications of systematic complexity evaluation for the lenders’ analyses and decision-making. Second, as an independent validation of this study’s previous findings, an additional interview is held with an engineer specialised as a lenders’ technical adviser. Together, the interviews provide input for discussing the answer to the final research question, highlighting the way in which the applied systematic complexity evaluation can improve the process of technical due diligence.
1.7 Structure of the report

The report is structured according to the research questions. Each chapter presents and discusses the results of the part of the overall research defined by each research sub-question. At the end of each chapter, an answer to the respective research question is discussed. Answers to all research questions are aggregated in the final chapter to provide the main conclusions and recommendations based on this study’s empirical findings.

In Chapter 2, the concept of project complexity is first explored based on its characterisations in project management literature. To explore the specific perspective of lenders not found in academic literature, the practice of TDD is reviewed first, following which the role of complexity is explored in the context of lenders’ risk-based decision-making. Taking into account a stakeholder-specific definition of project complexity, project-specific technical features are identified from the reviewed sources that are relevant for evaluating project complexity in TDD.

In Chapter 3, a systematic approach is specified for evaluating project complexity in the realm of lenders’ TDD. The need for complexity evaluation from a lenders’ perspective is observed as a missing starting point of technical due diligence. It is structured as a multi-criteria decision-making problem whereby the proposed approach comprises several steps that may provide more detailed insight into a project’s complexity from the lenders’ perspective.

In Chapter 4, the specified systematic approach to complexity evaluation approach is applied by revisiting the TDD stage of two case study projects.

In Chapter 5, interviews with lenders are carried out to explore the ways in which a systematic complexity evaluation by engineers can provide insight to help steer TDD and contribute to supporting the lenders’ risk analyses and decision-making on project finance loans.

Chapter 6 discusses the conclusions, recommendations and limitations based on findings of the study.
2 Role of project complexity in technical due diligence

In this chapter, the meaning of project complexity is explored in a desk review of academic and practice-based literature. First (2.1), the academic body of knowledge on project complexity in the domain of project management is explored. Second (2.2), the current approach to lenders’ technical due diligence (TDD) is reviewed in a desk study and exploratory interviews with practitioners. Third (2.3), a broader perspective of what TDD should entail is explored by turning to its context of lenders’ risk-based decision-making. Based on these exploratory insights, a lenders’ perspective of project complexity is discussed (2.4). By characterising the meaning of project complexity within the context of lenders’ decision-making, an answer to the first research sub-question is thus derived:

SQ1: What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on project finance loans?

2.1 Project complexity

Project complexity has become one of the most important topics of research within the domain of project management (Luo et al., 2017) with authors underlining the importance of better understanding project complexity for tailoring the project planning and management approach with a view to improving project performance (e.g. Dao et al., 2017; Luo et al., 2017; Qazi et al., 2016; Xia & Chan, 2012; Bosch-Rekveldt et al., 2011). The studies have predominantly focused on listing the sources of project complexity but also exploring the relationship between project complexity and performance, proposing approaches for evaluating project complexity, and discussing implications of increased complexity for project management. While a negative relationship between complexity and project success has been shown (Bjorvatn & Wald, 2018; Luo et al., 2017), the purpose of evaluating project complexity is not necessarily to tame a project’s behaviour, but to better anticipate the spectrum of turns it might take (Bosch-Rekveldt et al., 2011). Complexity is therefore seen as a characteristic of projects and has been used to help describe projects and their contexts, in turn identifying opportunities to improve their management (Bosch-Rekveldt et al., 2011). There remains a wide range of different views among scholars as to what project complexity is and what defining factors it entails (Luo et al., 2017), for example whether risk is a source of complexity or its consequence (Qazi et al., 2016; Thomé et al., 2016; Bosch-Rekveldt et al., 2011) and what dimensions and sources of project complexity need to be considered in its thorough assessment (see Table 1).

The perceptions of what contributes to project complexity vary per stakeholder and per project type (Luo et al., 2017, Xia & Chan, 2012). Furthermore, project complexity profile is time-dependent as it dynamically changes throughout the project lifecycle (Hertogh & Westerveld, 2010). Therefore, the complexity elements and measurement systems proposed in academic studies have mostly aimed to capture complexity at a broad level (Bakhshi et al., 2016) tailored to the needs of early stages of project definition and planning. The complexity elements that have been used in characterising project complexity are relatively abstract and generic (Xia & Chan, 2012), which has been exposed as a challenge to their use in practice (Luo et al., 2017; Xia & Chan, 2012). For construction projects, there is a widely recognised need to measure project complexity, but few objective measures have been proposed (Xia & Chan, 2012). Luo et al. (2017) exposed a continued lack of agreement on the meaning of project complexity within construction industry, underlining the need to specify the influencing factors of complexity from the perspectives of specific stakeholders in specific project types within the construction industry.
Table 1: Overview of different characterisations of complexity in existing studies

<table>
<thead>
<tr>
<th>Technical / technological / task complexity</th>
<th>Variation of technologies employed, technological newness of project</th>
<th>Building type, design and construction overlap, dependency on project operation</th>
<th>Number of tasks, complexity of their dependencies</th>
<th>Goals, scope, tasks, experience, risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisational complexity</td>
<td>Contractual conditions, number of contracts and work packages, coordination of stakeholders, planning and scheduling</td>
<td>Project staff, organisational structure, teams</td>
<td>Amount and complexity of participants, complexity of org. structure</td>
<td>Size, resources, project team, trust, risk</td>
</tr>
<tr>
<td>Environmental complexity</td>
<td>Climate, geology &amp; hydrology, environmental risk</td>
<td>Project’s context (natural, stakeholders, market, political, regulatory)</td>
<td>Stakeholders, location, market, risk</td>
<td></td>
</tr>
<tr>
<td>Goal / scope complexity</td>
<td>Ambiguity of scope, project capital size</td>
<td>Requirements, task complexity, limited resources</td>
<td>Different perspectives of multinational participants</td>
<td></td>
</tr>
<tr>
<td>Cultural complexity</td>
<td></td>
<td>Number of stakeholders and communication between them</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information complexity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socio-political complexity</td>
<td>Administrative procedures, number of laws, local experience needed, influence of politics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructural complexity</td>
<td>Site compensation and clearance, transportation systems near project site, contractor qualifications needed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Many different categorisations of complexity elements have been proposed (Table 1), with authors mainly agreeing that projects are characterised in terms of their technical as well as organisational complexity (Luo et al., 2017; Lu et al., 2015). Several authors additionally distinguish the environmental complexity (e.g. Nguyen et al., 2015; He et al., 2015; Bosch-Rekveldt et al., 2011). A visible example is the three-dimensional “TOE” framework for assessing project complexity of large engineering projects at an early planning phase of projects (Bosch-Rekveldt et al., 2011 & 2018), where:

(i) **technical complexity** entails complexity elements pertinent to the project’s own content, including the nature of its goals and scope, the tasks and related experience, technical risks, etc.;

(ii) **organisational complexity** concerns the various complexities stemming from the project’s internal organisation, including its size, type of internal stakeholders and relationships between them, management methods and tools, etc.; and

(iii) **environmental complexity** considers complexities arising from the environment with which the project interacts, including the physical environment, key external stakeholders and wider political, financial and economic environments.
It appears that the considered scope of complexity definition, the perception of the observer and its professional background can influence the insight obtained from the results of complexity evaluation. For example, while applying the TOE framework to survey the complexity perceptions of project management professionals in infrastructure construction sector (Bosch-Rekveldt et al., 2018), a subset of 13 complexity elements from all three categories were pointed out as most important, which were related to interfaces, planning, resources, project content, and stakeholders. Interestingly, no technical complexity element was among those rated most important overall by respondents (Bosch-Rekveldt et al., 2018) who instead seemed most concerned about the project’s environment, notably its external stakeholders and location.

In contrast, Xia & Chan (2012) took a narrower focus, assessing building project complexity defined as the difficulty of delivering a project, and determined the most important complexity drivers as: building function and structure, construction method, schedule urgency, project size/scale, geological condition, neighbouring environment. This demonstrates that the definition of scope of project complexity must be related to the purpose of complexity evaluation, an important consideration for obtaining useful insight from its results. A broader view of complexity can be used to facilitate discussion of different perspectives (Bosch-Rekveldt, 2011), while a narrower scope may be beneficial in uses where a more detailed scrutiny of a project is needed by the specific stakeholder concerned and at a specific stage in the project lifecycle.

Discussion

It is observed that the construct of project complexity from a project management perspective is the subject of an ongoing discussion in current academic studies, which consequently do not offer a widely agreed interpretation of what complexity is and what its evaluation should entail. While the existing studies focus on the context of project management, researchers have emphasised that a characterisation of project complexity depends on the characterisations and perceptions of each stakeholder in a project type, while also being dynamic and generally difficult to objectivise.

The present study aims to understand and systematically evaluate complexity on perceived by lenders as a specific stakeholder, in project-financed infrastructure as a specific construction project type. As further explored in the next sections, the purpose and timeframe of project complexity evaluation in lenders’ due diligence are different than in project management where the aim is to aid project planning and management by adapting these to the project’s key identified complexities from an early stage of the project lifecycle. This aim can be directly relevant to a project’s planners at the contracting authority’s side, or to equity sponsors who are often directly involved both in early project planning as one of the members of the bidding consortium, as well as in subsequent project management as an internal participant of the project (Yescombe, 2018). The lenders, on the other hand, are a stakeholder relatively external to the project itself (Gatti, 2018) in that they do not exercise direct control over the project’s planning or management. Their initial due diligence in PPP projects starts at an advanced stage of public procurement (see 1.1.1) when the project agreement is already tendered out and project plans and contracts of the bidding consortium, i.e. potential borrower, are largely ready for submission of a final, binding offer to the contracting authority. These quite thoroughly defined plans and contracts are the subject of TDD (Gatti, 2018) as they directly govern risk allocation arrangements in the overall project structure.

As mentioned in the introduction, lenders in a PPP project are a party most exposed to project risk and most risk-averse at the same time (Yescombe, 2018). They therefore have a risk perception distinct from both the SPV’s and the contracting authority’s managing teams (Demirag, 2011, Grimsey & Lewis, 2002). Due diligence by or on behalf of financiers is aimed exclusively at understanding the risk exposure of their loan (Demirag, 2011). As there is a relationship between the concepts of complexity and risk (Qazi et al., 2016), lenders’ distinct risk perception indicates that a tailored set of specific project complexity elements needs to be found for evaluating complexity from a lenders’ perspective in the practice of TDD.

That said, some notions appear widely agreed in the existing studies on project complexity reviewed and discussed above. These can provide a basis for further examining the lenders’ perception of project complexity. First, as mentioned above, a thorough characterisation of project complexity would not only consider a project’s content in technical terms, but also its organisational aspects, and its interactions with the environment in a wider context.
Second, a project’s complexity is a dynamic characteristic and therefore a forward-looking complexity profile may have to be reconsidered as circumstances change. Third, complexity definition and evaluation are inevitably subjective exercises, so it is important to leave enough space for discussion and critical reflection in complexity evaluation.

Notwithstanding the lack of academic studies on the drivers of complexity relevant to lenders’ decision-making, the above studies offer some complexity elements that can be relevant to the lenders’ perception of project complexity within the context of due diligence and decision-making on project finance loans. These were discussed (2.4) following a review, in the next sections, of the practice of TDD (2.2) and its broader context of lenders’ risk-based decision-making (2.3).
2.2 Technical due diligence – the current practice

In this section, the practice of lenders’ TDD carried out by LTAs is reviewed to gain an understanding of its approach to supporting lenders’ decision-making. First, a desk review is carried out of TDD reports prepared by engineers for three different projects’ respective lenders. Second (2.2.2), exploratory interviews are held with LTA practitioners that point to the key issues experienced in the practice.

2.2.1 Desk review of LTA reports

To illustrate the current approach to TDD, previously completed TDD reports of three past projects were reviewed. To gain general insight into due diligence analyses across different types of privately-financed infrastructure, the reviewed projects pertain to the two main broader project types, i.e. social infrastructure (buildings projects) and economic infrastructure (transportation projects). Furthermore, the aim was to select projects that were different in both capital value and the lenders they involved. Three projects located in North-Western Europe were selected that are financed by international syndicates of lenders and are currently in either construction or operations phases.

Characteristic LTA scope of works

The scope of work of LTAs was analysed for the reviewed projects. It is observed that the general scope of TDD analysis follows a relatively standard structure in all reviewed projects. As the scope of work is generally defined by bidding consortia commissioning LTA services on behalf of prospective lenders (see 1.1.1), this implies the bidders’ and technical advisers’ aligned understanding of what is important in lenders’ credit approval procedures. One reason for this is that the bidders are, as is common in such projects (Yescombe, 2018), major actors in the privately-financed infrastructure construction industry as well as themselves equity investors in the SPV. The involved parties have hence gained substantial experience in ensuring adequate bankability of their projects from a debt-financing perspective. On the other hand, the lenders involved in such projects also tend to be from a relatively select club of major financial institutions who often collaborate in lending syndicates (Yescombe, 2007). The seemingly standard general scope of works commissioned from LTAs in the reviewed projects is therefore not unexpected.

Moreover, it is observed that at the time of appointing LTAs, bidders tend to indicate their view on what aspects of the project may represent the key concern for lenders and therefore need to be scrutinized during due diligence. In Project A, for example, LTA’s attention was directed towards the risks related to tunnel designs; in Project C, interfaces with the existing lanes that had to remain operational throughout the construction period were emphasised as an important aspect to consider during due diligence. The bidders therefore appear to anticipate and emphasise the key points of attention important to lenders’ due diligence.

Key focus areas of the due diligence analysis

The approach to TDD as observed in LTA reports for the three considered projects was analysed. The approach to due diligence follows a largely standard structure across the reviewed projects in various sectors. It is governed by six main topics across the reviewed reports which can be summarised as follows (see Appendix A for details):

- **Stakeholders review** - Here, the focus is predominantly on main internal stakeholders, thus project participants (bidding consortium members and their subsidiaries usually acting as sub-contractors or service providers). External parties, although seen in literature (e.g. Bosch-Rekveldt et al., 2011) as potential drivers of project complexity, are often listed rather briefly and a detailed assessment of their attitudes is not provided.

- **Contract review** - a review of the main contracts is carried out (DBFM agreement and sub-contracts for design and construction and, where relevant, maintenance and operations, as well as any interface agreements between the sub-contracts) with a very specific focus on analysing the substance and mechanisms of risk allocation between the SPV and sub-contractors.

- **Design and construction** - the contracting authority’s specifications for technical solutions are reviewed, identifying any non-standard requirements a competent contractor may not be familiar with.

- **Operation and maintenance** - the operation and maintenance assumptions and plans are assessed starting with a review of authority specifications and the consortium’s proposals.
• **Performance regime** - the performance regime and its penalty and payment mechanism are considered, including the determination of various “worst case” scenarios with occurrence probabilities and penalties quantification.

• **Construction and operation costs** – costs are benchmarked and reviewed against projects of similar size, type and complexity

From the reviewed projects’ LTA reports, it can be concluded that their scope provides a thorough consideration of projects’ key technical, organisational and contractual characteristics and the related financial mechanisms. The reviewed reports are very detailed and comprehensive, and their structure is largely standardised across the reviewed projects. This applies especially to the high-level aspects considered in the reports – as shown above, in all reviewed reports by different teams active in the international LTA market, an almost identical reporting structure is used.

The TDD reports’ conclusions focus on the appropriateness of organisational, contractual and financial safeguards included in the project’s contracts. On virtually all aspects, the technical advisers conclude that the mitigations put in place in the plan are “reasonable” or “considered appropriate” for projects of similar complexity, type or size.

This also reflects the iterative nature of LTA due diligence process where any concerns are openly communicated back to the sponsors as all parties at the due diligence stage share an interest for the borrower to prepare a competitive bid and successfully achieve financial close (see 1.1.1). The analysis behind the LTA reports’ conclusions is connected to some project-specific characteristics which are presented at the beginning of due diligence analysis or highlighted by the bidding consortium. These can be seen as complexity elements that briefly describe the project’s content and its interfaces with the environment.

However, a systematic overview of project complexity is not given, and it usually remains unclear whether, or why, a project was considered more or less complex. This can be seen as an important omission given that the key conclusions of LTA reports tend to judge the extent to which the various aspects of the project plan are seen as reasonable for the complexity of the project. For example, the adequacy of project participants’ experience and sufficiency of construction scheduling items are considered with respect to the complexity of the project. The considered aspects potentially adding to complexity vary quite substantially in the reviewed projects, and their relevance from the lenders’ perspective is not clearly explained, quantified, analysed or presented in another systematic and vivid way. This provides limited insight into whether, from LTAs’ perspective, a project is considered complex, and what the key complexities of the project are.

### 2.2.2 Exploratory interviews

To gain more insight on the practice of lenders’ TDD and any issues encountered in informing the finance experts’ risk analyses, exploratory discussions were held with a team of LTAs at Mott MacDonald active in the European project financed infrastructure market. The firm is known for having built extensive experience as LTAs involved in most project-financed infrastructure projects in the region as well as globally. Due to the interviews’ exploratory nature, a preference was to give the interviewees freedom in steering the discussion. Therefore, the exploratory interviews were unstructured, and the aim was to open a discussion about the practice of lenders’ TDD in general, thus a focus on specific projects or pre-identified issues was not sought at this exploratory stage.

The practitioners noted that there appear to be dissimilar views on the optimal scope and detail of TDD required to adequately support the lenders’ decision-making. This observation was explained on different levels. First, the various expert teams’ approaches to TDD within the international network of the company’s subsidiaries have proven to differ with regard to the exact scope and depth. This has caused internal misunderstandings and inefficiencies in the past, for example as the company’s otherwise separated teams had to collaborate on the same project. Second, opposing views on the required level of detail of due diligence analysis have also been observed among the main engineering consultancy firms specialised for lenders’ technical advisory. The practitioners noted that while a relatively standard structure of reporting is followed across the industry, various levels of pragmatism are manifested in the level of detail and focus of TDD analyses. It was emphasised that the focus does often not depend on the project’s complexity but on what each expert is accustomed to. Finally, in one practitioner’s view,
the centre of attention in pre-financial close due diligence also appears to vary from one lender to another, and the reasons are often unclear.

Moreover, the interviewees exposed an issue of efficiently communicating a project’s technical risk details between the engineers and the less technically adept finance experts. Engineers have been asked by lenders “how complex is this project?”, either to opine on the project’s overall complexity at a high level, or to specify the project’s key complexities. Due to the lack of clarity on what aspects would be relevant to lenders in such a high-level complexity assessment, this has represented a troublesome question. Therefore, an intuitive opinion of the project’s complexity is often made by practitioners, which renders TDD process prone to subjectivity, risking omission of important aspects on the one hand, and superfluity of technical details communicated to lenders on the other hand.

In summary, it follows from the exploratory interviews that there appears to be a lack of clear consensus in the practice of TDD regarding:

- the aspects a comprehensive TDD analysis should cover,
- the detail to which the various aspects of projects should be studied,
- what constitutes project complexity from a lenders’ perspective,
- how the complexity of projects can be clearly communicated to inform finance experts involved in lenders’ decision-making.

Although the need to define an appropriate general scope of TDD was exposed as one of the issues by the practitioners interviewed, the desk study of LTA reports in the previous section indicated a rather widespread agreement as to what top-level aspects fall within the scope of TDD and thus represent projects’ high-level aspects important to lenders. Other findings of the exploratory interviews correspond to the observations in reviewed TDD documentation, notably as regards the need to define a suitable level of detail for TDD on a project-specific basis depending on its complexity, and the need to find a more transparent way of presenting the project’s technical risk character to lenders’ decision makers. This further confirmed the practical relevance of the research gap identified in the introduction (1.3) and marked the need to better align the communication of LTAs due diligence analyses’ results to the context of lenders’ decision-making. The related lenders’ risk perception in project-financed infrastructure is more closely analysed in the following section.
2.3 Lenders’ risk perception and decision-making

Given the lack of literature on lenders’ perspective of project complexity (2.1) as well as its unclear evaluation in the current practice of LTAs’ due diligence (2.2), this section looks at the broader context of TDD. This section explores the lenders’ considerations used in making decisions on project finance loans. As in any investment, the lenders’ decision-making is directly linked to their risk exposure in the project concerned. Therefore, an understanding of the lenders’ perception and analysis of risk helps put into perspective the observations from the current approach to TDD, and provides an understanding of the sources of project complexity from the lenders’ specific point of view.

As mentioned in the introduction, the risk from a lenders’ perspective refers to credit risk, which in project finance can be divided into three main categories. These include project risks, macro-economic or financial risks, regulatory risks and political risks, all together representing the overall credit risk from a lenders’ point of view (Yescombe, 2014). The risk issues listed in Table 2 provide an overview of project risks analysed at the due diligence stage of projects.

Table 2: Key project risk issues considered by lenders (adapted from Yescombe, 2014, p. 200)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial viability</td>
<td>The general needs the project addresses, its business case and position in the market.</td>
</tr>
<tr>
<td>Construction risk</td>
<td>Risk related to constructing the project in line with requirements, on time and within budget.</td>
</tr>
<tr>
<td>Revenue risk</td>
<td>Risk of SPV’s revenues being different than expected (low in availability-based PPPs).</td>
</tr>
<tr>
<td>Operating risk</td>
<td>Risk that project may not perform as required, incurring higher operating costs.</td>
</tr>
<tr>
<td>Input supply risk</td>
<td>Risk that the supplies needed for project’s operation are unavailable at expected cost.</td>
</tr>
<tr>
<td>Uninsured risk</td>
<td>Any risks neither borne by the involved parties nor insured.</td>
</tr>
<tr>
<td>Environmental risk</td>
<td>Risks of unexpected or unacceptable impacts on the project’s environment.</td>
</tr>
<tr>
<td>Residual value risk</td>
<td>Risks related to the project’s value at the end of the project agreement.</td>
</tr>
<tr>
<td>Contract mismatch</td>
<td>Risks related to interfaces between the stipulations project’s key contracts.</td>
</tr>
<tr>
<td>Sponsor support</td>
<td>Credibility and actual commitment of sponsors in the SPV, their dependence on the project.</td>
</tr>
<tr>
<td>Contracting authority’s risks</td>
<td>Risks assumed by the contracting authority its approach to managing them.</td>
</tr>
<tr>
<td>Reasons for failure</td>
<td>Project’s overall exposure to common reasons for failure.</td>
</tr>
<tr>
<td>Loss on default</td>
<td>Amount of lenders’ actual losses in case of default.</td>
</tr>
</tbody>
</table>

From a TDD perspective (see 2.2), the focus is predominantly on technical sources of construction and operating risks. As lenders depend on the project’s revenues to get their loan repaid, their construction and operating risk perception is concentrated on scenarios in which the project fails to meet requirements for drawing the expected revenues on time and within the projected budget. As mentioned in the introduction, empirical academic studies into the technical sources of lenders’ project risk perceptions remain scarce. Demirag et al. (2012) explored how and why risks in PPPs are allocated among various PPP stakeholders including debt providers, and underlined the lenders’ need to transfer any project risks away from equity partners to minimise their loan’s exposure to construction or performance risk. Compared to equity investors in PPP projects, lenders only face the project’s downside risks (Grimsey & Lewis, 2002), which they are not willing to bear due to low returns on debt finance. Therefore, lenders have to take a conservative perspective in their risk analysis and management.

In the project’s construction phase, the risks related to the project planning, technology and construction are at the centre of lenders’ attention (Gatti, 2018), with principal technical risks stemming from the project’s location, the process of construction, and the project’s design (Yescombe, 2018). All risks are identified with a view to assessing the robustness of their reallocation away from the borrower, as any construction risks the borrower retains are ultimately borne by the lenders. This reallocation is done contractually between the contracting authority, the SPV and its construction sub-contractor, or – in case of risks that are difficult to manage – through robust insurance arrangements (Gatti, 2018).

When a typical availability-based infrastructure PPP project is successfully constructed and enters its operations, the SPV’s revenues depend on ensuring the project’s continuous meeting of foreseen availability and performance requirements. In absence of demand risks (e.g. traffic risks in toll roads), risks of the post-completion phase continue to stem largely from the project’s technological features. The project’s revenues need to cover the SPV’s own costs, maintenance and operation costs, as well as enable the SPV to repay its debt. Like in case of construction risks, these risks are borne by the SPV according to the project agreement but are preferably reallocated to a
The lenders’ risk perception in the operational phase is therefore again focused on identifying all sources of risks and how well these are allocated to capable parties.

To gain an understanding of how project-specific risks of the project’s pre- and post-completion phases are treated in debt-providers’ decision-making, the key principles of credit risk analysis models are explored next.

2.3.1 Credit risk analysis models

The lenders interviewed by Demirag et al. (2012) refrained from detailing the specifics of their risk analysis models, instead pointing the researchers to analytical models published by Moody’s credit rating agency on its website and suggesting their good explanation of credit risk drivers usually considered in PFI projects (Demirag et al., 2012). Based on the agency’s long-running experience in project-financed infrastructure, the regularly revised credit rating methodologies provide insight on Moody’s key considerations in analysing construction and operational risks of project-financed infrastructure on behalf of debt providers. As such, their models enjoy remarkable acclaim in the industry (Demirag et al., 2012). The publications point to the key project-specific features affecting the agency’s independent assessment of risks, as well as note that one of the sources of information for its credit ratings are due diligence and project monitoring opinions provided by external advisers including technical experts (Moody’s, 2015 & 2016).

As noted in the introduction, a reference to lenders in this thesis is a general one broadly covering the sources of SPV’s debt financing that may include either commercial banks or bond investors. From the specific viewpoint of engineers supporting lenders’ risk analyses and decision-making, the role of a credit rating agency can be considered equal to that of a bank in terms of project risk perception. This is because borrowing funds from a commercial bank is one of the ways for bidders to secure debt finance in PPP infrastructure, another one being the issue of bonds. While banks usually manage their own credit risk analysis in project finance loans, bond investors rely on credit rating agencies and investment banks to carry out this work (Yescombe, 2018), determining a project’s creditworthiness through issuing a credit rating. In this process, both commercial banks and credit rating agencies work with independent external (technical) advisers and consider the same risks (Yescombe, 2018) as a basis for investors’ risk-based decision-making.

In line with this study’s objective of exploring project complexity from a lenders’ perspective, the leading credit rating methodologies can therefore provide a credible illustration of the key considerations likely to be considered by debt financiers in project-financed infrastructure. These analytical models were therefore explored next, with a focus on the treatment of risks stemming from the project’s engineering and management features. These models represent the receiving end of engineers’ thorough technical risk analyses and are thus directly relevant for understanding the lenders’ view of project complexity in line with the purpose of this study. Applicable rating methodologies that were reviewed include those for project finance in general (S&P, 2014; Fitch, 2018) and those specific to availability-based PPP infrastructure (Moody’s, 2015 & 2016; Fitch, 2015). These publications are accessible at the respective institutions’ official websites (links included in references) upon a free account registration.

Despite the reviewed publications’ solid empirical basis and credit rating agencies’ high acclaim in the industry, some of their limitations must be acknowledged considering the academic purpose of this study. These are mainly related to their non-scholarly, illustrative and thus possibly incomplete nature. The models have also been criticised by scholars for their possibly wrong focus (e.g. Pantelias & Roumboutsos, 2015). These limitations are considered acceptable for the purpose of this study due to its limited timeframe and the importance of exploring a lenders’ prevalent perception of project risks, which would enable a systematic evaluation of project complexity in line with the objective of this study.

As standard in all reviewed methodologies, the credit ratings are assigned separately for a project’s construction phase and its operation phase, and the riskier of the two is taken into account in deriving a project’s overall creditworthiness. The entire analysis furthermore includes financial analysis, counterparties, and external environment (Pantelias & Roumboutsos, 2015). The lenders’ risk perceptions with regard to technical aspects of a
project’s construction and operational phases are relevant for this study and discussed in the next two sections, respectively.

2.3.1.1 Construction risk perception in project finance credit ratings

The SPV’s revenues wholly depend on successfully completing its construction and demonstrating that the project meets the performance requirements specified in the project agreement. The credit risk analysis for the project’s pre-completion phase is therefore focused on assessing the probability that the asset will not be built on time, within the planned budget, and up to the performance standards required for commissioning. From a debt-financing perspective, a project’s pre-completion phase is often considered the project’s riskiest stage (Yescombe, 2018). Signifying the risk-averseness of debt finance, Moody’s (2016) and S&P (2014) automatically apply an upward limit to their ratings for projects that are yet to be constructed, due to the inevitable unpredictability of construction activities.

The key risks during construction of a PPP project from the perspective of debt providers are related by Moody’s to three scenarios (Moody’s, 2016, p. 4):

- A delay in construction beyond the agreed completion date, with SPV unable to finance completion to meet the requirements for availability payments;
- A delay in construction beyond the date giving the contracting authority a right to withdraw from the project agreement for a termination fee lower than the SPV’s outstanding debt;
- Poor performance or financial problems of the construction sub-contractor pointing to a need to replace the party. This may be impossible due to prohibitively increased construction costs, giving rise to a risk of termination of the project agreement with a termination fee insufficient to cover the borrower’s debt.

While the reviewed rating methodologies employ differently organised approaches based on their proprietary risk assessment criteria, similar high-level groups of risk drivers are observed to play an important role in construction risk analysis (see Figure 5). First, the project’s characteristic risk is assessed mainly based on the project’s location, design and technology employed, and the related construction uncertainties. Second, the contractor’s previous experience with similar projects plays an important role. Third, the robustness of the project’s construction plans is considered based on the project’s identified characteristic risks, assessing the project’s sensitivity to cost overruns and construction delays. As an illustration, the approaches by two leading credit rating agencies to their pre-completion phase credit risk ratings are summarised briefly in the following paragraphs.

The approach applied by Standard & Poor’s (S&P, 2014) first looks at technological and design variation risks. Then, risks related to the process of construction itself are analysed based on the difficulty of construction and the applied delivery method. Construction difficulty is related to the likelihood of overruns and is considered lower for real estate and higher for civil or heavy engineering works (S&P, 2014). Delivery method is characterised by the contractor’s experience and amount of project’s risk it accepts contractually. These two risk assessments are joined and adjusted based on the quality of project’s management, in particular its ability to address the risks the borrower retains (S&P, 2014). The obtained risk profile is further adjusted by the rating agency using parameters related to the amount of funding available to cover the worst-case downside scenario, and finally by modifiers related to the counterparties contractually involved in construction or financing of the project. In summary, for the agency’s assessments of the construction phase risk, the project’s technical characteristics that influence technology and design risk, construction risk and performance risk therefore represent the foundation for subsequently assessing the adequacy of financial, organisational and legal safeguards.

Compared to the example above, Moody’s (2016) independent assessment of construction risks in PPP projects is set up differently but similar fundamental risk drivers are considered. Five construction risk factors are analysed. First, an assessment is made of the extent to which the contracting authority has transferred construction risks to the borrower. Second, Moody’s assess the extent to which construction complexity gives rise to scheduling and budgeting uncertainty, i.e. “likelihood that construction complexity could result in schedule overruns or create operational or financial stress for the constructor” (Moody’s, 2016, p. 10). Third, the credit rating agency analyses the experience of the constructor and how well its plans consider the project’s specific risks identified under construction complexity. Fourth, the constructor is analysed regarding its ability and willingness to shoulder cost
overruns. Finally, the impact of potential delays is assessed based on the available schedule buffers and financial liquidity.

In summary, as indicated above and summarised in Figure 5, three main underlying considerations can be observed to appear across the reviewed construction risk analysis models. These include an analysis of the project’s characteristic risk, the quality of sub-contractor’s experience, and the robustness of project plans. These general considerations are further explained in the following paragraphs.

![Figure 5: Main considerations in construction phase credit risk analyses (own figure - general digest of reviewed models)](image)

**Project’s characteristic risk, construction difficulty or complexity**

In analysing credit risks of the project’s construction phase, the technical risk characteristics of a project provide a basis for the analysts’ ratings. Uncertainties related to the site condition, performance of technology employed, suitability of the design solution and feasibility of the construction method appear to be some of the key concerns of credit risk analyses. The focus is on assessing the extent to which these may raise doubts about the adequacy of project’s planned budget and schedule. Credit risk ratings favour projects built in well-known circumstances, based on extensively proven technology, conventional and thoroughly defined design solutions, and applying undemanding construction methods.

An assessment of a project’s complexity appears to often be generalised in relation to the type of the asset under consideration. For example, credit risk analyses by S&P (2014) relate difficulty of construction to a higher chance of delays and cost overruns, in principle considering typical building projects, like schools, simpler than specialised civil works or industrial projects. A project’s technological risk and design complexity are assessed by S&P (2014) with regard to how innovative or previously proven the technology and design are. Similarly, Fitch (2018) consider increased complexity of works as a precursor to higher likelihood of cost and schedule overruns. A project’s complexity and scale provide a basis for its analysis of the project’s organisational and planning measures, noting that complex and large projects can be creditworthy if complexity is managed well (Fitch, 2018, p. 30). Main technical aspects considered include environmental and geotechnical uncertainties, amount of earthworks, technology track record, and possibility of cost benchmarking. Fitch (2018, p. 32) lists school buildings, road rehabilitations and airport expansion projects among examples of projects usually scoring better on “project complexity and scale”, in contrast to major civil works, high speed railways, oil and gas and offshore wind plants.

The model applied by Moody’s (2016) uses project construction complexity as a risk factor directly adding an indicative 25% to the overall construction risk rating. Complexity as a construction risk factor is assessed by the
rating agency based on four high-level sub-factors that focus on the project’s characteristic risk (Moody’s, 2016, p. 10): “Site preparation requirements and substructure risk, structure complexity and construction technique risk, performance risk, construction constraints risk.” The first three sub-factors focus on the three main phases of the project’s construction, starting with the preparatory works, the erection of the structure itself, and the project’s entry into operation. The fourth sub-factor considers the boundary conditions for construction execution and focuses mostly on scheduling constraints imposed by the project’s environment. The credit rating agency acknowledges that complexity depends on the project and applies different weights to the above sub-factors depending on the specifics of the project type. Some engineering features considered by the rating agency as affecting construction complexity from a credit rating standpoint include the amount of heavy geotechnical works, uncertainties as to the ground condition, severity of geological risks, uniqueness of the design solution and interdependence of its elements, track record of applied materials and techniques, interdependence of installations systems, and amount of external scheduling constraints imposed by the project’s environment.

In summary, it is observed that several technical features are consistently emphasised in reviewed credit risk analysis models as main sources of a project’s perceived inherent riskiness from a credit risk analysis perspective. These include site condition, expected performance of technology employed, suitability of the design solution and feasibility of the construction method. Yet, assumptions regarding a project’s complexity appear dissimilar, variously detailed and often simplified to the extent that it is related to a very broadly-defined types of the asset under construction. The parameters giving rise to perceived complexity are mainly technical in the reviewed credit risk analysis models. In existing academic research (see 2.1) project complexity has been characterised as a more multi-faceted and indeed project-specific phenomenon. The reviewed publications explaining the applied credit rating criteria note that analysts partly rely on information provided by independent engineers. According to Fitch (2015, p. 6), LTAs are a “vital link between the project’s sponsors’ overall approach to a project and the investment community bearing a significant amount of the risk”. This indicates that a clearer understanding, assessment and communication of project complexity by technical experts may be beneficial to support the finance professionals’ credit risk analyses and decision-making, and points to the practical relevance of the objective of this study.

Contractor’s experience
The adequacy of construction sub-contractor’s experience plays an important role in all of the reviewed credit risk analysis models. As a general principle, the focus is on the sub-contractor’s previous experience successfully delivering projects similar in terms of risk characteristics and scale, contractual and legislative frameworks, employing similar technology, etc. Moreover, attention is paid to the involved parties’ track record of working together in case of multiple sub-contractors jointly performing construction works (Moody’s, 2016), as well as both the sub-contractors’ and equity sponsors’ capacity to manage and supervise the (sub-contracted) works (Moody’s, 2016; S&P, 2014). With a view to the scenario in which the sub-contractor must be replaced, the availability of capable replacement contractors is considered (Fitch, 2018; Moody’s, 2016).

Robustness of planning and management
The project’s plans are considered in credit risk analysis with regard to how well prepared the project is to recover from reasonably expected cost and schedule overruns and quality deficiencies. The focus is therefore on sufficiency of cost contingencies, activities on the project’s critical path and available buffers, as well as other organisational parameters such as team integration (Fitch, 2018), workable methods of dispute resolution (S&P, 2014) and the approach to risk management (Moody’s, 2016). In one agency’s view (Fitch, 2018), a robust project implementation plan can offset its complexity.

2.3.1.2 Operational risk perception in project finance credit ratings
Following a project’s successful fulfilment of requirements for entry into operational phase, the lenders’ risk exposure depends on the project’s continued meeting of expected availability and performance levels that enable its generation of revenues. Before the project’s revenues can be used for senior debt repayment, however, the project’s operating and maintenance costs must be covered. Therefore, the focus of credit risk analyses in the project’s operational phase is on the likelihood that the project’s revenues may be insufficient to enable the borrower’s debt repayment. For availability-based PPP infrastructure projects whose operations are not exposed to market forces such as reduced demand for the project’s services, the revenues depend mainly on the project
meeting the availability requirements defined in the project agreement. The project’s availability can be reduced due to scheduled maintenance or remedial interventions that partly or fully interrupt its operations.

The centre of attention in credit risk analysis is therefore on examining the likelihood of the project’s failure to meet performance standards at the expected costs that allow regular service of the SPV’s outstanding debt. The technical difficulty stemming from the prescribed performance requirements provides a basis for assessing the robustness of contractual risk transfers and forecasting the stability and sufficiency of the borrower’s cash flows. For example, in availability-based PPP infrastructure, Moody’s (2015) assess the complexity of facility management and lifecycle obligations, focusing on the content and context of the borrower’s responsibilities, and severity of any technical risks involved in their delivery. Similarly, S&P (2014) performance risk assessment considers the type of activities required and the related difficulties of meeting the requirements. Here, the focus is on the complexity of installed equipment, the likelihood of malfunctions and their impact. S&P (2014) assess performance risk by first categorising assets into ten classes according to their operations stability. These range from easily maintained buildings to assets based on mechanical and engineering equipment with uncertain long-term performance. Then, a more project-specific assessment is made by the agency’s analysts based on factors like the project’s performance redundancy, financial sensitivity, operations and maintenance service providers’ capability and technological performance risks. Fitch (2015, p. 9) consider technical risk as a function of operating complexity and scale, where complexity is related to the scope of services required according to the project agreement. The agency notes that simple services are usually related to assets like libraries or court buildings, in contrast to transport infrastructure or hospitals which have more strict performance standards resulting in perceived higher operating complexity. Undemanding operational and maintenance tasks on new-built assets generally yield better results in the credit rating agencies’ analyses.

2.4 A specific view of project complexity

Academic literature on project complexity (2.1) provides limited consensus on the definition of project complexity and a variety of extensive lists of variously specific complexity elements have been used in existing approaches to project complexity evaluation. Perspectives of project complexity furthermore tend to be stakeholder specific. Therefore, the perspective of lenders as a distinct stakeholder in PPP infrastructure projects was explored through practice-based literature (2.2 – 2.3). First, the practice of lenders’ TDD was investigated through a review of past projects’ TDD reports and exploratory interviews with LTA practitioners (2.2). The interviewees underlined the lack of mutual understanding of what contributes to project complexity from a lenders’ perspective. Following an overview of lenders’ risk perception (2.3) by looking at the credit risk rating models in the project’s pre-completion and operational phases, the role of project complexity in lenders’ risk-based decision-making can be better understood.

An understanding of the project’s complexity (or similar measures, such as construction difficulty) stemming from the borrower’s construction and operation responsibilities seems an important basis for credit risk analysis. As an initial step of risk analysis, lenders regard complexity as the key risks and uncertainties borne by the borrower and the challenges these may pose to successfully meeting the requirements of the project agreement. These mainly stem from a project’s technical features, for an analysis of which analysts rely on external engineering expertise – according to Fitch (2015), LTAs provide a “vital link between project sponsors’ overall approach to a project and the investment community bearing a significant amount of the risk’. The role and definition of project complexity as relevant in TDD can therefore be operationalised as related to the nature and severity of project’s inherent construction and operational risks and uncertainties borne by the borrower according to the project agreement. While other credit risk evaluation criteria appear to focus on assessing the robustness of the overall project plan from organisational, contractual and financial perspectives, complexity addresses the project’s characteristic risk profile that, in case not managed well by the borrower, may result in reduced overall creditworthiness. Therefore, a project’s complexity in the lenders’ perspective can be observed to have a relatively narrow meaning compared to characterisations observed in literature. In lenders’ perspective it can be understood as a preliminary measure of a project-financing operation’s inherent riskiness, before the particular risks are re-allocated away from the borrower.
That said, complexity is observed to be a relatively direct contributor to resulting credit risk ratings in the project’s operational or construction phases. It seems that its assessment is often made unsystematically based on the relative complexity of the asset type under consideration. For example, as shown in the previous section, a school building project tends to be considered simple by credit risk analysts, while an asset involving more specialised engineering works is seen as complex in itself. From an engineering and management point of view, one can think of complex school projects and simple civil works projects. Hence, such generalisation over broader project types may lead to wrong assumptions as to the specific project’s actual complexity and the related credit risk. Therefore, more differentiation of projects according to their complexity is needed, confirming the relevance of the research gap addressed in this study. Given the credit risk analyses’ reliance on external technical expertise, this can be related to the observed lack of LTAs’ clear opinion on a project’s complexity (section 2.2). While very detailed, the TDD reports did not highlight the key issues potentially important from the lenders’ specific perspective or take a stance on how complex a project is. To support lenders’ risk assessments, technical advisers need to help understand the key complexities from a debt-financing perspective and better focus the lenders’ due diligence attention to the nature of the particular project.

2.4.1 Literature and practice
Based on a literature study (2.1), it was explained that project complexity has been characterised as having various dimensions, such as technical, organisational and environmental (Bosch-Rekveldt et al., 2011). Indeed, lenders’ risk-based analysis and decision-making does not only consider the project’s technological aspects, but pays close attention to the borrower’s internal organisation and characteristics of both direct and macro-level environment. However, the role of project complexity appears more specific in the reviewed credit rating analyses for a project’s construction and operational phases. While in a project management context, one purpose of evaluating a project’s complexity has been posited as highlighting the project-managerial opportunities for improving a project’s strategic planning and management, lenders seem only interested in the end result of a project. Furthermore, researchers have shown that project planners and managers may also see positive effects of complexity, while lenders naturally only consider negative impacts.

A project’s complexity from a lenders’ perspective thus seems interpreted as making the project unpredictable and uncontrollable by the borrower’s own contractual safeguards. This scope of complexity assessment appears similar to Xia & Chan (2012) who rather narrowly defined construction complexity as the difficulty of delivering a project. Credit risk analysis is based on the notion that a very complex project can successfully secure financing on affordable terms provided that complexity is appropriately managed (Fitch, 2018). From a project-managerial perspective, a project’s complexity has been represented as not fully manageable (e.g. Bosch-Rekveldt et al., 2011). These views are not necessarily conflicting as lenders’ risk management is focused on ensuring that the project’s risks are “managed” contractually – that is, allocated away from the borrower (Demirag et al., 2012) to a party capable of managing them (Yescombe, 2018; Rajgor, 2011). The difficulty in contractually allocating some complexities may indeed be a reason why a project’s perceived increased complexity seems to directly and negatively affect credit ratings.

From the comprehensive project complexity characterisations found in literature, some project complexity elements can be considered relevant to the lenders’ decision-making as these have been among project-specific features seen as project risk drivers in reviewed TDD reports and credit rating analyses. The comprehensive TOE framework proposed by Bosch-Rekveldt et al. (2011) has been used to identify such elements. In Table 3 below, it can be observed that lenders mostly perceive the project’s technical and environmental complexity as important in appraising construction and operation risk within their TDD. This seems to differ from project managers’ views who did not select technical complexity elements as most important in previous studies (e.g. Bosch-Rekveldt et al. 2018). However, this may be due to their technical background and their direct involvement in the project: lenders, on the other hand, are external to the project and they, in the first instance, seek to gain an understanding of technical complexity in construction and operational risk assessment. With no direct control over a project’s planning, a distinctly risk-averse position, and a legalistic view of projects, the lenders’ perspective of project complexity is thus indeed different from that of project managers and engineers.
Table 3: Relevance of project complexity elements by Bosch-Rekveldt et al. (2011).

<table>
<thead>
<tr>
<th>Technical complexity</th>
<th>Organisational complexity</th>
<th>External/environmental complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of project goals</td>
<td>Project schedule drive</td>
<td>External risks</td>
</tr>
<tr>
<td>Alignment of project goals</td>
<td>Resource &amp; skills availability</td>
<td>Number of stakeholders</td>
</tr>
<tr>
<td>Clarity of project goals</td>
<td>Experience with parties involved</td>
<td>Variety of stakeholder views</td>
</tr>
<tr>
<td>Uncertainties in scope</td>
<td>HSSE awareness</td>
<td>Dependency on stakeholders</td>
</tr>
<tr>
<td>Strict quality requirements</td>
<td>Interfaces between disciplines</td>
<td>Political influence</td>
</tr>
<tr>
<td>Project duration</td>
<td>Number of financiers</td>
<td>Company internal support</td>
</tr>
<tr>
<td>Size in CAPEX</td>
<td>Number of contracts</td>
<td>Required local content</td>
</tr>
<tr>
<td>Number of locations</td>
<td>Type of contract</td>
<td>Interference with existing site</td>
</tr>
<tr>
<td>Newness of technology</td>
<td>Presence of JV partner</td>
<td>Remoteness of location</td>
</tr>
<tr>
<td>Lack of experience with technology</td>
<td>Number of time zones</td>
<td>Experience in country</td>
</tr>
<tr>
<td>Number of tasks</td>
<td>Number of nationalities</td>
<td>Internal strategic pressure</td>
</tr>
<tr>
<td>Dependencies between tasks</td>
<td>Size of project team</td>
<td>Instability of project environment</td>
</tr>
<tr>
<td>Uncertainty in methods</td>
<td>Different PM methods</td>
<td>Level of competition</td>
</tr>
<tr>
<td>Variety of technical disciplines</td>
<td>Trust in project team</td>
<td></td>
</tr>
<tr>
<td>Conflicting norms and standards</td>
<td>Trust in contractor</td>
<td></td>
</tr>
<tr>
<td>Technical risks</td>
<td>Organisational risks</td>
<td></td>
</tr>
</tbody>
</table>

Although some elements found in empirical characterisations of project complexity (Table 3) may be seen as giving rise to project complexity as perceived by lenders, their direct applicability for appropriately capturing project complexity in the specific context TDD may be limited. Some are too generic or may be relevant to several aspects considered in credit risk analyses. For example, any uncertainties in general scope of the project are unlikely at the advanced stage of procurement when the lenders’ risk analysis takes place – the project’s scope must already be specified in the project agreement. More specific scope uncertainties must be identified by engineers supporting lenders’ risk analyses. Indeed, any scope uncertainties are relevant in TDD, but their specific sources may be identified. These may, for example, stem from the ground conditions, the methods employed, or the lifecycle investment costs to be borne by the borrower. In the next section, based on the above insights from both academic and practice literature, specific complexity elements are identified as relevant to lenders’ risk assessment and decision-making.

2.4.2 Complexity elements relevant for technical due diligence

Based on the above discussion of the lenders’ seemingly distinct perspective of project complexity, potentially relevant complexity elements are identified from academic and practice-based literature reviewed previously.

The selection of elements is based on the following criteria. In line with the objective of this study, the focus is on complexity elements that fall within the scope of TDD analyses (see 2.2) and are relevant at the specific point in time. As described above, project complexity from a lenders’ perspective can be described as focused on uncertainties and risks borne by the borrower as per its project agreement during a project’s construction and operational phases. Based on understanding these, the quality of transfer of such risks in the relevant sub-contracts must be assessed in credit risk analysis.

The selection is further focused on complexity elements relevant to the lenders’ perception of construction and operational risks as a subcategory of project risk. Project risk is distinguished from other components of credit risk, namely macro-economic, regulatory or political risks (Yescombe, 2014). Therefore, some project complexity elements pertaining to a more strategic level of project planning are considered less relevant although often included in a broader view of project complexity prevalent in literature. As mentioned above, the lenders’ due diligence usually takes place at an advanced stage of public procurement processes, where the general business case is already justified and the general political support for the project is assumed to already be secured.

Some complexity elements otherwise applicable in the wider context of lenders’ decision-making are not observed as adding to the complexity and risk profiles of the project. The focus is on complexity elements providing detailed information on the technical risks related to the borrower’s obligations from the project agreement. For example, elements referring to borrower’s financial or contractual security directly (e.g. adequacy of schedule buffers and cost contingencies, financial and insurance guarantees and reserves, etc.) are indeed thoroughly analysed in due
diligence but this analysis first needs an understanding of the project’s inherent risk, i.e. complexity from a lenders’ external standpoint.

Similarly, although the capacity of involved parties is a key consideration in TDD and its context of credit risk analyses (2.2 & 2.3), and has been shown to contribute to organisational complexity (Bosch-Rekveldt, 2011), it must be considered with respect to the specific project’s identified complexities. In fact, an initial check of the adequacy of parties’ experience (with the country, with project type, etc.) is already made by contracting authority when selecting bidders for the final stage of PPP procurement, and contracting authority’s interests in this respect are largely aligned with those of the lenders (Yescombe, 2018).

2.4.2.1 Complexity elements from academic literature

Guided by the above considerations, the existing academic and reference literature was examined again to identify complexity elements relevant in the context of lenders’ TDD (Table 4). Studies clarifying the project managers’ view of project complexity in construction sector were reviewed. Bosch-Rekveldt et al. (2018), Nguyen et al. (2015) and Xia & Chan (2012) were selected due to different levels of abstraction in the lists of complexity elements they apply. In parallel, two of more lender-oriented works were examined, namely the study by Laishram & Kalidindi (2009) on factors influencing the desirability of PPP highway projects from a debt-financiers’ perspective, and a reference work by Yescombe (2018, pp. 151-181) providing an overview of construction and operation risk allocation principles in project finance. In the project’s construction phase, the principal technical risks from a project-financing perspective stem from the project’s location, the process of construction, and the project’s design (Yescombe, 2018), which was used as guidance. A project’s complexity in the operational phase is not very detailed in the reviewed literature. As shown in Table 4, some parallels could be drawn between the underlying concepts of some complexity elements referred to in the reviewed literature. To select the elements, a trade-off was made between overly broad complexity element definitions and too detailed complexity characterisation, which was guided by insights from the review of lenders’ credit risk analysis models in section 2.3.

Table 4: Relevant complexity elements based on academic literature

<table>
<thead>
<tr>
<th>Identified elements</th>
<th>Mentioned in:</th>
<th>Selected elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground condition complexity</td>
<td>1 2 3 4 5</td>
<td>Site condition complexity</td>
</tr>
<tr>
<td>Size of site area</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Permitting responsibility</td>
<td>X X X</td>
<td>Amount of permitting responsibilities</td>
</tr>
<tr>
<td>Site acquisition and rights of way</td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Remoteness of location</td>
<td>X X</td>
<td>Logistical complexity</td>
</tr>
<tr>
<td>Construction logistics and accessibility</td>
<td>X X X</td>
<td>Dependence on external stakeholders</td>
</tr>
<tr>
<td>Number &amp; variety of external stakeholders</td>
<td>X X X</td>
<td>Interference with environment</td>
</tr>
<tr>
<td>Dependence on external stakeholders</td>
<td>X X X X X</td>
<td></td>
</tr>
<tr>
<td>Interference with environment</td>
<td>X X X X X</td>
<td>Interdependencies between activities</td>
</tr>
<tr>
<td>Scheduling complexity</td>
<td>X X X X X</td>
<td>Functional requirements</td>
</tr>
<tr>
<td>Interfaces between disciplines</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dependencies between sub-projects</td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Interrelations between technical processes</td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Lack of resources and skills</td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Strict quality requirements</td>
<td>X X X</td>
<td>Construction technology</td>
</tr>
<tr>
<td>Clarity of goals</td>
<td>X X</td>
<td></td>
</tr>
<tr>
<td>Technology track record</td>
<td>X X X</td>
<td>Amount of maintenance responsibility</td>
</tr>
<tr>
<td>Uncertainty in methods</td>
<td>X X X</td>
<td>Timing constraints for maintenance</td>
</tr>
<tr>
<td>Variety of technologies</td>
<td>X X</td>
<td>Consequences of underperformance</td>
</tr>
</tbody>
</table>

Sources:
2.4.2.2 Complexity elements from practice-based literature

To detail the lenders’ specific perspective of project complexity not discussed in academic literature, a closer analysis of the practice-based literature reviewed in sections 2.2 and 2.3 was carried out. The overall insights from this sections review of academic and practice-based literature enabled a more informed consideration of elements described or implied as giving rise to complexity from a debt-financing perspective.

Two kinds of sources were used. First, TDD reports of the three past projects studied in Section 2.2 were examined based on the discussed lenders’ perspective of project complexity. Despite their unsystematic approach to complexity characterisation, all sorts of detailed technical risks of each project are discussed in the reviewed reports. Second, these were compared to publications describing the credit risk analysis models reviewed in Section 2.3 to identify specific technical features seen as complexity indicators from the lenders’ perspective. Given the varying detail to which the reviewed practical literature elaborates the assessed project-specific technical features and how they describe their potential contribution to project complexity, they were analysed in parallel. This helped provide a more comprehensive overview of potential complexity elements relevant in the context of TDD. An element was included when a cross-check between a credit rating methodology and a past TDD report was found, or when a single source provided sufficiently clear insight into why a project’s feature must be regarded as giving rise to project complexity.

As shown in Table 5, thirty-two detailed potential complexity elements can be identified, and these were simplified to twenty-three selected elements. These are grouped under seven groupings of elements representing a common denominator of the main higher-level chronologically distinct sources of a project’s inherent risk drivers in the reviewed practice-based literature.

The elements identified in academic and practice literature were then combined as shown in Table 6. The selected elements largely overlap, although it was observed that a project’s dependence on external stakeholders is not clearly addressed in LTAs’ or credit ratings’ construction risk assessment, which may be due to external support for the project being usually considered the responsibility of the contracting authority. However, given it is thoroughly emphasised in all reviewed academic literature on project complexity, it is included as a separate potential complexity element. The listed elements provide an overview of project-specific technical features that are considered as giving rise to project complexity from the lenders’ perspective.
### Table 5: Relevant complexity elements based on practice-based literature

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Identified elements</th>
<th>Mentioned in:</th>
<th>Selected elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4</td>
<td>Permits &amp; rights of way responsibility</td>
</tr>
<tr>
<td>Site complexity</td>
<td>Permits &amp; rights of way</td>
<td>X  X  X  X</td>
<td>Information on site condition</td>
</tr>
<tr>
<td></td>
<td>Coverage of site investigations</td>
<td>X  X  X  X</td>
<td>Preparatory works needed</td>
</tr>
<tr>
<td></td>
<td>Complexity of site condition</td>
<td>X  X  X  X</td>
<td>Site access and logistics</td>
</tr>
<tr>
<td></td>
<td>Legacy elements condition</td>
<td>X  X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preparatory works needed</td>
<td>X  X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site access and logistics</td>
<td>X  X  X  X</td>
<td></td>
</tr>
<tr>
<td>Interfaces with environment</td>
<td>Live traffic interfaces</td>
<td>X  X</td>
<td>Amount of construction restrictions</td>
</tr>
<tr>
<td></td>
<td>Timing constraints</td>
<td>X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environmental impact restrictions</td>
<td>X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ease of workaround</td>
<td>X  X  X</td>
<td>Complexity of restrictions</td>
</tr>
<tr>
<td>Solution complexity</td>
<td>Structure design uniqueness</td>
<td>X  X  X  X</td>
<td>Structure uniqueness</td>
</tr>
<tr>
<td></td>
<td>Level of design completion</td>
<td>X  X  X  X</td>
<td>Level of design completion</td>
</tr>
<tr>
<td></td>
<td>Design check procedures</td>
<td>X  X  X</td>
<td>Design verifications by client</td>
</tr>
<tr>
<td></td>
<td>Interdependence of sub-projects</td>
<td>X  X  X</td>
<td>Interdependence of sub-projects</td>
</tr>
<tr>
<td></td>
<td>Materials track record</td>
<td>X  X  X  X</td>
<td>Technology and materials track record</td>
</tr>
<tr>
<td></td>
<td>Technology track record</td>
<td>X  X  X  X</td>
<td></td>
</tr>
<tr>
<td>Ramp-up complexity</td>
<td>Equipment amount &amp; complexity</td>
<td>X  X  X  X</td>
<td>Amount &amp; complexity of equipment</td>
</tr>
<tr>
<td></td>
<td>Dependence on suppliers</td>
<td>X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Completion requirements</td>
<td>X  X  X  X</td>
<td>Completion requirements complexity</td>
</tr>
<tr>
<td></td>
<td>Testing period</td>
<td>X  X  X</td>
<td>Testing time required</td>
</tr>
<tr>
<td>Scope of O&amp;M obligations</td>
<td>Nature of FM/routine mtce. obligations</td>
<td>X  X  X  X</td>
<td>Nature of FM/routine maintenance obligations</td>
</tr>
<tr>
<td></td>
<td>Criticality of FM/routine mtce. services</td>
<td>X  X  X</td>
<td>Scheduling complexity</td>
</tr>
<tr>
<td></td>
<td>FM/routine mtce. timing requirements</td>
<td>X  X  X  X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amount of asset renewal responsibility</td>
<td>X  X  X  X</td>
<td>Amount of asset renewal responsibility</td>
</tr>
<tr>
<td></td>
<td>Lifecycle requirements predictability</td>
<td>X  X  X  X</td>
<td>Predictability of asset renewal needs</td>
</tr>
<tr>
<td></td>
<td>Technical specialisation required</td>
<td>X  X  X  X</td>
<td>Technical specialisation required</td>
</tr>
<tr>
<td>Performance regime</td>
<td>Onerousness of performance regime</td>
<td>X  X  X  X</td>
<td>Onerousness of performance regime</td>
</tr>
<tr>
<td>Technology outlook</td>
<td>Redundancy</td>
<td>X  X  X  X</td>
<td>Built-in redundancy</td>
</tr>
<tr>
<td></td>
<td>Capacity buffers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology track record</td>
<td>X  X  X</td>
<td>Technology track record</td>
</tr>
<tr>
<td></td>
<td>Availability of parts &amp; consumables</td>
<td>X  X  X</td>
<td>Availability of parts &amp; consumables</td>
</tr>
</tbody>
</table>

**Sources:**

1 – Mott MacDonald (unpublished) – past projects’ TDD analyses (see 2.2)
2 – Moody’s (2016 & 2015)
4 – Fitch (2018 & 2015)
<table>
<thead>
<tr>
<th>Table 6: Final overview of potential complexity indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elements from academic literature</strong></td>
</tr>
<tr>
<td><strong>Site complexity</strong></td>
</tr>
<tr>
<td>Site condition complexity</td>
</tr>
<tr>
<td>Preparatory works needed</td>
</tr>
<tr>
<td>Amount of permitting responsibilities</td>
</tr>
<tr>
<td>Site access and logistics</td>
</tr>
<tr>
<td><strong>Logistical complexity</strong></td>
</tr>
<tr>
<td>Site condition complexity</td>
</tr>
<tr>
<td>Amount of permitting responsibilities</td>
</tr>
<tr>
<td>Site access and logistics</td>
</tr>
<tr>
<td><strong>Dependence on external stakeholders</strong></td>
</tr>
<tr>
<td>Interference with environment</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Dependence on external stakeholders</td>
</tr>
<tr>
<td><strong>Solution complexity</strong></td>
</tr>
<tr>
<td>Level of design completion</td>
</tr>
<tr>
<td>Design verifications by client</td>
</tr>
<tr>
<td>Structure uniqueness</td>
</tr>
<tr>
<td>Interdependencies of activities</td>
</tr>
<tr>
<td>Construction technology</td>
</tr>
<tr>
<td><strong>Ramp-up complexity</strong></td>
</tr>
<tr>
<td>Amount of systems &amp; equipment</td>
</tr>
<tr>
<td>Complexity of systems &amp; equipment</td>
</tr>
<tr>
<td>Functional requirements</td>
</tr>
<tr>
<td>Testing time required</td>
</tr>
<tr>
<td><strong>Scope of O&amp;M obligations</strong></td>
</tr>
<tr>
<td>Amount of maintenance responsibility</td>
</tr>
<tr>
<td>Timing constraints for maintenance</td>
</tr>
<tr>
<td>Amount of maintenance responsibility</td>
</tr>
<tr>
<td>Predictability of asset renewal needs</td>
</tr>
<tr>
<td>Technical specialisation required</td>
</tr>
<tr>
<td><strong>Performance regime</strong></td>
</tr>
<tr>
<td>Consequences of underperformance</td>
</tr>
<tr>
<td><strong>Technology outlook</strong></td>
</tr>
<tr>
<td>Technology track record</td>
</tr>
<tr>
<td>Availability of parts and consumables</td>
</tr>
<tr>
<td>Built-in redundancy</td>
</tr>
</tbody>
</table>
2.5 Conclusion

In this chapter, the meaning of project complexity was explored in a desk review of academic and practice-based literature in the specific practice of lenders’ technical due diligence. By characterising the meaning of project complexity within the context of lenders’ decision-making, an answer to the first research sub-question is provided:

SQ1: What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on project finance loans?

Project complexity had been extensively studied in the domain of project management, and various definitions and characterisations had been elaborated. For a project’s internal stakeholders, complexity evaluation posits an aid to adapt early project planning and management, for which complexity is seen as having both positive and negative impacts. While influencing factors of project complexity have been said to differ per specific stakeholder perspective in each project type, empirical research had mainly focused on the perspective of project managers. However, lenders are a specific stakeholder with a different view of project complexity. In this context, lenders are (i) external to a project and thus have limited control over its planning, as they only get involved in late stages, (ii) distinctly risk-averse and thus predominantly consider negative impacts of project complexity, and they (iii) adopt a legalistic view with the project’s specific contractual arrangements shaping their risk perception. These differences may have led to observed inefficiencies in communicating a project’s complexity from a lenders’ perspective in collaboration between engineering and finance professionals in TDD.

A desk review of the context of lenders’ risk-based decision-making found that throughout the project’s lifetime, the lenders’ perspective of project complexity is related to the project-specific risk character at a high level. This perspective of project complexity mainly considers a project’s engineering and managerial features, for an understanding of which credit risk analyses generally rely on TDD performed by engineers. Representing an important element of credit risk assessment, the understanding of a project’s complexity may directly influence an infrastructure project’s affordability. Therefore, for project complexity evaluation in TDD supporting lenders’ risk analyses, a clearly defined and mutually understood definition of project complexity must be operationalised. The role of project complexity in TDD was found to be related to the nature and amount of project-specific uncertainties faced by the SPV, acting as the borrower, according to its overarching project agreement with the contracting authority.

With the lenders’ perspective understood, the desk study identified twenty-six project-specific technical features relevant as giving rise to complexity of projects from the lenders’ specific perspective. These potential sources of project complexity perceived in lenders’ risk-based decision-making provide a basis for better understanding the relevant attributes of project complexity in technical due diligence. Seven groups of potential complexity elements were identified. In the project’s construction phase, these are related to the project’s site, its interfaces with environment, the design solution, and ramp-up phase. The potential complexities in the project’s operational phase can be related to the scope of the borrower’s operational and maintenance obligations, the performance regime governing conditions for performance-based payments, and the expected long-term performance of technology the operations rely on.
3 Systematising complexity evaluation

As follows from the conclusions of the previous chapter, project complexity from a lenders’ perspective is mainly related to technical sources of construction and operational risks, for an identification and monitoring of which project finance experts rely on their technical advisers. The reviewed TDD analyses of past projects do not clearly express the engineers’ view of a project’s complexity, which has posed communication issues underlining the practical relevance of the problem addressed in this study. In line with the objective of this study, a systematic complexity evaluation facilitating communication between engineering and finance experts is therefore indeed needed as a preliminary analysis in technical due diligence to improve communication and draw attention to the specific complexities of a project. The establishment of a systematic approach to complexity evaluation is discussed in this chapter to help answer the second research sub-question:

SQ2: In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?

Taking into account the lenders’ specific perspective of project complexity and the identified need for its clearer evaluation by lenders’ engineers, this step starts by discussing the complexity evaluation challenge defining the practical requirements for systematising the approach to complexity evaluation in technical due diligence (3.1). The relevant high-level complexity factors and detailed-level complexity indicators are discussed and structured into a hierarchical model that may be used for complexity evaluation (3.2). Next, a method is elaborated that enables an analysis and quantification of the relative importance of detailed-level complexity indicators included a considered model (3.3). A qualitative complexity scoring system is discussed for detailed-level complexity indicators to enable quantification of a project’s complexity (3.4). To answer SQ2 of the research question, the way in which project complexity can be systematically evaluated in technical due diligence is explained, defining the series of steps to be taken in its application in this study (3.5).

3.1 The complexity evaluation challenge

To systematise complexity evaluation in a feasible approach tailored to the specific context of TDD, several key starting points were considered. Besides highlighting the main complexities of a project to which the detailed TDD attention should be focused, the outcome of complexity evaluation should enable the communication of a high-level answer to the commonly asked question of “How complex is this project?”’. A form of quantification of a project’s complexity based on a predefined qualitative complexity scoring scale was therefore envisaged. However, as shown in the previous chapter, the various existing characterisations of project complexity point to its multifaceted nature. Therefore, quantifying the project’s overall complexity to the level of condensing it into a single quantitative measure is not this study’s primary objective as it would do little to demystify the construct and increase the transparency of experts’ opinion on a project’s complexity.

On the other hand, the purpose of TDD analyses is for technical experts to inform finance specialists who ultimately perform credit risk analyses and make financing decisions. A form of a bottom-up approach to complexity evaluation can therefore be considered desirable, enabling technical experts to score project complexity at a detailed level and derive a more generic and top-down overview of complexity suited to finance experts’ analytical models. As shown in Chapter 2, an assessment of a project’s inherent risk is often made in credit risk analysis at a relatively high level of abstraction. For assessing the inherent construction risk, the analysis looks at aspects such as the project’s location, design and technology employed, and any related construction uncertainties the borrower is expected to deal with. The outcome of complexity evaluation should ultimately provide a high-level expert opinion on the project’s complexity covering such high-level factors used in credit risk analyses and lenders’ eventual decision-making.

To do so, a complexity evaluation model with a multi-level hierarchical structure can be used. A conceptual scheme of an envisaged two-level hierarchical model is shown in Figure 6. The hierarchical model’s top-level complexity factors represent various dimensions of project complexity and would, ideally, match well with the analysis criteria used by finance experts assessing a project’s creditworthiness. These factors must then be divided into more
comprehensive sets of respective detailed-level complexity indicators that enable a bottom-up examination of project complexity by the technical experts involved.

Translating the complexity scores of detailed-level indicators to a higher-level representation of project complexity calls for a method allowing the calculation of weights of indicators included in the hierarchical model. Project financing is applicable to many different types of projects. Indeed, this study employs a somewhat narrower focus on project-financed infrastructure. Yet, different infrastructure sub-sectors can be thought of, typically ranging from social infrastructure including e.g. schools, hospitals or prisons, to economic infrastructure including e.g. highways, waterways or airports. It is evident that in each of these sub-sectors, different technical aspects may be considered more or less likely to affect the project’s complexity. The aim of this study is to apply an approach that may be used in various types of projects. It is assumed that a comprehensive set of complexity indicators potentially relevant in various project types can potentially be determined, while inevitably, the indicators’ importance may vary per specific project type. Therefore, in translating the complexity scores of detailed-level complexity indicators to high-level complexity factors, different weights may apply in different project types.

Definitive weights indicating relative importance of various complexity indicators in the respective factor groupings could be determined based on sufficiently large statistical samples for each project type. Limited access to such statistical samples, as well as the time constraints of this study, could not allow the gathering of statistically significant data. On the other hand, a level of flexibility and expert judgement was considered desirable in assessing complexity within the specific domain of TDD in which each project sees the involvement of different individuals from various organisations, as well as different fields of expertise who may inevitably have different views and preferences. Previous research (e.g. Bosch-Rekveldt et al., 2011; Geraldi, 2009) has also shown that complexity evaluation can hardly be fully objectivised, and that systematically evaluating a soft parameter like complexity can at most serve to provide a means for gathering and reflecting on different parties’ views. For these reasons, a decision was made that both the determination of indicators’ importance and the bottom-up scoring itself be included as components of the approach to complexity evaluation to be applied in this study.

To address the above considerations, the following actions are needed to specify a systematic approach to complexity evaluation:

1. Select high-level complexity factors relevant to lenders’ decision-making
2. Identify detailed-level complexity indicators comprehensively defining each complexity factor
3. Select a way to quantify the importance of complexity indicators within each factor grouping
4. Define a qualitative system for measuring complexity at the detailed indicator level
5. Define a means of informatively representing the project’s overall complexity profile
3.2 Selection of complexity elements

Complexity elements acting as clear evaluation criteria must be selected first. As mentioned in the previous section, a hierarchical complexity evaluation model must be constructed whose top-level complexity factors reasonably correspond to assessment criteria used by finance experts to appraise a project’s inherent risk in the risk analysis models applied. For example (see 2.3), the rating methodology applied by S&P (2014) uses relatively high-level criteria such as design complexity and construction difficulty, while Moody’s (2016) make a more structured assessment of construction complexity as a risk factor based on four sub-factors including risks related to the projects’ site, construction technique, performance of installations, and construction constraints. These concepts are still relatively broad as e.g. a variety of engineering features could make a project’s design “complex” or its construction technique “difficult”. A bottom-up approach to complexity evaluation applied in TDD is supposed to help highlight a particularly complex aspect of a project and support finance experts’ ultimate credit risk analyses. This necessitates the definition of more exact evaluation criteria focused on the key technical features potentially giving rise to the project’s actual complexity. As shown in Figure 6, these are referred to as “complexity indicators” in this study and grouped under higher-level “complexity factors” in a conceptual hierarchical complexity evaluation model.

As shown in Chapter 2, no directly applicable or widely accepted model exists. However, based on a critical review of the available authoritative sources, a number of complexity elements related to the technical aspects of a project were identified as relevant – potentially giving rise to project complexity from a lenders’ perspective (see 2.4). These can be used to define a complexity evaluation model needed for the purpose of this thesis. It is recognised that any model inevitably has its limitations. Developing a complete and robust model encompassing all specific technical features giving rise to a project’s complexity from a lenders’ perspective needs extensive primary empirical research which is not feasible within the time constraints of this study and thus considered outside of its scope.

Twenty-six specific complexity elements identified in the previous chapter were thus used as complexity indicators and were grouped under seven respective higher-level complexity factors. Four factors cover construction risk drivers perceived by credit risk analyses in the project’s pre-completion phase, and three in the project’s subsequent operational phase. These are shown in Figure 7 representing the hierarchical model for evaluating complexity of projects applied in this study.
Figure 7: Hierarchical model for complexity evaluation
3.3 Determining the importance of complexity indicators

The selected complexity evaluation model (Figure 7) shows the multi-faceted nature of project complexity. Although the model’s exhaustiveness may not be claimed, a wide range of potential complexity indicators are included that are potentially relevant in different common types of project-financed infrastructure. It is clear that the importance of the included indicators may differ depending on the project type considered, which may affect the obtained result of complexity evaluation. Therefore, the question of the relative importance of complexity indicators needs to be addressed in specifying a systematic approach to complexity evaluation. For this purpose, multi-criteria decision-making methods (MCDM) have been reviewed.

3.3.1 Multi-criteria decision-making methods

As shown above, a comprehensive assessment of complexity must consider many different indicators that may sometimes act as conflicting criteria whose importance needs to be determined to appropriately characterise a project’s overall complexity. This makes a complexity evaluation problem related to multi-criteria problems commonly encountered in decision-making. In attempts to systematise the approach to addressing this type of problems in different fields including management and engineering (Zopounidis & Doumpos, 2017), a variety of multi-criteria decision-making (MCDM) methods have been developed. These can help systematise the comparison of different decision alternatives based on a relevant predefined set of multiple and often conflicting criteria, aiding a decision-maker’s ultimate selection of a best alternative based on the ranking of all available alternatives. The practical application of MCDM can be summarised as the structuring of decision criteria, determining the weights and scores on each criterion, and the final ranking of alternatives.

In TDD practice, a project under consideration is the sole “alternative” at the moment of analysis, and per se, no selection of “the best project” is made based on the analysis. However, benchmarking to other projects is often used in TDD (Gatti, 2018), and therefore a way of comparison to other projects possibly seen as “alternatives” may also be beneficial in practice. Project complexity evaluation in TDD can therefore be seen as a MCDM problem. For the purpose of this study, a MCDM method is applied to enable an analysis of experts’ opinions on the relative importance of complexity indicators. This is the input for quantifying indicators’ weights in each specific project type. The obtained weights can then provide a quantitative means for translating complexity scores to a higher-level representation of a project’s complexity, exposing a project’s overall risk character based on a debt-financing perspective of project complexity.

The Analytic Hierarchy Process (AHP) and the related Analytic Network Process (ANP) developed by Saaty (1980) are most often applied in academic research (Mardani et al., 2015). These have also been applied in studies quantifying the complexity of projects (Luo et al., 2017), and fuzzy logic has additionally been applied to account for subjectivity in complexity evaluation (e.g. He et al., 2015; Nguyen et al., 2015; Vidal et al., 2011). A novel MCDM method is Best-Worst Method (BWM) proposed by Rezaei (2015). It has practical advantages over the more established methods like AHP, including a reduced amount and more semantic judgements needed as qualitative inputs from its user, as well as the inputs’ improved consistency (Rezaei, 2015). Behind this is a key strength of BWM which only requires the inputs in the form of reference comparisons of the importance of criteria – i.e. comparing the importance of the “best” criterion relative to each of the others, and the importance of each criterion relative to the “worst” criterion – using a nine-step numerical scale (Rezaei, 2015).

3.3.2 Best-Worst Method applied to project complexity evaluation

Given the multidimensional and multifaceted nature of the selected complexity evaluation model, the BWM’s advantages mentioned in the preceding section are relevant for establishing a systematic complexity evaluation approach proposed in this study. While BWM has already been applied in various fields, it has not been used in evaluating project complexity.

Application of the BWM in determining the relative importance of complexity indicators under each of the factor groupings can be done by applying the five steps proposed by Rezaei (2015). With minor adaptations needed for this study, these are explained in the following paragraphs using the example of determining the weightings for the five complexity indicators (C1.1 – C1.5) under complexity factor Site complexity (C1).
Step 1 – select the set of indicators for pairwise comparison
In the first step, a set of $n$ relevant decision criteria is defined $\{c_1, c_2, ... c_n\}$. In this study, the sets of indicators under each corresponding complexity factor of the complexity evaluation model are considered. For determining the relative importance of indicators $C1.1$ – $C1.5$, the relevant set of criteria is:

- $c_1$ – Reliability of site information
- $c_2$ – Complexity of site condition
- $c_3$ – Preparatory works needed
- $c_4$ – Permits and rights of way
- $c_5$ – Logistical complexity

Step 2 – determine the most and least important indicator
In the next step, the “best” criterion (i.e. most important complexity indicator) and the “worst” criterion (i.e. least important complexity indicator) are selected from the set of indicators under consideration. Experts with experience in lenders’ TDD of projects within the respective sector are best equipped to rank the importance of indicators under steps 2 – 4, and questions soliciting the required inputs can be structured in a questionnaire form (see Chapter 4).

Step 3 – Determine the “best-to-others” vector
Using the preference scale shown in Table 7, rate the relative importance of the previously selected most important complexity indicator over the others in the set. The preference scale was simplified for the purpose of this study compared to the original Rezaei’s (2015) 1-9 scale.

A “best-to-others” vector is obtained:

$$A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$$

where $a_{Bj}$ indicates the relative importance of the most important indicator over indicator $j$. In the example of indicators listed in Step 1 above, the vector has five elements. One of them is $a_{BB} = 1$ due to the inevitably “equal importance” of the most important indicator compared to its own importance.

| Table 7: Applied BWM preference scale |
|--------------------------|------------------|
| Value  | Meaning          |
| 1      | Equally important|
| 2      | Somewhat more important|
| 3      | More important   |
| 4      | Strongly more important|
| 5      | Extremely more important|

Step 4 – Determine the “others-to-worst” vector
In contrast to the previous step, this step rates the relative importance of all other complexity indicators in the set over the least important indicator. The same rating scale from Table 7 is applied using which the “others-to-worst” vector is therefore determined:

$$A_W = (a_{1W}, a_{2W}, ..., a_{nW})^T$$

where $a_{jW}$ indicates the relative importance of indicator $j$ over the selected least important indicator. One of the vector parameters is $a_{WW} = 1$ due to the inevitably “equal importance” of the least important indicator compared to its own importance.

Step 5 – Deriving the weights of the indicators in the set
According to the BWM method, the optimal weights $(w_1^*, w_2^*, ..., w_n^*)$ can now be determined that signify the relative importance of all complexity indicators within the set considered. The optimal weight is the one where (Rezaei, 2015): $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{jW}$ for all $j$. To satisfy these conditions, a solution is needed where the maximum of $|w_B/w_j - a_{Bj}|$ and $|w_j/w_W - a_{jW}|$, for all $j$, is minimised.
This means determining

\[
\min \max_j \left\{ \frac{|w_B - a_{Bj}|}{w_j}, \frac{|w_j - a_{jW}|}{w_W} \right\}
\]

such that \(\sum_j w_j = 1\) and \(w_j \geq 0\) for all \(j\).

This problem gives multiple optimal solutions when applied to comparing more than three elements, but can be transformed to a linear programming problem to obtain unique solutions (Rezaei, 2016). Unique solutions are considered more practical for the purpose of this study where a specific value for the weights is ultimately sought. The following problem must therefore be solved to determine the relative importance of complexity indicators (Rezaei, 2016):

\[
\min \xi_L, \text{ such that: }
\]

\[
|w_B - a_{Bj} w_j| \leq \xi_L, \text{ for all } j
\]

\[
|w_j - a_{jW} w_W| \leq \xi_L, \text{ for all } j
\]

\[
\sum_j w_j = 1
\]

\[
w_j \geq 0, \text{ for all } j
\]

Using these steps on the set of five indicators belonging to factor C1, their relative importance expressed as weights \((w^*_{C1.1}, w^*_{C1.2}, w^*_{C1.3}, w^*_{C1.4}, w^*_{C1.5})\) of complexity indicators is obtained, as well as a value for \(\xi = \xi_{L^*}\). The closer \(\xi_{L^*}\) is to zero, the higher the consistency of an expert’s inputs.

The weights of twenty-five complexity indicators under each of the seven selected complexity factors (C1-C4 and O1-O3) must be determined to obtain a high-level multi-dimensional overview of a project’s complexity. Additionally, the weights of the two sets of complexity factors pertaining to the project’s construction (C1-C4) and operational (O1-O3) phases can be determined which would enable the calculation of an overall measure of a project’s construction and operational complexity (however, as mentioned earlier, the benefit of such an unidimensional complexity index may be limited considering the purpose of this study). Therefore, the nine weight vectors listed in Table 8 are determined:

\[
\text{Table 8: Weight vectors for the nine considered sets of complexity evaluation criteria.}
\]

<table>
<thead>
<tr>
<th>Complexity factor</th>
<th>Weight vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 - Site complexity</td>
<td>((w^<em>_{C1.1}, w^</em><em>{C1.2}, w^*</em>{C1.3}, w^<em>_{C1.4}, w^</em>_{C1.5}))</td>
</tr>
<tr>
<td>C2 - Interfaces w/ environmnt.</td>
<td>((w^<em>_{C2.1}, w^</em><em>{C2.2}, w^*</em>{C2.3}))</td>
</tr>
<tr>
<td>C3 - Solution complexity</td>
<td>((w^<em>_{C3.1}, w^</em><em>{C3.2}, w^*</em>{C3.3}, w^<em>_{C3.4}, w^</em>_{C3.5}))</td>
</tr>
<tr>
<td>C4 - Ramp-up complexity</td>
<td>((w^<em>_{C4.1}, w^</em><em>{C4.2}, w^*</em>{C4.3}, w^*_{C4.4}))</td>
</tr>
<tr>
<td>O1 - Scope of O&amp;M obligations</td>
<td>((w^<em>_{O1.1}, w^</em><em>{O1.2}, w^*</em>{O1.3}, w^<em>_{O1.4}, w^</em>_{O1.5}))</td>
</tr>
<tr>
<td>O2 - Performance regime</td>
<td>((w^*_{O2.1}))</td>
</tr>
<tr>
<td>O3 - Technology outlook</td>
<td>((w^<em>_{O3.1}, w^</em><em>{O3.2}, w^*</em>{O3.3}))</td>
</tr>
<tr>
<td>C – Complexity before completion</td>
<td>((w^<em>_{C1}, w^</em><em>{C2}, w^*</em>{C3}, w^*_{C4}))</td>
</tr>
<tr>
<td>O – Complexity after completion</td>
<td>((w^<em>_{O1}, w^</em><em>{O2}, w^*</em>{O3}))</td>
</tr>
</tbody>
</table>

Section 3.4 describes a qualitative complexity evaluation system applied in this study. After scoring the complexity with respect to each of the detailed-level indicators, the complexity scores at the detailed indicator level can be translated to the top-level factors using the weights obtained according to the above procedure.

BWM could also be used in TDD to determine the relative importance of the top-level factors of the complexity assessment model. This would in turn enable the calculation of the overall complexity profile expressed as one number. The practicality of doing so is limited, however. As mentioned in Section 3.1, a single complexity score would in itself provide too limited insight into the specific sources of complexity from a debt-financing perspective.
This would not enable clearly communicating the project’s key complexities to be addressed in TDD, which is the central objective of this study. Complexity evaluation is therefore considered a means to comprehensive due diligence and not a goal in itself.

3.3.3 BWM-based questionnaire design
A questionnaire survey provides a practical method to obtain experts’ inputs on the complexity indicators’ relative importance as a basis for calculating the weights. This also provides an efficient means of soliciting and comparing possibly different experts’ views. The questionnaire shall be structured in accordance with steps 2-4 of BWM described above, for which the required input can be summarised in four questions for each set of complexity indicators in the complexity evaluation model:

• Which of the listed complexity elements do you consider “most important”?
• Which of the listed complexity elements do you consider “least important”?
• Indicate relative importance of the “most important” complexity element over each of the “other” complexity elements.
• Indicate relative importance of each “other” complexity element over the selected “least important” complexity element.

Given many different sets of complexity indicators used in this study and conditional relationships between the questions, designing an easy-to-use BWM-based questionnaire is important. The respondents must concentrate on multiple sets of criteria and provide consistent inputs based on their pairwise judgement of the importance of different pairs of criteria. With a view to reducing the possibility of respondents making a mistake or getting confused, a clear questionnaire interface had to be prepared that could allow for conditional branching. Due to limited access to advanced survey design tools, the questionnaire was prepared in Excel spreadsheets making use of basic conditional functions in designing a transparent user interface. This also allows the addition of functions enabling the analysis of obtained inputs and the calculation of weights.

For application in this study (see 4.2), the questionnaire started with a summary of the study’s purpose, general questions on the respondents’ backgrounds, and instructions for filling out the BWM-based questions. This is followed by sections each entailing four questions formulated above. Each section concerns one of the groups of complexity indicators or complexity factors. For example, factor C1 comprises complexity indicators C1.1-C1.5 whose relative importance must be determined. Therefore, indicators C1.1-C1.5 constitute one group, i.e. one section of the questionnaire. An overview of the questionnaire structure is provided in Appendix D.

3.4 Qualitative system for measuring complexity
This section describes the qualitative system applied in measuring complexity in this study. A complexity scoring scale is defined first, and the selected complexity indicators are described to provide a basis for evaluating complexity from a debt-financing perspective.

3.4.1 Qualitative complexity scoring scales
To assess complexity of a project on each of the complexity indicators, a scale must be defined that allows a degree of differentiation between projects ranging from simple to complex. The scale must be predefined to enable the consistent scoring in a bottom-up approach and the scores’ translation to a higher-level project complexity profile. All the complexity indicators included in the hierarchical complexity evaluation model are of a qualitative nature and some have a somewhat intangible character. Likert-type scales are commonly used in such applications. In this study, the following five-step scale is used, its five positions representing the following qualitative values:

1 - Very simple; 2 – Simple; 3 – Somewhat complex; 4 – Complex; 5 – Very complex

In TDD, many analyses are based on expert judgement (see 2.2.) in which a degree of subjectivity is unavoidable. The same applies to previous attempts at systematising project complexity evaluation found in academic studies (see 2.1). A fully rigid complexity evaluation approach is thus not considered practical, and a trade-off must be made between the consistency a rating scale ensures and the flexibility it leaves to its users. This can be done by
selecting an appropriate degree to which the complexity scoring considerations are predefined. For the purposes of this study, a decision was made to predefine the extreme situations (corresponding to complexity scores “1 – very simple” and “5 – very complex”) for each complexity indicator, and additionally describe the situation in which a project could be considered “3 – somewhat complex”.

3.4.2 Description of selected complexity indicators
The complexity indicators included in the hierarchical complexity evaluation model were discussed with two LTAs to gain an understanding of how each indicator could be assessed to provide insight as a preliminary overview in TDD of a project’s complexity. Based on this, complexity indicators included in the complexity evaluation model can be explained based on practitioners’ inputs and insights from academic and practice-based literature reviewed in Chapter 2. Brief definitions of each complexity indicator are provided Table 9. In line with the observed role of project complexity in technical due diligence and its operationalised definition, a preliminary overview of a project’s inherent risk character is needed through project complexity evaluation. Thus, the definitions of complexity indicators were set to focus on identifying and evaluating project planning and implementation uncertainties to which the borrower is exposed according to its agreement with the contracting authority. Based on this, qualitative complexity scoring guidance was prepared for application in this study. In Appendix B, each complexity indicator is described, and the relevant qualitative scoring scales for each complexity indicator are provided in Appendix C.
Table 9: Overview of complexity indicators and their definitions used in this study.

<table>
<thead>
<tr>
<th>FACTOR LEVEL</th>
<th>INDICATOR LEVEL</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 – Site complexity</td>
<td>C1.1 Reliability of site information</td>
<td>For site condition risks borne by the borrower under project agreement, the extent to which the currently available information on site condition is lacking in terms of quality or coverage of the site, potentially hindering reliability of project planning assumptions.</td>
</tr>
<tr>
<td></td>
<td>C1.2 Complexity of site condition</td>
<td>Challenging character and diversity of any difficult site conditions known or likely to be present on site, for which borrower bears responsibility in PA.</td>
</tr>
<tr>
<td></td>
<td>C1.3 Preparatory works needed</td>
<td>Technical measures required before main civil works can commence on site (e.g. site clearance, access roads construction, soil decontamination, geotechnical structures, protection of cables and conduits, etc.).</td>
</tr>
<tr>
<td></td>
<td>C1.4 Permits &amp; rights of way</td>
<td>Amount of outstanding legal and administrative procedures, related to obtaining construction permits and land use rights, that are the borrower’s responsibility under the project agreement.</td>
</tr>
<tr>
<td></td>
<td>C1.5 Logistical complexity</td>
<td>Severity of logistical challenges posed by site location, such as limited accessibility in remote or physically constrained sites, interfaces with the facility’s ongoing use during construction, etc..</td>
</tr>
<tr>
<td>C2 – Interfaces with environ</td>
<td>C2.1 Amount of construction restrictions</td>
<td>Location-specific boundary conditions for scheduling construction works due to e.g. interfaces with neighbouring sites or facilities, sensitivity of environment, safety rules, weather and climate, etc.</td>
</tr>
<tr>
<td></td>
<td>C2.2 Complexity of restrictions</td>
<td>Need for innovative and unproven solutions for overcoming restrictions on timing of construction works arising from the project’s environment.</td>
</tr>
<tr>
<td></td>
<td>C2.3 Dependence on external stakeholders</td>
<td>Extent to which project planning, implementation and delivery are dependent on cooperation with any stakeholders external to the project.</td>
</tr>
<tr>
<td>C3 – Solution complexity</td>
<td>C3.1 Level of design completion</td>
<td>Current cost and schedule uncertainty due to preliminary nature of designs and dependence on concurrent design process.</td>
</tr>
<tr>
<td></td>
<td>C3.2 Design verifications by client</td>
<td>Amount of design risks borne by the borrower under project agreement in case design solutions are not prescribed and/or verified by client under the project agreement.</td>
</tr>
<tr>
<td></td>
<td>C3.3 Structure uniqueness</td>
<td>Non-standard character of the design solution or its key components.</td>
</tr>
<tr>
<td></td>
<td>C3.4 Interdependence of sub-projects</td>
<td>Extent to which the overall project’s key components are interdependent.</td>
</tr>
<tr>
<td></td>
<td>C3.5 Technology and materials</td>
<td>Amount of risk arising from the project’s reliance on technology or materials with limited or negative track record in similar applications.</td>
</tr>
<tr>
<td>C4 – Ramp-up complexity</td>
<td>C4.1 Amount of systems &amp; equipment</td>
<td>Amount of various systems that must be installed and coordinated after the main construction works are completed.</td>
</tr>
<tr>
<td></td>
<td>C4.2 Complexity of systems &amp; equipment</td>
<td>Complexity of installations systems that must be installed and coordinated after the main construction works are completed.</td>
</tr>
<tr>
<td></td>
<td>C4.3 Completion requirements complexity</td>
<td>Strictness of requirements regarding the performance of installations systems to meet completion requirements.</td>
</tr>
<tr>
<td></td>
<td>C4.4 Testing time required</td>
<td>Time required for the installations systems to be tested and accepted.</td>
</tr>
<tr>
<td>O1 – Scope of O&amp;M obligations</td>
<td>O1.1 Nature of FM/routine mtc. obligations</td>
<td>Extent to which the borrower’s obligations are labour intensive, technologically risky, uncertain in scope, etc..</td>
</tr>
<tr>
<td></td>
<td>O1.2 Scheduling complexity for FM/routine mtc.</td>
<td>Extent to which the operation obligations pose difficulties scheduling routine maintenance while maintaining the asset available.</td>
</tr>
<tr>
<td></td>
<td>O1.3 Amount of asset renewal responsibility</td>
<td>Extent to which the project agreement makes the borrower responsible for major asset renewals in the contracted period, level of strictness of borrower’s handback requirements for the asset.</td>
</tr>
<tr>
<td></td>
<td>O1.4 Predictability of asset renewal needs</td>
<td>Uncertainty regarding the exact timing and scope of needed major asset renewal works the borrower is responsible for.</td>
</tr>
<tr>
<td></td>
<td>O1.5 Technical specialisation required</td>
<td>Extent to which the required asset renewal needs require highly specialised technology or labour.</td>
</tr>
<tr>
<td>O2 – Performance regime</td>
<td>O2.1 Onerousness of performance regime</td>
<td>Sensitivity of the performance regime to minor fluctuations in the asset’s performance.</td>
</tr>
<tr>
<td>O3 – Technology outlook</td>
<td>O3.1 Technology track record</td>
<td>Extent to which the installed technology’s long-term performance is uncertain based on its newness or innovativeness.</td>
</tr>
<tr>
<td></td>
<td>O3.2 Availability of parts &amp; consumables</td>
<td>Extent to which the installed technology is unique and poses risks regarding availability of spare parts for maintenance.</td>
</tr>
<tr>
<td></td>
<td>O3.3 Built-in redundancy</td>
<td>Sensitivity of the asset’s availability to disruptions in technology on which it directly relies.</td>
</tr>
</tbody>
</table>
3.5 Specified systematisation of complexity evaluation

To address the complexity evaluation challenge described in Section 3.1, a systematic approach to complexity evaluation in TDD is proposed consisting of a series of steps needed for communicating, aggregating and analysing the experts’ inputs on a project’s complexity from the lenders’ perspective. The systematic approach is needed as a preliminary TDD analysis to identify the focus areas for subsequent risk analyses corresponding to the key complexities of a project. To do so, a three-component approach is specified as summarised below, together providing an answer to second research sub-question of this research:

**SQ2: In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?**

To systematise complexity evaluation in TDD, a three-component approach must be applied as shown in Figure 8. First, a complexity evaluation model must be constructed comprising project complexity indicators relevant from a lenders’ perspective and corresponding to the scope of technical due diligence. To do so, twenty-six relevant complexity elements identified in the literature study were used to define a hierarchical complexity evaluation model for application in this study. Its top-level complexity factors correspond to the top-down view of lenders in their credit risk analysis models. The underlying detailed-level complexity indicators comprehensively cover project-
specific technical features enabling engineers’ systematic bottom-up complexity evaluation focusing on particular technical features that may give rise to complexity perceived from a debt-financing perspective.

Second, given the multi-faceted hierarchical structure of a complexity evaluation model, the **importance of complexity indicators in a project type under consideration must be determined** based on the views of experts involved in TDD. BWM is applied that enables a structured solicitation of experts’ inputs and quantification of weights of complexity indicators. In this study, the inputs on the importance of complexity indicators are provided in a questionnaire survey by experts from fields of finance and engineering, namely the representatives of lenders appraising a particular project for debt-financing, and engineers acting as LTAs performing TDD analyses. Any differences in experts’ views and specific concerns can be identified at this stage, helping set the direction for detailed TDD. BWM (BWM) is applied due to its reduced data intensity and improved consistency of inputs, where for which each factor grouping of complexity indicators, the following four standard questions must be answered:

- From the set of complexity indicators under complexity factor considered, select the **MOST IMPORTANT complexity indicator**.
- From the set of complexity indicators under complexity factor considered, select the **LEAST IMPORTANT complexity indicator**.
- Using a 1-5 scale (see 3.3.2) express the relative importance of the selected **MOST IMPORTANT complexity indicator relative to EACH OF THE OTHER indicators** in the considered group.
- Using a 1-5 scale (see 3.3.2) express the relative importance of **EACH OF THE OTHER indicators** in the considered group **relative to THE LEAST IMPORTANT complexity indicator** in the considered group.

The BWM-based steps applied for analysing the expert inputs and quantifying the weights of complexity indicators are described in section 3.3. The weights of complexity indicators are the output of this second component of the proposed systematic approach.

Third, separately from determining the weights of complexity indicators, the **project’s complexity must be scored using the detailed-level complexity indicators** included in selected hierarchical complexity evaluation model. To do so, a qualitative scoring system consisting of numerical scoring scales and qualitative considerations for complexity evaluation must be defined that enable consistent scoring and quantification of a project’s complexity. In section 3.4, a five-step complexity scoring scale is selected and the complexity indicators applied in this study are defined, based on which a qualitative scoring system is defined as shown in Appendix C. In line with the purpose of TDD, the bottom-up scoring of a project’s complexity using the proposed approach relies on structured expert judgement of LTAs involved in a project’s due diligence. The numerical values representing the scores on each complexity indicator are obtained as output of this part of the proposed system.

Finally, with the resulting weights and scores for each complexity indicator, the detailed-level evaluation can be translated to a higher-level overview of a project’s complexity. This shall facilitate the finance experts’ and engineer’s common high-level understanding of a project’s complexity, and identify the key detailed focus areas for TDD based on insight into the key project-specific risks relevant from a debt-financing perspective. In this study, a seven-dimensional complexity profile is obtained using the twenty-six potential complexity indicators applied in the hierarchical complexity evaluation model.
4 Case studies: revisiting technical due diligence

In this step, two case study projects’ complexity from a lenders’ perspective is explored by applying the specified systematic approach. The early TDD phase is revisited for the two case study projects. First, a document review of the projects’ background information that had been available before detailed due diligence is carried out, providing a basis for assessing the complexity of each project. Based on the inputs of each project’s LTAs and finance experts involved at the time of TDD, the importance of complexity indicators is analysed using a questionnaire survey. Based on inputs solicited through semi-structured interviews with LTAs, the case study projects’ complexity from the lenders’ perspective is explored. Two real-life, ongoing projects are revisited in this way, enabling a discussion of their overall complexity profiles, while empirical observations from the approach application provide input for answering the third research sub-question:

SQ3: How can the systematic approach to complexity evaluation be applied in technical due diligence?

In the next section (4.1), the selection of case study projects is explained first. Section 4.2 explains the approach to, and analysis of, gathering practitioners’ inputs required for applying the proposed complexity evaluation approach. Section 4.3 discusses the results of complexity evaluation and the empirical observations, leading to answering (4.4) the addressed third sub-question of this study.

4.1 Case study project selection

Several criteria were used to select the projects for the explanatory case study. First, projects of two main types of privately financed infrastructure projects in The Netherlands were targeted, namely public buildings and availability-based (i.e. non-tolled) highways. Second, the experts involved in the targeted projects had to be prepared to share and discuss the required project documentation, as well as able and willing to participate by providing the needed expert inputs. To revisit TDD and illustrate the practical application of the proposed approach to complexity evaluation, at least the following two groups of sufficiently experienced experts were required per project:

- Finance experts involved prior to and following financial close as representatives of one of the lenders. These were needed to provide questionnaire responses for needed expert inputs on the perceived relative importance of complexity indicators in line with the specified evaluation approach. In addition, following complexity evaluation these were invited to participate in follow-up interviews (see 5.1).
- Engineers involved in the project as LTAs during TDD and in subsequent construction and operations monitoring. These were also first needed for providing expert inputs on the perceived relative importance of complexity indicators. In addition, the LTAs were needed to provide inputs for complexity scoring itself in semi-structured interviews as per the proposed approach.

A preference was therefore for projects where the involved experts took part in the TDD analyses of the bidding consortium having emerged as the preferred bidder and successfully reaching financial close (see 1.1.1). Third, it was aimed to select projects that started recently enough but have subsequently passed most of their respective construction phases. This allows insight on whether the complexity evaluation result appropriately captures the project’s key complexity as it was observed in real life.

Two projects that meet the above criteria were identified. The projects are located in The Netherlands and have reached financial close several years prior to this study. The first project (Project Alpha) belongs to the economic infrastructure category and concerns the design, construction, financing and maintenance of an availability-based highway construction project. The second project (Project Beta) represents the social infrastructure sector and concerns the availability-based contract integrating design, construction, financing, maintenance and operation of a public office building. The two projects are briefly presented in the following sub-sections.

In line with the observed role of project complexity in TDD, complexity evaluation is primarily needed at an initial stage of TDD, when limited information is available on the details of a borrower’s project plan. The robustness of risk allocation away from the SPV can then be analysed based on the project’s complexity from a debt-financing perspective. However, a project enabling such real-time application of the complexity evaluation system was not available within the scope of this research. Therefore, the due diligence stage of past projects was revisited instead.
While such retrospective approach may have its limitation in the difficulty of limiting complexity evaluation to the information available at the point in time that is revisited, a benefit is that the project’s real-life performance can provide useful feedback on the accuracy of evaluation. As a mitigation to the effects of the mentioned limitation, a thorough review of the TDD documentation had to be carried out first to gain an understanding of the extent of information available before the project’s financial close.

4.1.1 Case study Project Alpha

The first case study project (*Project Alpha*) is based on an availability-based PPP contract that entails the reconstruction and expansion of a highway section and the adjacent interchange, followed by its maintenance over a period of 25 years. The project is located in a heavily urbanised setting. The existing highway was characterised by heavy traffic loads and needed to remain operational throughout the project’s construction phase. Additional constraints to the project’s implementation were related to interfaces with existing utilities and infrastructure including a railway and a local road network crossing the construction site at 15 specific locations. The central construction works were related to the implementation of a cut-and-cover tunnel in length of several kilometres. The tunnel’s cross-section had to house a multi-lane highway for transit traffic, an additional reversible lane for heavy traffic, and a multi-lane local road leading to additional tunnel exits halfway through the tunnel, connecting to a local road network. Other main works included the reconstruction and expansion of a highway bridge, the relocation of existing utilities, maintenance of existing water retaining structures, implementation of traffic management systems, and following completion of works, the long-term maintenance of all newly built infrastructure.

The overall project was valued at around half a billion Euros and remuneration was based on two partial lump-sum payments conditioned upon successful completion of the construction phase, followed by monthly payments conditioned on the project’s sufficient availability in the long-term maintenance phase. The integrated contract covering design, construction, financing and maintenance was awarded by a public client through a procurement procedure with competitive dialogue based on national and European Union’s legislation. The contracting authority previously gained extensive experience procuring similar works under the same procurement and contracting model.

The members of the bidding consortium considered in TDD and winning the public tender were major construction and engineering companies that together provided equity funds to establish a special purpose vehicle (SPV) which entered into a DBFM project agreement with the contracting authority (see Figure 9). The SPV then transferred all its responsibilities from the project agreement to a single sub-contractor on a ‘back-to-back’ principle via a fixed-price engineering, procurement, construction and maintenance (EPCM) sub-contract for the whole construction and maintenance period. As is common in such arrangements, the sub-contractor was also a joint venture between the subsidiaries of the companies owning the SPV.

![Figure 9: Simplified organisational structure of Project Alpha](image-url)
4.1.2 Case study project Beta

The second case study project (Project Beta) involved the redevelopment and expansion of a public office building. A construction period of approximately 2.5 years was followed by the building’s 25-year maintenance and operation (including any needed major maintenance, the supply of energy and water, catering services, cleaning, building-related security, building related ICT and reception, supply of furniture, moving, office equipment and sanitary tools, green maintenance, monitoring, and waste management). The project’s location was characterised by a very constrained site in an urban area, and parallel construction activities at a neighbouring site. The limited access and insufficient storage space necessitated the use of just-in-time delivery strategies for the main construction supplies. The construction phase consisted of a brownfield and a greenfield part. First, the existing building underwent the stripping of existing façade and other non-structural elements, partial demolition of the existing structure, asbestos removal, rearrangement of floor plans and vertical connections. After that, the connection and construction of the new part of the building was carried out.

The project was procured by a public contracting authority under a negotiated public procurement procedure based on EU and national legislation. The contractual relation between the contracting authority, the user and the SPV is governed by an integrated project agreement defining the SPV’s responsibilities for project design, construction, financing, maintenance and operation (DBFMO agreement). The value of the project was around one hundred million Euros and remuneration was based on two partial lump-sum payments conditioned upon successful completion of the construction phase, followed by monthly payments conditioned upon the project meeting the agreed availability levels in the maintenance and operations phase.

The members of the bidding consortium considered in TDD and winning the public tender were two major construction and facilities management companies that together provided equity funds to establish a special purpose vehicle (SPV) entering into a DBFMO project agreement with the contracting authority (see Figure 10). The SPV then transferred all its responsibilities from the project agreement to a single sub-contractor on a ‘back-to-back’ principle via a fixed-price date-certain design, build, maintain and operate (DBMO) sub-contract for the entire period agreed in the project agreement.

![Figure 10: Simplified organisational structure of Project Beta](image-url)
4.2  Approach application
As discussed in section 3.5, the specified systematic approach to complexity evaluation consists of three main components entailing several steps (see Figure 8). The first component focuses on the selection of potentially relevant complexity elements and their structuring in a hierarchical complexity evaluation model. For application in this study, these steps were carried out in Chapter 3 based on complexity elements identified in a review of literature and practice. In this section, the steps of the parallel second and third components of systematic complexity evaluation are applied for the two selected case study projects.

4.2.1  Determining the importance of complexity factors and indicators
As per the proposed approach to evaluating project complexity (see 3.5), the various complexity indicators and factors are ranked according to their relative importance in each project type considered. This is done based on inputs of experts involved in TDD and allows the calculation of the complexity indicators’ weights using the Best-Worst-Method. The gathering of data in a questionnaire survey is explained in this section, and the next section explains the quantification of weights based on questionnaire responses.

4.2.1.1  Questionnaire design validation
The weights of the complexity indicators had to be determined for each of the two case study project types. Using a questionnaire survey designed as explained in Section 3.3, finance and engineering experts involved in each of the two projects’ due diligence and monitoring activities were asked to indicate their perception of the relative importance of complexity factors and indicators in the project type of the respective case study project.

The questionnaire was first validated with one lender and one engineer selected on the basis of suitable background and experience to confirm the clarity of the instructions and included questions. Two corrections on the general instruction for filling out the questionnaire were suggested. First, it was suggested to correct the instruction by clarifying that the respondents should focus on projects in the Dutch market for privately-financed infrastructure. It was emphasised that international finance professionals would inevitably consider the importance of some complexity indicators differently in markets where the PPP sector is not developed compared to mature PPP market found in The Netherlands. Indicators exposed as sensitive to the maturity of a local market for PPP infrastructure included particularly those referring to the interfaces with external stakeholders and those concerning the permitting procedures. Similarly, it was suggested to instruct the respondents to consider a narrower project type than “PPP buildings” or “PPP highways” to obtain inputs more relevant for the project type concerned in the case study. Both of these considerations are in line with the purpose of gathering experts’ inputs in the proposed approach. In particular, the BWM-based steps are intended to enable an analysis of the involved expert’s views regarding the included complexity indicators’ relative importance in a specific project type considered. According to one validator, whether the project is a greenfield construction in a rural environment or a brownfield construction in an urban environment automatically affects the perceived importance of various complexity indicators. Based on these suggestions, the general instruction when administering the questionnaire was for the respondents to base their answers on their experience either with the project type “PPP building project in an urban environment” or “PPP highways in an urban environment” in The Netherlands. For clarity, these two project types are hereafter referred to as “buildings” and “highways”, respectively.

4.2.1.3  Questionnaire respondents
Fourteen lenders and their technical advisers actively involved in one of the two case study projects were asked to fill out questionnaires indicating their view on the relative importance of complexity indicators for the respective project types. The participating respondents were nine professionals with 10 to 20 years’ general professional experience and 5-10 years of specific experience in the field of infrastructure project financing. These included six lenders and three LTAs. Three lenders’ representatives and one technical adviser completed the questionnaire based on their experience with PPP building projects, and three lenders’ representatives and two technical advisers based on their experience with PPP highway projects.

4.2.1.4  Questionnaire limitations
Although the respondents were instructed to fill out the questionnaire based on their overall experience with the respective project types (i.e. not specific projects), it is recognised that the respondents’ inputs may be guided by their specific experience with the case study project they were involved in. Furthermore, due to the limited number
of privately-financed infrastructure projects in the region in recent years, the case study projects may also be the respondents’ most recent experience of this type. Therefore, the results of the questionnaire presented in the following section may not be generalised and are partly representative of the specific projects whose TDD is revisited in this chapter. As mentioned in 4.1, such a limitation is unavoidable in retrospectively analysing a project (see 4.1). Given the generally illustrative purpose of case studies, it can be considered acceptable for this study.

4.2.2 Quantification of complexity elements’ weights

The expert inputs obtained through the questionnaire were each analysed separately based on the BWM steps described in Section 3.3.2 to derive the weights of indicators for each respondent, as well as a consistency indicator to control the reliability of the obtained inputs. As an illustration of the BWM analysis, the analysis of one respondent’s views of relative importance for indicators under factor C3 is presented here. The respondent provided answers for building projects. Factor C3 entails five indicators: level of design completion (C3.1), design verifications by client (C3.2), structure uniqueness (C3.3), interdependence of sub-projects (C3.4), and technology & materials (C3.5). These indicators are coded under C3.1 - C3.5 and the set of criteria under consideration can therefore be defined as:

\[ \{c_1, c_2, c_3, c_4, c_5\} = \{C3.1, C3.2, C3.3, C3.4, C3.5\} \]

As shown in Figure 11, this respondent selected C3.3 (structure uniqueness) as the most important indicator, and C3.1 (level of design completion) as the least important.

Based on the respondent’s ranking of the relative importance of other indicators, the following “best-to-others” and “others-to-worst” vectors are considered:

\[
A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn}) = (a_{BC3.1}, a_{BC3.2}, a_{BC3.3}, a_{BC3.4}, a_{BC3.5}) = (4,3,1,2,2) \\
A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})^T = (a_{C3.1W}, a_{C3.2W}, a_{C3.3W}, a_{C3.4W}, a_{C3.5W})^T = (1,2,4,3,3)^T
\]

Therefore, as explained in section 3.4, the lowest positive \( \xi^L \) must be found that satisfies the following respondent-specific set of constraints:

\[
\begin{align*}
\xi^L & \geq \left| w_{C3.3} - 4w_{C3.1} \right| \\
& \geq \left| w_{C3.3} - 3w_{C3.2} \right| \\
& \geq 0 \\
& \left| w_{C3.3} - 2w_{C3.4} \right| \\
& \left| w_{C3.3} - 2w_{C3.5} \right| \\
& \left| w_{C3.2} - 2w_{C3.1} \right| \\
& \left| w_{C3.4} - 3w_{C3.1} \right| \\
& \left| w_{C3.5} - 3w_{C3.1} \right| \\
\end{align*}
\]

\[
w_{C3.1} + w_{C3.2} + w_{C3.3} + w_{C3.4} + w_{C3.5} = 1 \\
w_{C3.1}, w_{C3.2}, w_{C3.3}, w_{C3.4}, w_{C3.5} \geq 0
\]

Using the Solver plug-in in MS Excel, the following optimal weights are obtained that can solve the above system:

\[
w^*_{C3.1} = 0.0822, w^*_{C3.2} = 0.1370, w^*_{C3.3} = 0.3699, w^*_{C3.4} = 0.2055, w^*_{C3.5} = 0.2055
\]

and a consistency indicator of \( \xi^{L^*} = 0.04 \).

In total, nine respondents’ inputs on eight sets of complexity elements were analysed (see Appendix E), thus requiring seventy-two BWM analyses. The consistency of the obtained responses ranged from 0.02 to 0.11 in most cases, indicating a satisfactory consistency. Weaker consistencies were recorded in three instances, namely in one respondent’s inputs regarding indicators C2.1-C2.3 (\( \xi^{L^*} = 0.17 \)), and another respondent’s inputs regarding indicators C4.1-C4.4 (\( \xi^{L^*} = 0.14 \)) and factors O1-O3 (\( \xi^{L^*} = 0.19 \)). While less consistent, the weights obtained from these inputs did not deviate significantly from other answers and were therefore not excluded. Individual
respondents’ weights in each group of complexity elements were averaged for each of the two project types considered (Table 10), enabling to proceed with complexity evaluation for the two case study projects. Several observations on the obtained individual and average results are given in the following section.

### Solution complexity

The factor ‘Solution complexity’ entails five indicators as shown in the table below.

<table>
<thead>
<tr>
<th>Solution complexity</th>
<th>C3.1</th>
<th>C3.2</th>
<th>C3.3</th>
<th>C3.4</th>
<th>C3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level of design completion</td>
<td>Design verifications by client</td>
<td>Structure uniqueness</td>
<td>Interdependence of sub-projects</td>
<td>Technology &amp; materials</td>
</tr>
</tbody>
</table>

#### Question 1: Most important indicator

From the above listed complexity indicators, which one do you consider MOST IMPORTANT?

<table>
<thead>
<tr>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure uniqueness</td>
</tr>
</tbody>
</table>

#### Question 2: Least important indicator

From the above listed complexity indicators, which one do you consider LEAST IMPORTANT?

<table>
<thead>
<tr>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of design completion</td>
</tr>
</tbody>
</table>

#### Question 3: Most important vs. others

In green areas of the table below, please indicate the importance of each indicator listed on the left compared to the LEAST IMPORTANT indicator (selected in Question 2 above).

<table>
<thead>
<tr>
<th>&quot;Most important&quot;</th>
<th>is (select from drop-down) .. as/than the indicator below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure uniqueness</td>
<td>4 - strongly more important</td>
</tr>
<tr>
<td>Structure uniqueness</td>
<td>3 - more important</td>
</tr>
<tr>
<td>Structure uniqueness</td>
<td>1 - equally important</td>
</tr>
<tr>
<td>Structure uniqueness</td>
<td>2 - somewhat more important</td>
</tr>
<tr>
<td>Structure uniqueness</td>
<td>2 - somewhat more important</td>
</tr>
</tbody>
</table>

#### Question 4: "Others" vs. LEAST important

In green areas of the table below, please indicate the importance of each indicator listed on the left compared to the LEAST IMPORTANT indicator (selected in Question 2 above).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>is (select from drop-down) .. as/than &quot;least important&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of design completion</td>
<td>1 - equally important</td>
</tr>
<tr>
<td>Design verifications by client</td>
<td>2 - somewhat more important</td>
</tr>
<tr>
<td>Structure uniqueness</td>
<td>4 - strongly more important</td>
</tr>
<tr>
<td>Interdependence of sub-projects</td>
<td>3 - more important</td>
</tr>
</tbody>
</table>

Figure 11: Example of one respondent’s questionnaire inputs on complexity indicators C3.1-C3.5.
Table 10: Overview of obtained BWM-based weights, average of all respondents per project type

<table>
<thead>
<tr>
<th>COMPLEXITY FACTOR / INDICATOR</th>
<th>BUILDINGS (n=4)</th>
<th>HIGHWAYS (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w*&lt;sub&gt;average&lt;/sub&gt;</td>
<td>st.d.</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSTRUCTION COMPLEXITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1 Site complexity</td>
<td>0.40*</td>
<td>0.09</td>
</tr>
<tr>
<td>C2 Interfaces with environment</td>
<td>0.23</td>
<td>0.11</td>
</tr>
<tr>
<td>C3 Solution complexity</td>
<td>0.22</td>
<td>0.06</td>
</tr>
<tr>
<td>C4 Ramp-up complexity</td>
<td>0.16</td>
<td>0.06</td>
</tr>
<tr>
<td>C1.1 Reliability of site information</td>
<td>0.15</td>
<td>0.04</td>
</tr>
<tr>
<td>C1.2 Complexity of site condition</td>
<td>0.26</td>
<td>0.07</td>
</tr>
<tr>
<td>C1.3 Preparatory works needed</td>
<td>0.10</td>
<td>0.04</td>
</tr>
<tr>
<td>C1.4 Permits &amp; rights of way</td>
<td>0.32*</td>
<td>0.09</td>
</tr>
<tr>
<td>C1.5 Logistical complexity</td>
<td>0.16</td>
<td>0.03</td>
</tr>
<tr>
<td>C2 INTERFACES WITH ENVIRONMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2.1 Amount of constr. restrictions</td>
<td>0.40</td>
<td>0.12</td>
</tr>
<tr>
<td>C2.2 Complexity of restrictions</td>
<td>0.18</td>
<td>0.02</td>
</tr>
<tr>
<td>C2.3 Dependence on external stakeholders</td>
<td>0.42*</td>
<td>0.13</td>
</tr>
<tr>
<td>C3 SOLUTION COMPLEXITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3.1 Level of design completion</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>C3.2 Design verifications by client</td>
<td>0.13</td>
<td>0.01</td>
</tr>
<tr>
<td>C3.3 Structure uniqueness</td>
<td>0.29*</td>
<td>0.07</td>
</tr>
<tr>
<td>C3.4 Interdependence of sub-projects</td>
<td>0.24</td>
<td>0.08</td>
</tr>
<tr>
<td>C3.5 Technology and materials</td>
<td>0.22</td>
<td>0.12</td>
</tr>
<tr>
<td>C4 RAMP-UP COMPLEXITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4.1 Amount of systems &amp; equipment</td>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>C4.2 Complexity of systems &amp; equipment</td>
<td>0.25</td>
<td>0.06</td>
</tr>
<tr>
<td>C4.3 Completion requirements complexity</td>
<td>0.37*</td>
<td>0.09</td>
</tr>
<tr>
<td>C4.4 Testing time needed</td>
<td>0.27</td>
<td>0.09</td>
</tr>
<tr>
<td>O OPERATIONAL COMPLEXITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O1 Scope of O&amp;M obligations</td>
<td>0.36</td>
<td>0.10</td>
</tr>
<tr>
<td>O2 Performance regime</td>
<td>0.39*</td>
<td>0.16</td>
</tr>
<tr>
<td>O3 Technology outlook</td>
<td>0.25</td>
<td>0.17</td>
</tr>
<tr>
<td>O1.1 Nature of FM/routine mtce. obligations</td>
<td>0.19</td>
<td>0.04</td>
</tr>
<tr>
<td>O1.2 Scheduling complexity for FM/rout. mtce.</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>O1.3 Amount of asset renewal responsibility</td>
<td>0.19</td>
<td>0.09</td>
</tr>
<tr>
<td>O1.4 Predictability of asset renewal needs</td>
<td>0.22</td>
<td>0.12</td>
</tr>
<tr>
<td>O1.5 Technical specialisation required</td>
<td>0.23*</td>
<td>0.12</td>
</tr>
<tr>
<td>O2 PERFORMANCE REGIME</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2.1 Onerousness of performance regime</td>
<td>1.00</td>
<td>n/a</td>
</tr>
<tr>
<td>O3 TECHNOLOGY OUTLOOK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O3.1 Technology track record</td>
<td>0.46*</td>
<td>0.15</td>
</tr>
<tr>
<td>O3.2 Availability of parts &amp; consumables</td>
<td>0.31</td>
<td>0.13</td>
</tr>
<tr>
<td>O3.3 Built-in redundancy</td>
<td>0.23</td>
<td>0.08</td>
</tr>
</tbody>
</table>

* - most important in a set
4.2.3 Interpretation of obtained weights

In Figures 12-14, an overview of the individual respondents’ inputs is provided. Each column represents the weight of a complexity factor or indicator obtained based on each respondent’s questionnaire inputs, and the line plots the averages of responses in each cluster of complexity elements.

Although the applied 5-step BWM rating scale included the option for respondents to mark the relative importance of a pair of complexity elements as “1 – equally important” (see 3.3.2), this option was not used in many responses (one exception is the factor grouping site complexity (C1) where for highway projects, two respondents marked three of the five complexity indicators as equally important). While the average weights show a relatively equal importance of all complexity elements — obtained average weights mainly ranging from 0.20 to 0.40, many respondents showed a clear preference regarding a certain indicator’s importance.

The differences in experts’ views were relatively high in certain sets of complexity elements. For instance, most respondents considered a different complexity indicator under factor groupings C3, C4 and O1 as most important (Figures 12 and 13) in both project types. Moreover, while most respondents pointed to superior relative importance of the indicator site complexity (C1) in a building’s pre-completion phase (see Figure 14), one of the respondents assigned highest importance to the project’s interfaces with environment (C2) — and in contrast, this factor was considered least important by another respondent. One of the reasons for the lack of consensus in the questionnaire results could be the respondents’ different interpretations of complexity indicators. However, the clarity of the questionnaire was generally confirmed in questionnaire validation (4.2.1.2) and respondents did not provide negative feedback in that regard (5.1). Therefore, subjective preferences may be at play that could explain the differences in views. As also suggested by experts interviewed following the questionnaire survey (Sections 4.2.3 and 5.1, respectively), the subjective preferences may be formed by practitioners’ backgrounds and past experience with specific issues. For example, one respondent (Respondent 4) in project type “buildings” clearly underlined the importance of all complexity indicators related to the newness of technology (C3.5, O1.5, O3). The questionnaire responses differed both between the two groups of respondents (i.e. engineering and finance professionals) and among individuals in each group.

Lacking statistical significance that would enable a quantitative analysis, averaging inevitably has a moderating effect on the differences in perceived importance of complexity indicators — it makes the weights converge towards suggesting the complexity elements’ nearly equal importance. In practice, this may not be practical and considered acceptable by experts who seem to have a clearly defined preference regarding the importance of some complexity indicators. This points to a need for expressing and discussing, rather than averaging, the individuals’ views of the complexity indicators’ importance. In the proposed systematic approach to complexity evaluation, the BWM-based step appears useful in aggregating and analysing different experts’ views. For the purpose of this study, however, average weights shown in Table 10 were used to proceed with the illustration of systematic complexity evaluation in the following sections. Several possible reasons for experts’ opposing views are subsequently identified in results of validation interviews with lenders (5.1).

Comparing the resulting weights in the two project types (Figures 12-14), there do not seem to be significant overall differences between perceived importance of complexity indicators in buildings and highway projects according to participants of the survey. However, some contrasts can be observed. For example, all respondents agreed that a highway project’s most important complexity indicator in the group interfaces with environment (C2) was its dependence on external stakeholders (C2.3), while for building projects, half of the respondents instead marked the amount of construction restrictions (C2.1) as most important, resulting in similar average weights of complexity indicators C2.1 and C2.3 for buildings. Structure uniqueness (C3.3) on average seemed to contribute more to the perceived solution complexity (C3) in building projects than in highway projects, which can be explained by relatively standard designs more often found in highway projects compared to buildings where architecture can play a more significant role. In a building project’s ramp-up phase (C4), the completion requirements (C4.3) were considered most important by most respondents, whereas the complexity of installed equipment (C4.2) was important to most respondents in a highway project. Finally, technology track record (O3.1) was of superior concern for most respondents in a building project, while for highway project, this indicator was considered least important relative to the two other indicators included in the factor technology outlook (O3).
While there seem to be some differences in average weights obtained for each of the two project types considered, the limited amount of data gathered and the mentioned spreads between individual responses do not provide for clear conclusions on the main complexities in each project type. Furthermore, based on the overall questionnaire results, no complexity element is clearly most important or unimportant altogether, resulting in relatively flat charts shown in Figures 12-14. The majority of indicators marked as most important obtained a weight ranging from 0.30 to 0.40, with the exception of indicator C2.3 and factor O2 in highway projects ($w_{\text{average}}$ of 0.52 and 0.49, respectively), and indicator O1 in building projects ($w_{\text{average}}$ = 0.46). The lowest weights (0.10 to 0.15) were assigned to preparatory works needed (C1.3) and the level of design completion (C3.1) in both project types, and the amount of systems and equipment (C4.1) in building projects.

In summary, the participating experts expressed different and sometimes surprisingly opposing views regarding the importance of potential sources of complexity in a project type. While the obtained weights do not point at significant differences between the two project types, differences in individual views are evident instead. Given the respondents’ similar amount and type of experience, notably their previous joint involvement in the same project’s debt-financing transaction, this is somewhat surprising. As different respondents’ concerns may point at different preferred focus areas for TDD, this observation is of relevance for this study. For practice, the subjective preferences likely at play behind the differences in practitioners’ views point to a possible need to express, discuss and align the different parties’ and stakeholders’ views of complexity indicators’ importance. This may itself help identify the preferred focus areas for TDD. For doing so, a BWM-based survey analysis may provide a useful tool to express different parties’ and stakeholders’ views before proceeding with complexity evaluation of a specific project itself.
Figure 12: Comparison of respondents’ views on importance of construction complexity indicators in the two project types.
Figure 13: Comparison of respondents’ views on importance of operational complexity indicators in the two project types.

Figure 14: Comparison of respondents’ view on importance of high-level complexity factors for the two project types.
4.2.4 Scoring complexity of case study projects

As per the proposed approach, each case study project’s complexity is scored in a bottom-up approach guided by the selected hierarchical model of complexity elements. To do so, inputs were needed from LTA experts involved in each case study project’s TDD and construction monitoring. The data gathering was organised as a semi-structured interview with one LTA per case study project. As a general structure for the interview, the following three questions were prepared:

- Can you briefly describe the project?
- In your view, what was the most complex aspect of this project?
- Please assess the complexity of your project using the complexity model presented below. Assign a complexity score on each complexity indicator using the attached scale and descriptions of indicators.
- Please reflect on the use of the overall systematic approach to complexity evaluation.

Before proceeding with the interview, the results of the questionnaire survey discussed in the previous section were shown to the LTAs for corroboration and reflection. The different views of practitioners were generally not very surprising to the interviewees and it was explained that in practice, the involved lenders as well as engineers often raise specific concerns about a project based on their previous experience and professional background.

In one LTA’s view, the complexities that a sub-contractor can control are generally less important as they are easy to allocate contractually. In that regard, it was explained that this controllability depends on the amount of risk transfer in the project agreement, however. For example, standard project agreements do not prescribe technology and materials (complexity indicator C3.5) and this freedom of choice is often passed down to a competent contractor, making this complexity indicator less important in the interviewed LTA’s view. Similarly, from an engineering perspective, predictability of asset renewal needs (indicator O1.4) is controllable with appropriate regular maintenance and thus, according to an interviewee, not usually of main concern in TDD. As can be seen in Figures 12 and 13, some of the questionnaire respondents contrarily considered these indicators as most important. Asked whether such specific view of a lender as a recipient of due diligence could change the focus of attention in TDD analyses, both LTAs agreed that the reasons for such concerns would have to be discussed, but the LTAs independent view would probably have to prevail in the analysis.

As mentioned above, the main data gathered from the interviews related to the complexity scores of each case study project. These are presented in the following sub-sections for projects Alpha and Beta, respectively.

4.2.4.1 Complexity of Project Alpha

Before applying the proposed systematic complexity evaluation approach, the LTA interviewed for Project Alpha was asked to intuitively categorise the project in terms of its overall complexity. The project was considered very complex by the interviewee. The main reason for this view was related to project’s location: overall space on site was limited to the area that had to be built-up due to constraints stemming from a densely populated urban environment and a number of interfaces with infrastructure networks crossing the construction site at multiple places. Another aspect considered as giving rise to perceived complexity were new national rules and administrative procedures for tunnel projects, to which the project had to comply to secure a number of permits. These procedures were applied for the first time on Project Alpha, giving rise to uncertainty about potential amount of delays in obtaining the permits.

Table 11 shows the complexity scores of Project Alpha assigned based on the inputs of the interviewed LTA asked to consider the complexity indicators and revisit the project’s initial TDD analysis. For guiding the scoring, the predefined qualitative complexity scoring scales shown in Appendix C were used by the LTA. Some complexity (complexity score 3 and above) was recorded on eleven complexity indicators, of which scores indicating an especially high complexity (complexity scores 4-5) were assigned on six complexity indicators. The reasons for key complexities reflected in the scoring were explored with the interviewee and can be summarised as explained in the following paragraphs.
### Table 11: Overview of complexity scores for Project Alpha at indicator level.

<table>
<thead>
<tr>
<th>COMPLEXITY INDICATOR</th>
<th>SITE COMPLEXITY</th>
<th>COMPLEXITY INDICATOR</th>
<th>INTERFACES WITH ENVIRONMENT</th>
<th>COMPLEXITY INDICATOR</th>
<th>SOLUTION COMPLEXITY</th>
<th>COMPLEXITY INDICATOR</th>
<th>RAMP-UP COMPLEXITY</th>
<th>COMPLEXITY INDICATOR</th>
<th>SCOPE OF O&amp;M OBLIGATIONS</th>
<th>COMPLEXITY INDICATOR</th>
<th>PERFORMANCE REGIME</th>
<th>COMPLEXITY INDICATOR</th>
<th>TECHNOLOGY OUTLOOK</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C4</td>
<td>O1</td>
<td>O2</td>
<td>O3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1.1</td>
<td>Reliability of site information</td>
<td>3</td>
<td>C2</td>
<td>Amount of constr. restrictions</td>
<td>2</td>
<td>C3</td>
<td>Level of design completion</td>
<td>2</td>
<td>C4</td>
<td>Amount of systems &amp; equipment</td>
<td>5</td>
<td>C1</td>
<td>Nature of FM/routine mtce. obligations</td>
</tr>
<tr>
<td>C1.2</td>
<td>Complexity of site condition</td>
<td>3</td>
<td>C2.2</td>
<td>Complexity of restrictions</td>
<td>2</td>
<td>C3.1</td>
<td>Design verifications by client</td>
<td>3</td>
<td>C4.2</td>
<td>Complexity of systems &amp; equipment</td>
<td>2</td>
<td>C1.2</td>
<td>Scheduling complexity for FM/rout. mtce.</td>
</tr>
<tr>
<td>C1.3</td>
<td>Preparatory works needed</td>
<td>3</td>
<td>C2.3</td>
<td>Dependence on external stakeholders</td>
<td>4</td>
<td>C3.2</td>
<td>Structure uniqueness</td>
<td>5</td>
<td>C4.3</td>
<td>Completion requirements complexity</td>
<td>2</td>
<td>C1.3</td>
<td>Amount of asset renewal responsibility</td>
</tr>
<tr>
<td>C1.4</td>
<td>Permits &amp; rights of way</td>
<td>4</td>
<td>C2.4</td>
<td></td>
<td></td>
<td>C3.3</td>
<td>Interdependence of sub-projects</td>
<td>2</td>
<td>C4.4</td>
<td>Testing time needed</td>
<td>4</td>
<td>C1.4</td>
<td>Predictability of asset renewal needs</td>
</tr>
<tr>
<td>C1.5</td>
<td>Logistical complexity</td>
<td>4</td>
<td>C2.5</td>
<td></td>
<td></td>
<td>C3.4</td>
<td>Technology and materials</td>
<td>3</td>
<td>C4.5</td>
<td></td>
<td></td>
<td>C1.5</td>
<td>Technical specialisation required</td>
</tr>
</tbody>
</table>

The borrower’s planning had to meet various newly introduced requirements which was the reason for a high complexity score assigned on indicator C1.4. As mentioned above, a new set of national rules and procedures for tunnel construction came into force recently before Project Alpha was tendered. The borrower was responsible for fully meeting these requirements, although, as is common in similar projects, the effects of any delays caused by the permit-issuing authorities were compensable under the project agreement and thus this risk was retained by the contracting authority.

A high complexity score was assigned on logistical complexity (C1.5). This was due both to the limited space available for construction, and to the limited access to site. The latter was characterised by only four access points that could be used at the construction site stretching over several kilometres.

The project’s dependence on various external stakeholders was high (C2.3). Although the contracting authority ensured public support as part of usual spatial planning procedures finalised prior to procuring the project, the borrower had to coordinate its activities with a range of external stakeholders. The main dependence was on the municipality and the tunnel safety authorities who had to approve the detailed designs and implementation plans. Additional stakeholders included the operators of traffic networks crossing the site, nearby residents, adjacent...
construction projects, water authority, and others. According to the interviewee, an even higher complexity would be considered in an unlikely case where a private partner itself would be responsible for spatial planning procedures.

The project was considered very complex with regard to structure uniqueness (C3.3), related mainly to unprecedented design features of both the tunnel’s cross-section and longitudinal profile. Fifth, the project was considered complex due to the substantial amount of technical installations needed in the tunnel (C4.1) that had to be installed and tested following completion of the main structures and before the project’s targeted availability date. While these installations were standard for tunnel projects, their amount and interfaces were significant and seen as possibly leading to compatibility and calibration issues. Finally, given the variety of required technical tunnel installations, the time required for installation, testing and calibration (related to indicator C4.4) was about two years following completion of the main structures, which could incur or further deteriorate construction delays in the final stages before the targeted availability date.

4.2.4.2 Complexity of Project Beta

Before applying the proposed systematic complexity evaluation approach, the LTA interviewed for Project Beta was asked to intuitively categorise and describe the project in terms of its overall complexity from a TDD perspective. The project was considered relatively simple by the LTA. A tight construction schedule caused some concerns already in TDD, and there were some actual difficulties managing programme delay in the construction phase. The mentioned delay was due to a major unforeseeable disruption in the supply of prefabricated flooring material. However, the effects of delays were compensated by insurance and therefore, from a lenders’ perspective, this did not cause damage. Another possible source of complexity in the interviewee’s view were specific requirements imposed by a special user of the building, which had to be taken into account in the detailed design solution.

Table 12 shows the complexity scores of Project Beta assigned based on the inputs of the interviewed LTA asked to use the complexity indicators to revisit the project’s initial TDD analysis. As guidance for the scoring, the predefined qualitative complexity scoring scales shown in Appendix E were provided in the interview LTA. Some complexity (complexity score 3 and above) was recorded on eight indicators, from which scores indicating an especially high complexity (complexity scores 4-5) were assigned on three complexity indicators.

Most indicators under site complexity were not regarded as causing complexity from an engineering perspective. The only indicator where some complexity was highlighted by the LTA was the potentially substantial preparatory works needed (C1.3), which related to the removal of asbestos, demolition of existing structure, and needed ground works. Though most of these works were not demanding from a technological perspective, the uncertainty in their precise scope could be considered a complexity in technical due diligence according to the LTA. Although limited information on site condition was available before financial close, the information provided a sufficiently reliable basis for borrower’s planning, and any unforeseeable site conditions were compensated by the contracting authority. Similarly, although site was known to contain several potentially complex characteristics such as contaminated soil, presence of asbestos in existing structure, various existing utilities, and protected fauna, the related risks were comprehensively covered by the contracting authority.

The project’s interfaces with its environment were marked as an important source of complexity. The site was located in a densely built-up area, giving rise to the amount of restrictions on scheduling of construction works, as well as project-specific restrictions on environmental impacts. For example, other major construction works were ongoing in the area that could affect site access if each project’s activities were not timed appropriately. This was managed through a tripartite agreement between the borrower, the contracting authority and the concerned external stakeholder, which was considered unusual and a potential source of conflicts. However, the interviewed LTA noted that during the actual construction, the parties cooperated very well and no major problems were encountered. The project’s overall construction phase scheduling was further constrained by other construction projects scheduled to begin on the same site following its completion. In addition to neighbouring construction projects, the project’s design and construction depended on many other external stakeholders including suppliers, local authorities, operators of infrastructure networks, and others. These gave rise to a high complexity score assigned on complexity indicators C2.1 and C2.3.
The time available to complete the project’s construction phase was relatively limited. Although several workflows could be implemented simultaneously, the LTA pointed at a very high interdependence of activities under indicator C3.4. As mentioned above, the limited access and insufficient storage space available on site necessitated precise scheduling of activities and just-in-time strategies were used for the delivery of required construction materials and other supplies.

### Table 12: Complexity scores for Project Beta

<table>
<thead>
<tr>
<th>COMPLEXITY INDICATOR</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1 SITE COMPLEXITY</strong></td>
<td></td>
</tr>
<tr>
<td>C1.1 Reliability of site information</td>
<td>2</td>
</tr>
<tr>
<td>C1.2 Complexity of site condition</td>
<td>2</td>
</tr>
<tr>
<td>C1.3 Preparatory works needed</td>
<td>3</td>
</tr>
<tr>
<td>C1.4 Permits &amp; rights of way</td>
<td>2</td>
</tr>
<tr>
<td>C1.5 Logistical complexity</td>
<td>2</td>
</tr>
<tr>
<td><strong>C2 INTERFACES WITH ENVIRONMENT</strong></td>
<td></td>
</tr>
<tr>
<td>C2.1 Amount of constr. restrictions</td>
<td>4</td>
</tr>
<tr>
<td>C2.2 Complexity of restrictions</td>
<td>2</td>
</tr>
<tr>
<td>C2.3 Dependence on external stakeholders</td>
<td>4</td>
</tr>
<tr>
<td><strong>C3 SOLUTION COMPLEXITY</strong></td>
<td></td>
</tr>
<tr>
<td>C3.1 Level of design completion</td>
<td>2</td>
</tr>
<tr>
<td>C3.2 Design verifications by client</td>
<td>1</td>
</tr>
<tr>
<td>C3.3 Structure uniqueness</td>
<td>3</td>
</tr>
<tr>
<td>C3.4 Interdependence of sub-projects</td>
<td>5</td>
</tr>
<tr>
<td>C3.5 Technology and materials</td>
<td>1</td>
</tr>
<tr>
<td><strong>C4 RAMP-UP COMPLEXITY</strong></td>
<td></td>
</tr>
<tr>
<td>C4.1 Amount of systems &amp; equipment</td>
<td>3</td>
</tr>
<tr>
<td>C4.2 Complexity of systems &amp; equipment</td>
<td>3</td>
</tr>
<tr>
<td>C4.3 Completion requirements complexity</td>
<td>2</td>
</tr>
<tr>
<td>C4.4 Testing time needed</td>
<td>3</td>
</tr>
<tr>
<td><strong>O1 SCOPE OF O&amp;M OBLIGATIONS</strong></td>
<td></td>
</tr>
<tr>
<td>O1.1 Nature of FM/routine mtce. obligations</td>
<td>2</td>
</tr>
<tr>
<td>O1.2 Scheduling complexity for FM/rout. mtce.</td>
<td>2</td>
</tr>
<tr>
<td>O1.3 Amount of asset renewal responsibility</td>
<td>1</td>
</tr>
<tr>
<td>O1.4 Predictability of asset renewal needs</td>
<td>2</td>
</tr>
<tr>
<td>O1.5 Technical specialisation required</td>
<td>2</td>
</tr>
<tr>
<td><strong>O2 PERFORMANCE REGIME</strong></td>
<td></td>
</tr>
<tr>
<td>O2.1 Onerousness of performance regime</td>
<td>2</td>
</tr>
<tr>
<td><strong>O3 TECHNOLOGY OUTLOOK</strong></td>
<td></td>
</tr>
<tr>
<td>O3.1 Technology track record</td>
<td>2</td>
</tr>
<tr>
<td>O3.2 Availability of parts &amp; consumables</td>
<td>2</td>
</tr>
<tr>
<td>O3.3 Built-in redundancy</td>
<td>2</td>
</tr>
</tbody>
</table>

### 4.2.4.3 Reflection on the process

Following the scoring, the LTAs provided some feedback on the process of complexity evaluation. According to one of the LTAs, a stepwise approach to complexity evaluation helps “make you think” about the project in a more structured way which can be helpful in identifying and underlining the project’s main complexities for technical due diligence. According to the interviewees, the considered complexity indicators generally cover the sources of a project’s inherent risks usually taken into account in TDD. The interviewees agreed that the perception of their importance may vary per project type and welcomed the flexibility of adjusting their importance for each project based on involved experts’ different preferences and views. Overall, the demonstrated approach was accepted positively by both LTAs providing inputs for scoring complexity of the case studies.
4.3 Resulting complexity profiles

By factoring and summing the complexity scores under each factor grouping with the average weights obtained in the previous phase, a higher-level overview of a project’s complexity from a lenders’ perspective can be obtained. The seven-dimensional complexity profiles for projects Alpha and Beta are shown in Figures 15 and 16, respectively.

For Project Alpha (Figure 15), all considered factor-level aspects of construction complexity obtain a score around 3.0, indicating a “somewhat complex” project according to the applied scoring scale, though from a site complexity standpoint, the project may be seen as most complex. Operational phase turns out “simple”, with no factor-level complexity score exceeding the value of 2.0 on the applied five-step scoring scale.

Looking another level higher, Project Alpha’s overall complexity in the construction phase obtains a complexity score of 3.2, thus its construction can be described as “somewhat complex”. The operational phase of Project Alpha is scored as 1.8 overall, indicating an operationally “simple” project according to the applied scale. Based on an LTA’s intuitive assessment of the project’s complexity, the project was described as “very complex” as mentioned in the previous section. The obtained high-level complexity profile does not support this view, and while several specific complexity indicators were scored as “very complex” by the expert, this is not directly visible from the high-level complexity scores after accounting for the respondent-average importance of complexity indicators.

For Project Beta (Figure 16), the construction phase emerges as relatively simple at the factor level (complexity scores between 2.1 and 2.6 for factors C1, C3 and C4), but quite complex from the particular perspective of its interfaces with environment. Like for Project alpha, this project’s resulting factor-level complexity in the operational phase is around the score of 2.0 indicating a “simple” project from the perspectives of O&M obligations, performance regime, and long-term technological performance.

One level higher, the construction phase complexity for this project results in a complexity score of 2.7, indicating a “simple” to “somewhat complex” construction phase; the operational phase is scored as 1.9, thus a “simple” operational project. Before bottom-up scoring, the project was intuitively categorised as rather simple by the interviewed LTA. While this may be supported by most resulting complexity scores at factor-level, the complexity profile indicates that the project cannot be considered entirely simple based on the inputs of the applied bottom-up complexity evaluation.
Figure 16: Obtained complexity profile for Project Beta.
4.4 Conclusion

In this section, the technical due diligence stage of two projects was revisited to understand their complexity from a lenders’ perspective. The systematic approach to complexity evaluation, as specified in Chapter 3, was applied to two explanatory case studies explaining its possible use in technical due diligence. Based on the insights and empirical observations from the mixed-method approach defined by the applied systematic complexity evaluation, the third sub-question of the research question can be answered:

SQ3: How can the systematic approach to complexity evaluation be applied in technical due diligence?

First, as per the second component of the approach specified in Chapter 3, the weights of complexity indicators included in the complexity evaluation were quantified. Based on a questionnaire survey soliciting inputs of finance and engineering experts for each specific project type, weights were determined for complexity indicators by applying the BWM. Whereas a systematic approach is intended to provide a sensible degree of objectivization of complexity evaluation, its application in this study underlines the inevitably subjective character of complexity evaluation. Although the respondents previously collaborated in the same technical due diligence, they often had different views of what are the most important sources of complexity in a project type. The views on the most important complexity indicators differed relatively significantly both individually and between engineering and finance professionals. For practice, the subjective preferences likely at play behind the differences in practitioners’ views point to a need to explore, discuss and align the different parties’ and stakeholders’ views of the most important project complexity sources. This may itself help identify the needed focus areas for technical due diligence. For doing so, a BWM-based survey analysis may provide a useful tool to express different parties’ and stakeholders’ views of complexity of a project of a certain type, before proceeding with complexity evaluation of a specific project itself.

As per the third component of the approach specified in Chapter 3, a qualitative scoring system was applied that provided insight into the revisited projects’ complexity from the lenders’ perspective. At complexity indicator level, both projects were regarded as generally simple in their operational phases, and both were marked as complex in terms of the borrower’s dependence on external stakeholders. In contrast to a general understanding that ensuring stakeholder support is the responsibility of the public partner in PPPs, the need for more attention to externally-oriented implementation of privately-financed infrastructure has previously been highlighted by Verweij (2015). At indicator level, Project Alpha was additionally complex from the perspectives of structure uniqueness, logistical and administrative complexities, and the equipment requiring extensive testing ahead of project completion. Though the complexity of Project Beta was intuitively assessed as simple, the amounts of interdependences, construction timing restrictions and dependence on external stakeholders were its distinctly complex aspects.

Based on obtained scores and respondent-average weights of complexity indicators calculated by applying the BWM, a complexity profile was derived as a higher-level overview of each project’s complexity. Project Beta was considered rather simple prior to the approach application, and a specific area in which it was indeed complex emerged. On the other hand, the complexity profile obtained for Project Alpha only showed the project as “somewhat complex” in the construction phase at complexity factor level, although two complexity indicators were marked as “very complex” by the LTAs. This showcases that only looking at higher-level overview of project complexity may conceal its specifically complex aspects.

All in all, the applied multiple-component approach to complexity evaluation appears as a strength of the specified systematisation as each component seems to provide new insight into the sources of complexity in a project. The importance of exploring and aligning the experts’ different views of complexity is highlighted using the BWM, whereas the value of transparent and comprehensive bottom-up complexity evaluation by LTAs is showcased by the applied qualitative scoring system. A systematisation of complexity evaluation is therefore beneficial in practice of technical due diligence but should be assisted by reciprocal communication between the involved experts, for which the tested BWM-based component of the approach may provide a useful basis.
5 Interviews: project complexity and implications for decision-making

To expose the ways in which systematic complexity evaluation in TDD could contribute to supporting lenders’ risk analyses and decision-making, several interviews were conducted that provide a degree of research validation and an answer to the final research sub-question:

\[
\text{SQ4: In what way does the applied systematic approach to complexity evaluation contribute to the process of technical due diligence and support lenders’ decision-making?}
\]

The organisation of interviews with lenders is presented in Section 5.1. The interview results covering three main themes and their sub-themes are discussed in Section 5.2. An additional validation interview with a lenders’ technical adviser was carried out, and its results are discussed in Section 5.3. A discussion of findings and a conclusion to the final research sub-question are given in Section 5.4.

5.1 Setting up the interviews

Following the specification (Chapter 3) and an application (Chapter 4) of a systematic approach to complexity evaluation, the obtained results were discussed with lenders involved in the case study projects to validate the results and discuss their implications. For each of the two case study projects whose complexity was evaluated in Chapter 4, semi-structured interviews were held with the project’s respective lenders.

Several topics had to be addressed in the interviews. First, given the interviewees previously participated in the questionnaire survey, the background of their responses had to be discussed to explore the underlying reasons for observed (see 4.2) different views of the importance of complexity indicators. Second, as a central part of the interviews, the specific case study projects had to be discussed with regard to their complexity. The practitioners would be asked to discuss their view of the particular case study project’s complexity, before the result of systematic complexity would be presented to the interviewees to corroborate and reflect on the results. Finally, the interviewees were asked to explain whether and how the presented systematic complexity assessment can contribute to better collaboration in TDD and lenders’ subsequent decision-making.

Semi-structured interviews were selected as most appropriate for several reasons. As mentioned above, a predefined general framework of themes had to be covered and a set of predefined questions enabled a degree of control over the direction the interviews would take. On the other hand, as the aim was to explore the broader contexts of the interviewees’ views previously observed in the questionnaire responses, fully structured interviews would excessively limit the opportunities for additional insights to emerge from the responses. A partially predefined structure of the interviews helped guide and manage each interview within the scheduled 45-60-minute timeframes, while allowing a degree of freedom to address any other related topics. Last but not least, the semi-structured interviews turned out beneficial in mitigating the language barriers during the interviews by allowing further clarifications and additional questions to be asked where needed. Therefore, eight main questions were formulated for the interviews with a view to covering the three main themes (Table 13).

The respondents needed for the interviews were project finance professionals from lending institutions involved in the case study projects. Prior to the interviews, interviewees had filled out the BWM-based questionnaires providing their inputs on the relative importance of complexity indicators for one of the project types analysed in Chapter 4. The participants were therefore familiar with the research and knew one of the projects used as case studies since its due diligence phase, but were not involved in the complexity evaluation step carried out based on the inputs of their LTAs.

Five finance professionals with 5-20 years’ experience participated as interviewees. The interviewees described their professional experience as related to project finance deal structuring, credit risk analysis and credit risk management for banks involved in project finance market. Two of the five practitioners were familiar with the case study project Alpha, and three with the case study project Beta. Four separate interviews were held, each taking
between 45 and 60 minutes. One interview was attended by two interviewees. Three of the interviews were carried out in person, and one interview was organised via phone. The in-person interviews were recorded and transcribed for later analysis, with prior consent of the interviewees, while only manual notes could be taken for the phone-based interview due to technical limitations. Aggregated results are presented and discussed in the following sections.

Table 13: Semi-structured interview questions

<table>
<thead>
<tr>
<th>Theme</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>General perception of complexity</td>
<td>1. A You were asked to indicate the importance of various complexity indicators for the project type, which is an important initial step of the proposed approach. Do you consider the BWM-based questionnaire a good way to highlight the key complexities relevant to your decision-making?</td>
</tr>
<tr>
<td></td>
<td>1.B Did you encounter any difficulties in filling it out? If so, can you describe them?</td>
</tr>
<tr>
<td>Reflection on the case study project’s complexity</td>
<td>2. A Before I present to you the complexity profile obtained through revisiting the TDD stage of the case study project, what did you consider as the project’s key complexity at the time of TDD?</td>
</tr>
<tr>
<td></td>
<td>2.B The TDD phase was revisited and this is the resulting complexity profile after assessing each complexity indicator and applying the weights indicating its importance in this project type. Can you reflect on the obtained complexity profile for the project as regards the scoring on the shown dimensions?</td>
</tr>
<tr>
<td>Implications for decision-making</td>
<td>3. A The systematic approach to complexity evaluation could help focus engineers’ detailed TDD to the key complexities identified in a project at an early stage of TDD. To what extent, and why, do you think it can do so?</td>
</tr>
<tr>
<td></td>
<td>3.B The systematic approach to complexity evaluation could facilitate engineers’ comprehensive evaluation and efficient communication of infrastructure projects’ complexity to support the lenders’ decision-making process. To what extent, and why, do you think it can do so?</td>
</tr>
<tr>
<td></td>
<td>3.C How can the results of complexity evaluation in TDD help your identification, evaluation and management of risks in PPP infrastructure deals?</td>
</tr>
<tr>
<td></td>
<td>3.D In what ways do you think the systematic approach can support lenders’ decision-making on PPP infrastructure loans?</td>
</tr>
</tbody>
</table>

5.2 Interview analysis and discussion of results

A qualitative analysis of data was carried out by manually transcribing, reviewing and coding the interview transcripts and notes. Although the interviews were generally structured according to three main themes, additional information relevant to one of the themes often emerged at discrete points throughout the interview. Open coding was first carried out on the transcripts as a whole to identify the sections of responses describing the interviewees’ views on any of the three main themes defined in interview preparations. In the second step of the analysis, sub-themes were sought within these three main themes. Figure 17 illustrates a summary of the interview results, their hierarchy and an interrelation of the identified sub-themes.
The following sub-sections discuss the main aggregated interview results pertaining to each of the three themes, and cover the main sub-themes identified in the analysis.

5.2.1 General perceptions of complexity
In the first part of the interview, interviewees generally confirmed that the BWM-based questionnaire had provided a good way to express their views on the importance of complexity indicators considered in the case studies. However, it was pointed out that their perception of project complexity is formed on a project-specific basis – “I keep in mind the particular project as background – for this type of projects yes I was able to express how I think the different aspects compare. But if it was for another project where there are no environmental constraints and you have to just build one building then it would be quite different” – and most interviewees considered it difficult to have a general view on what aspect of project complexity is most important because the centre of attention may shift in each project.

According to one interviewee, each project has its complexities – “[So] there is really not one specific complexity I would say as a lender that I look at”, and any complexity present in a particular project could be important because practitioners “(...) look on whether there are high complexities – yes or no? – not the one that is really the highest”. In relation to this, the interviewees all emphasised that any construction risk borne by the borrower needs to be contractually allocated to a competent and financially stable subcontractor that is willing and able to bear the risk. This can be problematic with very high risks, so according to an interviewee “A complexity score of close to 5 on any aspect would make us consider if this is the right project for us at all”. The limit of liability in the subcontracts was underlined as a key risk mitigation measure from the lenders’ perspective that must accommodate for any complexity stemming from the project agreement. However, there appear to be different views on whether all complexities can be borne by the subcontractors – while one interviewee argued that complexity can be “mitigated” if the companies acting as construction subcontractors can “solve it”, another was of the opinion that “(...) even though we say there are always mitigants for complexities, just the amount of complexity for us means a higher risk automatically”. This sensitivity to anything that might be considered complex in a project may explain the rather equal importance of complexity indicators emerging from some of the obtained questionnaire responses – “I used very often the option of saying something was equally important or a little more important, because yes in many cases each of the complexity indicators cannot be ignored”.

The interview results provided additional insight on the lenders’ individual perception of project complexity. Several key preconceptions were identified that appear to guide the practitioners’ perception of how complex a project is. These preconceptions often seem to be based on issues experienced by a practitioner in the past projects, but also
appear related to more widely established convictions regarding the complexity of the infrastructure sector under consideration, the location of the project’s site, or the country in which the project takes place. Some key complexity attributes related to these preconceptions seem to commonly be of concern in the interviewed lenders’ view, notably the risks related to new technologies, permitting procedures and interfaces with surrounding infrastructure.

Individuals’ experience in past projects seems to importantly affect the individual focus of attention in appraising future projects: “There are some signals where I say I need to be more careful. This is always when I encounter something about technology risk, or permit risk, these are some keywords I pay attention to because of my previous experience with such issues.”. The differences in professionals’ past experience and background were underlined as a likely reason for different opinions on the importance of complexity indicators exhibited in the responses of the BWM-based questionnaire: “[Because] when something becomes a problem then we will remember it and, in the future, look at it more”. This points to inherently subjective views on the importance of complexity indicators, however some factual cases of project risk underestimations in past due diligences were noted in the interviews. Examples of risks that have been underestimated or omitted in the past due diligences but have led to serious problems for the involved companies include risks related to design, permitting procedures, flooding on site, and the project’s interfaces with existing infrastructure.

The project type under consideration seems to often be the basis for the practitioners’ relatively instinctive conclusions on a project’s complexity. In decision-making, lenders tend to categorise projects in broad complexity classes such as “non-complex project, low complexity, medium complexity and high complexity, so these are used. So, in our view, schools, libraries, and office buildings are not considered highly complex”. In contrast, a hospital, prison or laboratory were noted as among the more complex sectors, while roads were considered generally more complex than buildings. One of the common reasons implied in this respect is the perception that “you have more permits involved, you also have expropriation and all these aspects”. If there is a tunnel planned on the road section concerned, then a higher complexity is assumed because “a tunnel has much more complexity because of [such] interfaces with other infrastructure”. A flood protection project like the Afsluitdijk in the Netherlands was pointed out as highly complex. However, according to one interviewee, such arbitrary approach to complexity evaluation has indeed led to underestimations of a project’s risks in the past: “For a typical building project, we may often think it is a ‘plain vanilla’ project (...) because it is a less complex project in terms of technical difficulty. But then also such projects run into problems e.g. with permissions required to reach the commencement date and one permission is not obtained in the right time”.

The location of the project has also shaped the practitioners’ preconceptions of a project’s complexity. A limited site size typically seen in building projects is considered to point to a lower project complexity than extensive sites seen in linear infrastructure projects. This is mainly explained by a greater amount of interfaces with the environment exhibited in interactions with existing infrastructure, required permit procedures, and logistics. While size and technological difficulty of the project are often indicative of the project’s complexity according to one interviewee, the specifics of the location are what should make for more nuanced perceptions of project complexity – “There is a locks project that was a really big project maybe one billion or so, but then it is just in the port, and they have to build a lock and there is nothing else surrounding it. And of course, you need high quality engineers to build the lock but they exist in the country, so yes – these are very large projects but not complex I think.”

Finally, the country in which the project takes place emerged as another important source of practitioners’ views as to the most important attributes of a project’s complexity. Several interviewees underlined the importance of complexities arising from the amount of permitting responsibilities borne by the borrower according to the project agreement. However, they argued that in certain countries, the experience of the competent authorities issuing permits can already provide sufficient confidence that the permitting procedures are unlikely to cause unexpected disruptions to the project. The flexibility and cooperativeness of authorities was exposed as having been especially supportive in The Netherlands, while one of the lenders suggested that more attention to the permitting and other administrative risks is usually needed in some other European countries.
5.2.2 Lenders’ reflection on case projects’ complexity

Part two of the interview asked the interviewees to focus on the specific projects whose complexity was evaluated as case studies in Chapter 4. First, the lenders were asked to discuss their perception of case study project Alpha or Beta which they were involved in. Table 14 summarises the interviewees’ answers with regard to the project’s overall complexity and the project’s specific aspects they considered as potentially giving rise to complexity.

Project Alpha was considered very complex by the interviewed lenders. A source of this perception were the project’s interfaces with environment, in particular the difficulties in coordinating the reciprocal interruptions of the project and the surrounding infrastructure networks. Drawing up the traffic management plans and the related coordination with external stakeholders was the responsibility of the borrower under its project agreement with the contracting authority. The bidding consortium had demonstrated experience with regard to this aspect – “This was one of the reasons why this consortium won the deal”. However, the complexity of the project’s interfaces with environment was only fully understood by lenders following a site visit later in the project’s construction phase “[we] did not really assess the complexity of this whole traffic management [at the time of due diligence]”. Asked whether any related problems ultimately arose for the borrower, lenders confirmed that the sub-contractors successfully managed the interfaces with other infrastructure and encountered supportive external stakeholders. The sub-contractors were “reasonably successful, they had the luck that authority was cooperative and working with them. Otherwise they would have quite some troubles I think”. These lenders’ views support the findings of Verweij (2015) emphasising the importance of externally-oriented approach during PPP projects’ construction by both the contracting authorities and private partners.

In contrast to Project Alpha, none of the interviewees familiar with Project Beta had previously considered the project as generally complex. The reasons given were largely related to the type of the asset under consideration, which as explained in the previous section is a common source of lenders’ presumptions regarding a project’s complexity. Although no specific complexity was pointed out by engineers in TDD, the interviewees could remember some specific concerns they had at the beginning of TDD. The first concern was related to initial uncertainties regarding the mechanisms of risk allocation for delays in permitting procedures. Due to the project’s tight schedule, a delay in one of the permitting procedures in fact nearly endangered the project’s scheduled construction commencement date, which could empower the contracting authority to terminate the contract. No such problems were ultimately encountered and according to the one interviewee, it was “very important that the SPV and the competent authority [worked] in a very harmonic way”. Another concern and a complexity in retrospect of two of the interviewed lenders was the initial uncertainty as to the amounts of asbestos present on site and the related risk allocation: “So we had to have a closer look before credit approval to make sure that if there is more asbestos the costs would be borne by the contracting authority as a compensation event”.

Finally, the complexity profiles obtained in Chapter 4 were presented to lenders for verification of their representativeness of each project. For both projects, the interviewees could relate to the obtained scores, also taking into account the project’s actual performance. The lenders mainly looked at the high-level overview of the project’s complexity. They did not have particular comments regarding the scoring provided by LTAs, pointing out that engineers are ultimately the experts they rely on. For Project Alpha, the complexity profile reflected the project well according to the interviewees. The result provided accurate insight regarding the project’s ramp-up phase in particular – “In this project, it was in fact high complexity in the ramp-up phase. With all the technical requirements for the tunnel, all the software to control the entire tunnel (...) otherwise this would be a bit less, but for this project I can agree with this result”. The complexity evaluation result for Project Beta was described as showing the complexities faced in reality during the project’s construction. According to one of the related interviewees, the profile was “a good representation of the complexity of the project because we talked a lot about those external stakeholders and the various permission issues”. For both projects, the interviewees agreed to the evaluation results regarding the low obtained complexity scores in the projects’ operational phases, explaining that upon successful completion, availability-based infrastructure projects do not tend to come under significant stress, which is one of the reasons why they are attractive for financing.
### Table 14: Lenders’ views of case study projects’ complexity

<table>
<thead>
<tr>
<th>Project</th>
<th>Complexity</th>
<th>View</th>
<th>Excerpt from interview</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alpha</strong></td>
<td>General</td>
<td>A complex project</td>
<td>“Certainly, if I think now it is certainly a complex project.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complexity was underestimated</td>
<td>“Maybe we underestimated at that time the complexity: we didn’t really recognise that there is so much complexity involved in it I think.”</td>
</tr>
<tr>
<td>Specific</td>
<td>Interfaces with environment</td>
<td>“What struck me most is indeed when I had the site visits how much interdependency with existing traffic flows, a ring road with so much traffic and the traffic needs to keep going all the time. Complexity was in keeping the existing traffic going and the train lines that have to pass over and under.”</td>
<td></td>
</tr>
<tr>
<td>Specific</td>
<td>Interfaces with environment</td>
<td>“Also, all the interactions with the road and rail infrastructure operators”</td>
<td></td>
</tr>
<tr>
<td><strong>Beta</strong></td>
<td>General</td>
<td>Not a complex project</td>
<td>“We didn’t really consider this project complex. Because (...) in our decision-making, we have the levels ‘non-complex project, low complexity, medium complexity and high complexity’ (...). So, in our view, schools, libraries, and office buildings are not considered highly complex.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is a less complex project</td>
<td>“In comparison with other types of projects it is less complex. As a public building, (...), the area in which you act is limited. A very long section of a road with different areas to cover and different structures to include, compared to this type of project, is more complex.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It is a less complex project</td>
<td>“I consider it a less complex project. Office, school is simple. But this office project is perhaps a bit more complex because it is partly brownfield.”</td>
</tr>
<tr>
<td>Specific</td>
<td>No specific complexity</td>
<td>“TDD did not point out a specific complex part”</td>
<td></td>
</tr>
<tr>
<td>Specific</td>
<td>Permit risk allocation</td>
<td>“The question was who is responsible for getting the permits. We found out through the TDD that at the end the party responsible is the authority and the client [ borrower] just needs to take care of the format and act at the right time. By looking at the track record of the companies, we were able to confirm that they have the experience and they can manage professionally to get all permits on time”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permits</td>
<td>“One thing we were not really aware of at the time of TDD, was this permission issue. [...] one permission application was not submitted at the right time and the permission was granted but there was a possibility for objections and complaints, so the commencement certificate was a bit preliminary”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site complexity and permits</td>
<td>“Site complexity was an issue because of the presence of asbestos on site, and because of the permissions issue from the beginning”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site condition risk allocation</td>
<td>“It was not sure what costs would have to be paid by the SPV for dealing with asbestos and what was borne by the contracting authority”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site condition</td>
<td>“Uncertainties with regard to actual condition of the existing building”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site condition</td>
<td>“Uncertainties in the ground, historic findings.”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Creditworthiness</td>
<td>“At a more high level the key complexity for us was the creditworthiness of the companies themselves that are involved in the project. And this is not a project complexity in terms of construction complexity, but this was the key discussion point”</td>
<td></td>
</tr>
</tbody>
</table>
5.2.3 Implications for decision-making

Finally, the wider-context implications of a systematic complexity evaluation for lenders’ decision-making were discussed in the interviews. The interview results mainly pointed to potential practical merits related to improved communication and collaboration among experts from various disciplines involved in project finance dealings. General first-hand insight was provided into the ways in which lenders’ decision-making would ultimately treat a project’s identified key complexities. These results can contextualise and validate this study’s observations, based on which the benefits and limitations of systematic complexity evaluation in TDD can be identified.

Communication and collaboration in due diligence

The reliance of lenders’ risk analysis and subsequent decision-making on the issues communicated by technical advisers was repeatedly underlined in the interviews. Due to an imbalance of expertise regarding a project’s technical aspects, lenders’ risk analyses are fully dependent on information highlighted as potential issues by engineers: “we are not engineers and we don’t know nothing, really nothing about the technical side of the project. So we entirely rely on what [they] are saying and what they are telling us. And if they forget to tell us something, so to say, we will also never know it”.

The interviewees indicated that the best LTAs’ analyses were often very comprehensive by covering all engineering details of a project, which is seen as beneficial. However, the interviewees emphasised that this poses difficulties for finance experts with a non-technical background to gain a higher-level understanding of the project’s actual riskiness from an engineer’s perspective. A high-level understanding and a general overview is ultimately required as input for lenders’ decision-making. The interviewees voiced a preference for clear visualisations of a project’s technical risk, colloquially referred to as “traffic-light systems”, for representing a project’s complex aspects. The complexity profile and the underlying indicator scores presented in the interviews provided a similar graphical representation of the project: “I think it is useful, similar to ‘traffic light’ signals that we sometimes have for risks, and then we look at the ‘red’ ones”. Moreover, the interviewed lenders appreciated the presented complexity profiles and indeed recognised particularly complex aspects of the case study projects (notably in Project Beta) that were previously not identified as such. An engineers’ stance on project complexity, if presented in such systematic way, could therefore effectively inform the due diligence and lenders’ ultimate overall risk analysis. As one of the interviewees pointed out: “In the end you of course need to cover everything, but it is helpful to focus on the aspects that are indicated as more complex”.

It was noted in the interviews that lenders’ analyses largely rely on comparisons with other projects: “We compare of course what we have done in the sector, what were the characteristics, what we have learned and how we can put this together.” This is a reason why past experiences play such an important role and unique individual perceptions of a project’s riskiness are developed. A desire for more systematically benchmarking projects by their complexity was expressed by the interviewees, for which the approach applied in this study could provide a good starting point: “when you have more projects done with this approach you could benchmark more easily. I mean it is, when I say okay this project for example has these certain complexities here, but it is similar to another project that we have done, this really helps”. Though reminded that further extension may be needed of the list of elements considered in the complexity model applied for this study, they evaluated it as a good aggregation of main aspects they would normally pay attention to in initial due diligence.

Despite the underlined reliance on engineers’ independent views, lenders pointed to a need for more two-way communication and feedback loops in their collaboration with technical experts. The observed different opinions among lenders and between lenders and technical advisers involved were seen as expected and inevitable. Further interfaces and possibly opposing views appear in collaboration of technical, legal, financial and other advisers involved in analysing the deals. In the practice as a whole, lenders have looked for more flexibility and ways to point to their specific concerns: “(...) I often need information on one issue in particular, and I need that there is an open communication to change priorities in the due diligence”. As explained in 5.2.1, the lenders considered the BWM-based component of the proposed approach a suitable method to provide a degree of such communication.
Based on the above views, it can be concluded that a systematic complexity evaluation by engineers was seen by interviewees as beneficial for communication and collaboration in the following ways:

- providing a clear overview of the project from an engineer’s point of view
- better understanding the project at the outset
- providing guidance for finance experts’ risk analyses
- highlighting the key issues for finance experts to concentrate on
- offering an interface for reciprocal communication
- facilitating collaboration and a common understanding among financial, technical, legal, and other professionals involved in due diligence

Mitigating complexity in financing deals

The interviewees indicated that increased complexity gives rise to the perceived construction risk, which in turn contributes to credit risk. Lenders’ initial analysis pays attention to any aspects of a project that could be considered as complex. For such initial analysis, preliminary information on the project is obtained from the borrower promoting the project. Based on this, an indicative pricing of a project is prepared by lenders internally already before detailed TDD. According to one interviewee, a clearer stance on the project’s complexity at this stage can support their “very early assessment and the very early pricing of the project”. Following this, a detailed risk analysis is carried out based on technical, legal, financial and other due diligence based on which a general overview of a project is needed in the eventual decision-making.

The latter is based largely on assessing whether the deal is structured well around the project’s key complexity. “Mitigating” complexity was exposed as important in this respect, which was linked to mitigation measures in either the project plan, in the project’s contracts, or in the financing agreement itself. An overarching mitigation from a credit risk perspective, however, was the strength of the involved sub-contractor who must contractually bear responsibility for any complexity: “In a DBFMO, we are the happiest if everything [design, building, maintenance and operation] is allocated away from the SPV on a back-to-back basis, except for the ‘F’”. The robustness of such contractual risk allocation is defined by adequacy of sub-contractor’s contractual limits of liability. This is assessed based on engineers’ opinions who define and price a realistic worst-case scenario for an analysis of whether the liability caps are sufficient to prevent potential financial stress spreading to the SPV as a borrower. If a cost overrun of 25% is expected as a realistic worst-case scenario, but the relevant contractual liability cap is 30%, the complexity is considered as mitigated by lenders: “This is a very important thing we always look on. But it is often unclear what is behind this LTA’s calculation, what is taken into account in this 25%. We can imagine, but it is not transparent in detail what complexity of the project is taken into account in this scenario.”

The strength of sub-contractor’s experience in managing a certain complexity is seen by the interviewees as a key first line of defence for lenders, and the presence of an equally strong joint-venture partner in the sub-contractor company was suggested by one interviewee as an important second line of defence. While complexity as the inherent project risk is usually well mitigated in this way, one interviewee pointed out that lenders ultimately have to look at the creditworthiness of the sub-contractor rather than its technical and organisational capacity. This is important in assessing a sub-contractor’s ability to independently raise its own funds in case of financial stress during the project: “of course when we do due diligence (...) we analyse [construction risk] and it is important to us, but really in the construction phase we rely on the construction companies”. This view is related to the view of Pantelias & Roumboutsos (2015) who called for more focus of lenders’ credit risk assessments on the parties’ ability to “manage” a risk, and not just “cope” with the risk materialising.

In sum, a clearer and more mutual understanding of a project’s complexity given was seen by interviewees as beneficial in helping identify and evaluate the specific risks considered in credit risk analysis, as well as manage them through adjusting the relevant mitigations in the project and the financing agreement. A complexity evaluation was not seen as a direct support to lenders’ decision-making but as an aid for further due diligence analyses – in the interviewees’ perspective, it can provide the key input for assessing construction companies’ ability to deal with a specific complexity, which in combination does represent the most important input for ultimate decision-making on a project’s quality, as an investment, for a lender.
5.3 Independent validation interview

The interviews discussed above were with finance experts representing lenders previously involved in this study by providing questionnaire survey inputs related to the case studies. While their views provided a degree of clarification and verification of this study’s findings including the proposed systematic approach, another independent view was needed to validate the study’s previous findings. As the lenders underlined the need for engineers’ clearer communication of project complexity, an engineer was sought for this step to complete the circle of empirical findings.

The additional validation interview was therefore held with an engineer with extensive experience as a lenders’ technical adviser but not involved in the previous case study or familiar with this thesis. The overall aim was to evaluate whether and how the application of the systematic approach to complexity evaluation would affect the process of TDD. The basis for the interview was a prior workshop where the interviewee was instructed to consider one of their recent transport infrastructure projects, independently revisit its early TDD phase, and evaluate complexity by applying the steps of the proposed systematic approach. For doing so, the interviewee was provided with the tools that were previously applied in this study – the list of indicators of project complexity from the lenders’ perspective, the questionnaire for BWM inputs (Appendix D) and the qualitative complexity scoring scale (Appendix E). The interviewee’s complexity scorings and the filled-out questionnaire were analysed as per the proposed approach and used as a basis for the interview.

According to the interviewee, the applied approach allowed to thoroughly examine a project’s complexity and provided more specific insight into a project than what was usually considered when beginning the TDD. Had the systematic complexity evaluation been carried out at the beginning of the project’s TDD, engineers may well have focused their attention differently, and reported on the project in a different way. The interview confirmed that clarity of communication between engineers and finance experts is a key aspect in TDD. Complexities in the revisited project that were highlighted by applying the systematic complexity evaluation have indeed materialised as risks. These seemed to have been overlooked in lenders’ risk analyses although they were noted in the engineers’ reports – “we did mention it, but it was mentioned in three lines...of a report of 300 pages”. It was explained that very comprehensive reports on the project’s technical aspects must usually be prepared to support lenders’ risk analyses – “(...) we cover so much it is hard to point out to lenders what are those few things which we see as being risks that would categorise this project as complex”.

Ability to clearly express an engineer’s view about what is most important was seen as the key strength of the proposed approach. Systematic complexity evaluation applied as a preliminary characterisation of the project could help engineers draw the lenders’ attention to the aspects of a project that make it a complex project. The overview of the project’s complexity could be revisited later when additional information becomes available, and examined whether the TDD analysis is still looking at the right things with the right amount of attention. The engineer was asked how the obtained result of complexity evaluation would itself affect further engineers’ analyses – “I would look at how the borrower addresses this complexity...ask the right questions to the borrower...it would influence the way I look at information provided by the borrower”.

The interviewee was finally also presented with this study’s main findings from measuring the case studies’ complexity using the proposed approach – that the lenders’ views on what makes a particular project complex may differ from engineers’ views, and that there also seem to be individual subjective concerns and preferences at play in finance experts’ views on each complexity indicator’s importance. The interviewee was asked how these views of finance experts at the receiving end of TDD analyses would be dealt with, if encountered in the results of the BWM component in the proposed approach. The engineer stressed the need to discuss and find out why something is a concern in a lenders’ view, and that engineers should be looking at a project’s complexity more from the lenders’ perspective – “(...) because what we see as manageable...they may not understand it that way. We need to help them understand it, and be able to see if their ideas of complexity are confirmed or alleviated based on our information.” Reminded that in absence of engineers’ clear stance on a project’s complexity lenders indeed resort to categorising projects in broad classes per project type, the LTA emphasised: “I can think of many schools not simple. Things can go just as horribly wrong with a school, town hall or prison...as they can with a technologically complex powerplant”.

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In sum, it is observed that the interview confirmed that streamlined communication between finance and engineering experts is a key aspect in which the process of TDD must indeed be improved. The applied systematic approach to complexity evaluation provided a useful platform for addressing this by better aligning the engineering and finance professionals’ views of a project’s complexity early on in the process.

5.4 Conclusion

Based on a set of interviews carried out with the representatives of lenders in project-financed infrastructure, this chapter explored the decision-making implications of engineers’ evaluation of project complexity in TDD. With this, the previous findings of this research get their practical context which points to an answer to the final sub-question of this research:

SQ4: In what way does the applied systematic approach to complexity evaluation contribute to the process of technical due diligence and support lenders’ decision-making?

Seemingly due to a lack of systematic evaluations of project complexity in TDD, finance professionals’ perspectives of a project’s complexity have previously been formed on the basis of various preconceptions. In many cases, these have been linked to general convictions about the complexity of a project type instead of a particular project. Furthermore, past experience and subjective beliefs have led the intuitive judgement of how complex a project is. This has in turn led to wrong assumptions as to a project’s complexity and the related perception of credit risk which is a direct basis for lenders’ decision-making. Based on these observations as well as the interviewees’ reflection on the case study projects, it has been shown that more differentiation as to a project’s complexity is indeed needed. The systematic approach to complexity evaluation applied collaboratively by engineers and finance experts can identify specific areas in which a particular project is more or less complex. This can enrich the finance experts’ perception of a project’s complexity, improving the understanding of project-specific risks in a project’s construction and operational phases. On the basis of a clear overview of a project’s complexity, the various parties involved in the multidisciplinary context of lenders’ overall due diligence can more competently communicate and collaborate to identify and mitigate the project-specific sources of complexity and thus support the analyses of credit risk, a basis for lenders’ ultimate decision-making.
6 Conclusion, recommendations and limitations

This chapter discusses the outcome and implications of this study. First, the answers to the research sub-questions are presented (6.1) followed by a discussion aggregated to answer the main research question (6.2). Based on these, key recommendations to practice are formulated (6.3). Contribution of this study to the initial research gap is summarised (6.4), key limitations of the research are highlighted (6.5), and finally, a personal reflection on the learning process during the thesis research project is provided (6.6).

6.1 Answers to the research sub-questions

To answer the main research question formulated for this study, four sub-questions had to be answered in sequential order. Based on results discussed in previous sections, and subject to limitations explained in section 6.3, the following conclusions are drawn that lead to answering the main research question.

SQ1: What is the role of project complexity in the practice of technical due diligence and lenders’ decision-making on project finance loans?

In project-financed infrastructure, lenders have a distinct perspective of project complexity that is related to the project-specific risk character inherent to a project’s main phases of construction and operations. This perspective of project complexity mainly considers a project’s engineering and managerial features, for an understanding of which lenders’ credit risk analyses rely on technical due diligence performed by engineers. Representing an important element of credit risk assessment, the understanding of a project’s complexity directly influences an infrastructure project’s affordability. For project complexity evaluation in technical due diligence supporting lenders’ risk analyses, a clearly defined and mutually understood definition of project complexity must be operationalised. The role of project complexity in technical due diligence is related to the nature and amount of project-specific uncertainties faced by the SPV, acting as the borrower, according to its overarching project agreement with the contracting authority. This calls for the identification of project-specific sources and elements of complexity relevant in technical due diligence.

SQ2: In what systematic way can project complexity be evaluated in technical due diligence to support lenders’ risk analyses and decision-making on project finance loans?

Based on the identified need for better mutual understanding of a project’s complexity among the engineering and finance experts involved in technical due diligence, a systematic approach to complexity evaluation is proposed. The systematisation of project complexity evaluation is organised in a way that necessitates three main components:

- First, a complexity evaluation model must be constructed comprising project complexity indicators relevant from a lenders’ perspective and corresponding to the scope of technical due diligence. To do so, twenty-six potential complexity elements identified in a literature study were used to define a hierarchical complexity evaluation model. The top-level complexity factors correspond to the top-down view of lenders in credit risk analysis models. The underlying detailed-level complexity indicators comprehensively cover project-specific technical features enabling engineers’ bottom-up complexity evaluation.

- Second, the relative importance of complexity indicators in the considered project type must be determined by experts participating in a lenders’ due diligence process. The BWM method is applied to transpose detailed-level complexity scores to a higher-level overview of a project’s complexity, while also reflecting different individual views of the experts.

- Third, through a consistent qualitative complexity scoring system, project complexity must be quantified based on inputs of engineers carrying out a technical due diligence analysis. A five-step numerical scale was used to define a qualitative complexity scoring system for application in this study.

Applying the above systematic approach to complexity evaluation in technical due diligence provides for an establishment of an expert opinion on project complexity, on different levels of aggregation, and effectively facilitates technical due diligence supporting lenders’ risk analyses and decision-making.
**SQ3: How can the systematic approach to complexity evaluation be applied in technical due diligence?**

The use of the proposed approach in technical due diligence has been demonstrated on two case studies for which the initial due diligence phase was revisited. The results have shown that the systematisation of complexity evaluation could be beneficial to better differentiate between projects by their complexity. However, the process of evaluation must itself be supported by communication between the experts involved in a project’s technical due diligence analysis. Different perceptions of a project’s complexity inevitably emerge regarding the indicators’ relative importance, stemming from different concerns of parties involved. These must be taken into account in analysing a project, for which the BWM-based component of the proposed approach provides a useful platform. A high-level complexity profile resulting from approach application is as accurate as aligned the involved experts’ perspectives are. Such alignment of different views is needed before the attention is focused to the project’s perceived key complexity. The case studies confirmed that the systematic approach to complexity evaluation can be effectively applied in technical due diligence by following the proposed steps and facilitating a two-way communication between the involved engineering and finance experts.

**SQ4: In what way does the applied systematic approach to complexity evaluation contribute to the process of technical due diligence and support lenders’ decision-making?**

In the final phase of this study, the results of interviews with project finance professionals confirmed that the proposed systematisation of complexity evaluation improves the finance experts’ understanding of project-specific risks in a project’s construction and operational phases. Based on the systematic evaluation of a project’s complexity informed by engineering expertise, the various parties involved in the multidisciplinary arena of lenders’ due diligence can therefore engage in better informed communication and collaboration. If applied as a preliminary analysis of a project’s complexity from a lenders’ perspective, systematic complexity evaluation improves the process of technical due diligence as confirmed in the final validation interview. Based on the identified complex aspects of the project, a clearer stance on a project’s complexity can be obtained, enabling more careful analyses of critical aspects in a borrower’s project plan. This in turn helps identify and mitigate the project-specific sources of risks from a lenders’ perspective and thus supports the analyses of credit risk, a basis for lenders’ ultimate decision-making.

### 6.2 Answer to the main research question

By taking into account the lenders’ perspective of project complexity in project-financed infrastructure, the aim of this research was to systematise project complexity evaluation in technical due diligence performed by engineers supporting lenders’ risk analyses and decision-making on project finance loans. The above answers to the systematisation related sub-questions therefore help answer the main research question:

**In what ways can a systematic project complexity evaluation in technical due diligence contribute to supporting lenders’ decision-making on project finance loans?**

This study confirmed that an absence of a systematic project complexity evaluation by engineers in technical due diligence can give rise to conflicting perceptions about a project’s inherent risk character. The lenders’ perspective of project complexity and its role in technical due diligence was found to be related to the nature and amount of project-specific uncertainties faced by the borrower according to its overarching contractual agreement with the contracting authority. Posited on this premise, project-specific technical features were identified that may give rise to project complexity from a lenders’ perspective. For an analysis of a project’s technical features, finance experts rely on engineers. The results suggest that this expertise imbalance is a potential source of important information asymmetries between engineering and finance professionals in technical due diligence. Due to a lack of cross-disciplinary understanding, project complexity is often under- or overestimated in lenders’ risk-based decision-making in project-financed infrastructure. However, regardless of how the level of complexity is derived, its perception represents an important basis for establishing the creditworthiness of a project and therefore affects the overall cost of infrastructure development.
To address this issue, a systematic approach was specified that enables project complexity evaluation tailored to the multi-disciplinary context of technical due diligence. Its application was demonstrated in identifying a project’s complex aspects and discerning a simple project from a complex one. It was shown that the systematic approach to complexity evaluation can act as a needed nexus between engineering and finance expertise. If applied at an early phase of lenders’ due diligence, the approach can facilitate communication and collaboration, complementing the existing practices and methodologies by establishing a common understanding of a project’s substance. Through critically considering different experts’ views enabled by a BWM-based analysis, an enriched understanding of project complexity can be gained. This can act as a common starting point and support for lenders’ due diligence, risk analyses, and ultimate decision-making.

As suggested by the lenders interviewed, a clearer engineers’ stance on a project’s specific complexities can help better substantiate the prediction of realistic downside scenarios which a project could experience during its lifecycle. These are important in view of a key principle in project finance whereby any project-specific risks must be allocated to the party best suited to accept them. As suggested by Pantelias & Roumboutsos (2015), while lenders’ existing credit risk analyses have mainly looked to the parties’ ability to “cope” with the risk materialising, they should put more emphasis on a party’s ability to “manage” a risk. While the former is related to financial and contractual parameters such as a party’s creditworthiness and liability caps, managing a risk necessitates engineering and management capacity. The results of this study suggest that systematic complexity evaluation could better assist both of these analyses by facilitating understanding among finance and engineering disciplines. On the other hand, some complexities may not be managed contractually, notably dependences on stakeholders external to the project. This complexity was an important aspect of both case study projects revisited in this study. In this respect, the projects’ successful completion was attributed by lenders in hindsight to the supportive stakeholders and construction companies’ strong stakeholder management, which also supports the findings of Verweij (2015) underlining the importance of externally-oriented project implementation strategies by both public and private sector participants in PPP projects.

While the ultimate aim of complexity evaluation may be to communicate complexity as a definite parameter, the results of this study suggest that transparent communication and collaboration is also necessary during the process of complexity evaluation. This shall ensure a comprehensive and more widely agreed view of a project’s complexity. This study also shows that the concept of project complexity is more nuanced and that the level of complexity should not be evaluated arbitrarily. Any project has more and less complex aspects from both engineers’ and lenders’ perspective. Each individual observer’s perception must therefore be taken into account to establish a balanced complexity profile of a project. Specific project’s complexities and individual experts’ views can remain concealed in high-level opinions on project complexity. Therefore, the systematic approach to complexity evaluation is useful primarily as a means of communication and facilitating the establishment of common understanding among the parties involved. While complexity evaluation results can expose the key complex aspects from a lenders’ perspective relevant for engineers’ analyses and vice versa, they should be taken as needed guidance for detailed risk analysis, rather than a self-sufficient information of a project’s riskiness.

Taking into account these considerations, the systematic approach can help streamline the identification, evaluation and management of risks. Its outcomes can help tailor the due diligence attention to the complexity of a specific project. These findings address the research gap considered in this study (Section 1.3) and with that, the demonstrated contribution of the proposed systematisation of complexity evaluation to improving the process of technical due diligence meets the objective of this study (1.4).
6.3 Recommendations to practice

This thesis was motivated by daily practice issues encountered by engineers supporting lenders' due diligence. Therefore, the study’s findings and positive conclusions lead to the following recommendations.

*Take a clear stance on a project’s complexity and be aware of the lenders’ specific perspective*

In project finance, engineers’ expert opinions play a pivotal role in shaping the lenders’ perception of a project’s complexity and associated project risks. In absence of a clear stance on a project’s complexity, lenders’ perception is often different to that of engineers or project managers. The asymmetry in expertise and project-specific information may lead to wrong assumptions regarding a project’s complexity in lenders’ risk analyses. Lenders’ assumptions are often simplified to the extent of relating project complexity to the general type of the asset under consideration, one common simplification being that a school is less complex than a power plant. More differentiation per specific project is needed, notably as the perceived complexity directly affects credit risk ratings and associated terms of financing agreements. While engineers’ focus on detailed technical risks is ultimately needed in technical due diligence supporting lenders’ risk analyses, a clear stance on a specific project’s overall complexity from a technical perspective is an important starting point for due diligence analyses by various disciplines involved in technical due diligence.

*Apply the proposed approach facilitating communication and collaboration in early TDD*

Drawing on different experts’ unique views from an early stage of technical due diligence, an enriched perspective of a project’s complexity can be obtained. Collaboratively working out a project’s key complex aspects can provide for a more thorough and better aligned understanding of a project’s risk characteristics between engineering and finance professionals. To do so, the proposed approach to systematising complexity evaluation is based on three complementary components (see Chapter 3) each of which should be applied to provide insight into a project’s specific complexity:

- **Establishment of a robust model of project complexity from a lenders’ perspective**
  
  To better link the engineers’ and finance experts’ analyses, a hierarchical complexity evaluation model must be applied. The model’s top-level complexity factors cover the top-down view of project complexity in lenders’ risk analyses, while its detailed-level complexity indicators comprehensively cover the specific sources of project complexity enabling engineers’ clear and consistent complexity assessment. The model applied in this study comprises twenty-six complexity indicators in seven factor groupings to cover the main potential sources of project complexity from a lenders’ perspective. The model successfully captured the complexity of revisited projects representing the main types of project-financed infrastructure. With growing practical experience with this model, periodical revision, reorganisation or extension of the model shall be needed to further improve its robustness.

- **Application of BWM analysis to streamline the diversity of experts’ views on complexity indicators’ importance**
  
  The relative importance of complexity indicators in each grouping varies per specific project type, but also importantly depends on subjective views related to past experience of experts involved in a project’s due diligence. Efficient expression of expert views on indicators’ relative importance is enabled by a BWM-based survey and analysis enabling the quantification of weights. The parties’ different perceptions may stem from underlying concerns important for detailed risk analyses. Therefore, it is recommended as vital to compare, discuss and align the involved finance and engineering experts’ individual views prior to detailed due diligence.

- **Quantification of complexity profiles through a qualitative scoring system**
  
  Clear inputs of engineering expertise are needed in a bottom-up assessment of a project’s complexity. The five-step numerical scale provides a good basis for the qualitative system facilitating consistent complexity scoring of each indicator included in the applied evaluation model. The weights obtained in previous step provide for establishment of complexity profiles showing project complexity at a higher level of aggregation needed in lenders’ risk analyses and decision-making.

*Focus on the manageability of specific complexities and the parties’ risk management capacity*

From a debt-financing perspective, complexity is mitigated through allocating the related risks away from the borrower through financial and contractual mechanisms that protect the borrower from bearing the consequences of any risk materialising. It is clear that certain complexities may not be manageable in this way, and more active
risk management strategies are needed to prevent risks from materialising altogether. The project participants’ substantial engineering and management experience is especially important in such cases and should be at the centre of attention of engineers supporting lenders’ risk analyses. Conversely, certain aspects of projects often seen as complexities by lenders are easily manageable from a technical point of view. More clarity on the manageability of project complexity is therefore important for appropriately supporting lenders’ risk analyses and eventual decision-making.

6.4 Contribution to the addressed research gap
This thesis contributed to addressing the identified gap in academic research on project-financed infrastructure projects’ complexity. As discussed in Chapter 1, the existing studies on project-financed infrastructure have focused on the perspectives of different stakeholders. Among these, the lenders’ distinctly risk-averse perspective has received relatively limited attention although its importance has been repeatedly underlined. In particular, existing studies discussing influencing factors of lenders’ risk perception have offered limited clarity on project-specific technical features important in lenders’ risk analyses.

**Insight into a lenders’ perspective of project complexity**
The project’s technical features can be related to the concept of project complexity which has been extensively discussed in the context of project planning and management. These studies have underlined the different perspectives on project complexity of particular stakeholders in specific project types, but the perspective of lenders in project-financed infrastructure has not been specifically addressed. In Chapter 2, a review of the practice of technical due diligence has confirmed the relevance of the research gap highlighting the need for better mutual understanding between engineering and finance disciplines involved in lenders’ risk-based decision-making. Therefore, Chapter 2 further explored the relative uniqueness and relevance of understanding the lenders’ perspective of project complexity, and pointed to project-specific technical features that characterise project complexity from a lenders’ specific perspective.

**BWM applied to complexity evaluation in a multidisciplinary context**
Complexity can be evaluated systematically in different ways and at different levels of aggregation, and multiple-criteria decision-making methods offer a way to address the concept’s multi-faceted, dynamic and subjective nature. From a range of possible methods, this thesis applied BWM and showed its usefulness for assessing project complexity in the context of technical due diligence, a field where apparently it has not been applied before. BWM provides a feasible way to express, quantify and discuss the preferences or concerns of different experts as these are exhibited in the relative importance assigned to different complexity indicators. The results of BWM application to case study projects exposed the need to account for subjectivity in complexity evaluation to derive a good footprint of a project’s overall complexity at higher levels of abstraction.

**Streamlined risk identification and complexity-sensitive due diligence**
This thesis further addressed an important research gap exposed by Cui et al. (2018) related to the availability of workable methods streamlining the risk identification, evaluation and management in public-private partnerships. This was related to the identified need (Steffen, 2018) for better tailoring lenders’ due diligence to smaller and less complex projects. This thesis indeed showcases the importance of more nuanced and project-specific views of project complexity from a lenders’ perspective and relates this to better mutual understanding with engineers representing the lenders’ interests. The results demonstrate how a systematic complexity evaluation applied as a communication and collaboration tool in early technical due diligence can enhance and streamline risk analyses of involved finance and engineering experts.
6.5 Limitations and further research

The findings and conclusions of this thesis ought to be considered in light of a number of research limitations. The most important limitations are discussed below and point to needed further research in the field.

Selection of complexity indicators

Complexity is an ambiguous concept in itself and specific project complexity attributes are addressed to different detail in the available literature, allowing different interpretations and posing difficulties for establishing convergence needed to design a robust complexity evaluation model. Following an exploratory study of the lenders’ specific perspective of project complexity, a comprehensive model of project complexity from the lenders’ specific perspective was constructed as a basis for applying a systematic approach to complexity evaluation in TDD. A list of relevant project-specific technical features adding to complexity from this specific perspective was established in a desk research of relatively limited amount of academic and reference literature, past projects’ TDD reports, and explanatory publications by credit rating agencies. In large part, the view of credit rating agencies had to be adopted due to its clarity and representativeness of the lenders’ prevalent perception of technical sources of project complexity needed as input for this study’s empirical part. However, these practice-based publications themselves have limitations related to their non-scholarly, illustrative and thus possibly incomplete nature. Their approaches to credit risk assessment have also been criticised for danger of emphasising wrong issues (Pantelias & Roumboutsos, 2015).

Based on these insights, as well as validation and additional insight from LTAs, a qualitative complexity scoring system was set up for the purpose of this study. However, due to its exploratory nature, this model may have limitations and must therefore undergo at least periodical revision, reorganisation or extension to further improve its robustness. In terms of research approach, a further limitation is that the lenders’ perspective observed in limited number of sources served as initial input for the empirical part of this research. However, as indicated by the results of the empirical part, an opposite approach may well have resulted in a different set and organisation of complexity indicators. Given the observed variety of individual perceptions of project complexity, more primary academic research would be required on the technical attributes of project complexity from a lenders’ perspective, for which a mixed-method approach on a statistically significant sample would be needed. Further research on the lenders’ perspective should focus on more thoroughly investigating the different individuals’ and organisations’ views of project complexity to build a more detailed, robust and empirically tested list of complexity indicators.

Sample size

Additional limitations are related to the study’s sample on the basis of which the conclusions were drawn on the merit of the proposed systematic approach to complexity evaluation in TDD. Due to time constraints, this approach was only applied to two explanatory case study projects corresponding to two main types of project-financed infrastructure in the Netherlands. The number of respondents for questionnaire surveys and interviews was also limited to the engineering and finance experts involved in these two projects’ due diligence. Testing the conclusions on a statistically more significant sample would therefore strengthen its reliability.

Retrospective view / potentially biased perceptions

The retrospective view adopted in case studies revisiting TDD posed difficulties fully discriminating between the information on project complexity available at the time of initial analyses and information obtained later. The practitioners’ views of a project’s complexity were also inevitably affected by their ex-post knowledge of a considered project’s actual performance. This may have affected the results of case studies analysis demonstrating the application of complexity evaluation. The approach must therefore be further enhanced through testing in live environment to establish its ability to properly capture a project’s complexity. In this respect, taking into account the observed ever-developing nature of individual perceptions of project complexity, an interesting further research would be to follow engineering and finance practitioners across several projects, exploring the mechanisms of how these individual perceptions are formed and how they affect technical due diligence, credit risk analyses and decision-making in subsequent projects.

BWM limitations and interpretation of results

This thesis applied BWM as a feasible method to elicit the experts’ perspective on complexity indicators’ importance. Its strength was shown in providing an effective means of highlighting the different individual views’
and concerns in a project’s technical due diligence. However, limitations of this approach are observed that are not directly related to the method itself, but its application and interpretation of the results. The application of BWM could be streamlined through a different form of gathering inputs on the indicators’ relative importance. The questionnaire survey could for example be substituted by structured interviews to provide more direct insight into the experts’ reasoning. While this feedback was partly obtained through follow-up interviews, the practitioners’ explanations could not be directly linked to each response in the survey. Furthermore, although the method allows for multiple indicators’ equal importance, the need to first select the most and least important indicators may itself lead a respondent to supposing they must have a different importance. The grouping of indicators in the complexity evaluation model may also have an effect in this respect, and a different grouping may have given a different result. Finally, the interpretation of the resulting weights in this study focused on highlighting the differences in subjective views. Since the sample of respondents was small, only a qualitative analysis of BWM results was possible. Given the respondents’ participation in the same project’s due diligence, the differences in views were considered an important finding. As a result, definitive conclusions on the weights of complexity indicators could not be drawn, hence the need for discussion and alignment of views among experts was highlighted. Further applications of the method on a greater sample allowing a quantitative analysis may provide clearer answers as to the indicators’ relative importance in each project type. Nevertheless, BWM analysis is an important component of the proposed approach as it provides a platform for communicating the subjective views of experts involved in a project’s technical due diligence. For addressing this observed subjectivity, other approaches shall also be explored, for example by supplementing the BWM component with fuzzy logic and group decision-making.

**Interviews**

The final conclusions on the merit of systematic complexity evaluation were drawn based on a set of interviews whose preparation and execution itself carries limitations. Some of these include the limited time available for interviews, the presence of language barriers, and the interviewer’s limited experience in moderating and analysing interviews. Furthermore, the interviews were carried out with professionals who were previously involved in the case study projects. This was beneficial in providing informed insight into their intuitive complexity evaluation, the projects’ actual performance, and the background of decision-making process. Finally, the independent validation of findings was carried out with a single interviewee. Therefore, additional independent interviewees and an improved interview protocol could help better understand, interpret and validate the findings.

### 6.6 Personal reflection

Finally, I welcome my supervisors’ encouragement to take the opportunity and reflect on this graduation thesis project as a personal learning and development journey, but also a source of valuable first-hand insight into construction projects from a perspective previously little known to me as an aspiring engineer. Indeed, this new insight points at relevant areas of improvement relevant personally, in terms of approaching the task, as well as in terms of practice in the addressed field. This section thus aims to present some of these final reflective thoughts.

This research was my first serious contact with predominantly qualitative research which was a valuable and enjoyable learning experience despite a number of practical difficulties faced along the way. These related to analysing, interpreting and reporting on the findings of my qualitative analyses which often took more time and effort than initially envisaged, and the vast openness to interpretation itself felt somewhat unnatural when trying to draw objective conclusions. It goes without saying that a qualitative approach was necessitated by the choice to address complexity which is quite an intangible characteristic in otherwise rather exact discipline of engineering I was trained to. My personal desire to more objectively measure complexity as a parameter of construction projects had left me looking for clear and tangible indicators of complexity as a needed basis for seeing what insight such measurement can provide. However, difficulties emerged as only relatively vaguely explained complexity indicators could be found, and in two rather different bodies of knowledge – academic project management literature and practice-based finance literature. To allow proceeding with the empirical part of this research, a lenders’ prevalent perspective of project complexity was therefore assumed based on characterisations in available practice-based literature. In turn, the empirical part exposed a variety of experts’ very individual perspectives of project complexity sources, which points to the need for more research time devoted to exploring these individual perspectives before
proceeding with measuring complexity itself. In hindsight I can say that, in absence of timing constraints and in spite of the mentioned personal preference to try to measure something, I would narrow the scope and focus of my study on gathering statistically significant primary data on the lenders’ perceptions of project complexity to present an independent and robust list of complexity elements.

Setting out to more closely explore the financing side of civil engineering projects, I expected that studying the interface between engineers and lenders in PF would show me techniques to more thoroughly understand project-specific technical risks from two complementary perspectives. Throughout the process of this thesis, it surprised me that both engineers’ and finance experts’ risk analyses are inevitably subjective and based on more or less cautious expert judgement. Moreover, although the lenders’ reliance on independent engineers’ specialist opinions is much emphasised, I was surprised to see how far apart the finance and engineering professions often sit. Interestingly, discussing complexity of the case study projects, the LTAs showed as much interest in finding out the lenders’ view as vice versa. The asymmetry in expertise, complexity of organisational structures and intricacy of information flows in project finance environment seem the source of many information imbalances. The due diligence practice is based largely on one-way written communication in identifying and evaluating risks, and a very legalistic view is adopted in analyses to avoid neglecting anything that may possibly go wrong. This is problematic because the clarity of information on what is most important may suffer, and important misunderstandings may arise. It would seem beneficial for the borrowers, lenders’ risk analysts, engineers and any other needed experts to collaborate more and earlier in the project to align views on its risks. Moreover, a higher level of engineering expertise would seem beneficial in project finance circles, as well as more finance expertise in engineering disciplines supporting lenders’ risk analyses. In any case, a more multidisciplinary mindset and more knowledge sharing could improve the understanding between the parties involved.
References


Rajgor, G. (2011). Spotlight on due diligence: The more cautious lending environment means wind projects will only get off the ground once they pass the scrutiny of some major due diligence investigations. Renewable Energy Focus, 12(2), 26-31.


Appendices

Appendix A – Key focus areas of technical due diligence analysis
Appendix B – Descriptions of selected complexity indicators
Appendix C – Qualitative complexity scoring scales
Appendix D – Structure of the BWM questionnaire
Appendix E – BWM inputs analysed per respondent
Appendix A – Key focus areas of technical due diligence analysis

The approach to technical due diligence as observed in LTA reports for the three reviewed projects (2.2) was analysed. The approach to due diligence follows a largely standard structure across the reviewed projects in various sectors. It is governed by six main topics across the reviewed reports:

**Stakeholders review:** First, the parties involved in the project are considered, particularly the participants of the bidding consortium and any sub-contractors involved. Their suitability for roles assigned within the project is assessed based on their previous experience in projects of comparable type, size, complexity, location and contractual structure. Here, the focus is predominantly on main internal stakeholders, thus project participants (bidding consortium members and their subsidiaries usually acting as sub-contractors or service providers). External parties, although seen in literature (e.g. Bosch-Rekveldt et al., 2011) as potential drivers of project complexity, are often listed rather briefly and a detailed assessment of their attitudes is not provided.

**Contract review:** Second, a review of the main contracts is carried out (DBFM agreement and sub-contracts for design and construction and, where relevant, maintenance and operations, as well as any interface agreements between the sub-contracts) with a very specific focus on analysing the substance and mechanisms of risk allocation between the SPV and sub-contractors. The analysis is limited to technical aspects, for example the allocation of responsibilities for the works and services, site conditions and latent defects, responsibility for consents and approvals, procedures related to variations, force majeure and relief events etc. Appropriateness of risk allocation is assessed through a review of compensation and delay events to ensure that the risks allocated to the SPV and sub-contractors can be borne by them. The discussion of provisions on termination of contracts has an important role, for example the termination triggers, liability caps and performance penalty points. Centre of attention is on ensuring that standard provisions usually seen in similar projects are used and that the contractual requirements are clearly defined and manageable for a competent sub-contractor.

**Design and construction:** Third, the contracting authority’s specifications for technical solutions are reviewed, identifying any non-standard requirements a competent contractor may not be familiar with. Although the design may be at a preliminary stage, an opinion is provided on the consideration of lifecycle costs, the design’s compliance with contracting authority’s requirements, how it takes into account the site conditions and how it satisfies general industry standards. Focus is on ensuring that well-known design and construction techniques are used. The construction programme and methodologies are analysed from a feasibility perspective, with attention to including sufficient float and minimising any material risks to the SPV.

**Operation and maintenance:** Fourth, like for the design and construction phase, the operation and maintenance assumptions and plans are assessed starting with a review of authority specifications and the consortium’s proposals. Appropriateness of performance indicators and requirements specified in the main contracts is an important consideration. The realistic capabilities of the consortium to carry out the required work is assessed with a view to meeting the requirements for drawing the full availability payments.

**Performance regime:** Fifth, the reviewed TDD reports analyse the performance regime and evaluate its penalty and payment mechanisms, including the determination of various “worst case” scenarios with occurrence probabilities and penalties quantification.

**Costs:** Finally, construction costs, FM and operating costs, and lifecycle costs are benchmarked with projects of similar size, type and complexity.
Appendix B – Description of selected complexity indicators

The complexity elements identified in Chapter 2 and applied in the hierarchical complexity evaluation model (Section 3.2) were discussed with two LTAs to gain an additional understanding of how each indicator could potentially make a project complex from a debt-financing perspective. Based on this, complexity indicators included in the complexity evaluation model can be explained based on practitioners’ inputs and insights from theoretical and practice-based literature reviewed in Chapter 2. Below, each complexity indicator is described briefly as a basis for qualitative scoring scales provided in Appendix C.

Factor C1: Site complexity

Using the identified indicators described below, the sources of complexity related to the project’s immediate location are considered. Five complexity indicators are included, focusing on site investigations, permitting procedures, preparatory works needed on site, and the logistical challenges characteristic of the site.

Reliability of site information (C1.1)

At the time of lenders’ due diligence, the information on site condition may still be limited and of preliminary quality (Yescombe, 2018). The available information is often limited to preliminary site investigation results provided by the contracting authority who may or may not take any responsibility for their accuracy. This can pose technical risks and uncertainty regarding the precise scope of work, which have been considered as part of technical complexity (Xia & Chan, 2012; Bosch-Rekveldt et al., 2011). Additional investigations needed for detailed engineering and planning solutions can only be executed by the borrower after contractual and financial close. In a complex situation from a debt-financing perspective, the information available during TDD would not provide a good basis for borrower’s realistic budget and schedule planning due to uncertainties regarding the precise location and scale of unfavourable subsoil phenomena. Therefore, the solution included in the borrower’s bid to the contracting authority would therefore likely be subject to changes following further measures applied after financial close.

Complexity of site condition (C1.2)

In addition to uncertainties as to the site condition due to limited information available before financial close, complexity may also be related directly to the character and diversity of site conditions known or foreseeable to be present on site. Aspects usually considered in TDD include site geology itself, but also the condition of any legacy structures, location of existing utilities, neighbouring structures, presence of dangerous substances and contaminated soil, unexploded ordnances and archaeological findings, etc. From these, specific focus of lenders’ engineers has been on those site conditions not retained by the contracting authority and difficult to allocate to a sub-contractor, for instance site decontamination requirements.

Preparatory works needed (C1.3)

While preparatory works are not necessarily technically demanding, increased complexity is perceived from a debt-financing perspective where required site preparation works are substantial and take place in complex site conditions (Fitch, 2018; Moody’s, 2015). This indicator thus focuses on extent and character of technical measures required before main civil works can commence. These may include requirements for site clearance, construction of access roads, soil decontamination, erection of geotechnical structures, relocation of cables and conduits, etc.

Permits & rights of way (C1.4)

Pending permitting and site clearance issues can reduce a project’s desirability from the lenders’ perspective (Laishram & Kalidindi, 2009). They can delay the completion and incur additional expenses that may endanger a project’s timely completion and start of debt repayment. The responsibility for acquiring the main planning permits and land use rights does not normally rest with the borrower (Yescombe, 2018) – in PPPs, the public authority is considered best suited to manage the main spatial planning risks. In project agreements considered simple from this indicator’s perspective, borrower’s scheduling and budgetary consequences of permitting delays would therefore be fully compensated. TDD must identify specific risks related to permitting procedures not resolved before financial close, e.g. construction permits dependent on the borrower’s detailed designs.
Logistical complexity (C1.5)
A construction project’s location can pose logistical challenges which are a source of project complexity (Xia & Chan, 2012; Bosch-Rekveldt et al., 2011). This indicator looks at the severity of logistical challenges stemming from the construction site’s characteristics such as limited accessibility to remote sites, sites that are severely constrained in either physical terms or due to logistics inhibited by the site’s ongoing use during construction, etc.

Factor C2: Interfaces with environment
This factor takes a wider view to the project’s environment surrounding the project’s immediate site in which construction takes place. Environmental complexity has been an important complexity indicator (He et al., 2015; Nguyen et al., 2015; Xia & Chan, 2012; Bosch-Rekveldt et al., 2011). Three complexity indicators were identified, covering the boundary conditions project planning and implementation are subject to, and project’s dependence on external stakeholders that could influence the progress of project implementation.

Amount of construction restrictions (C2.1)
Each construction project has location-specific boundary conditions relevant for planning and implementing the construction works. Construction restrictions may be related to working at certain time periods or using certain techniques (Xia & Chan, 2012). While some are related to industry-wide regulations, unusual project-specific restrictions may give rise to complexity perceived from a debt-financing perspective (Moody’s, 2016). The restrictions may be due to interfaces with neighbouring sites or facilities, sensitivity of environment, safety rules, conditions of various stakeholders’ consents, weather and climate, etc. The various construction restrictions can reduce the time available for construction or affect the possibilities to fast-track works in case of delays. Missing strict timing windows can require major reprogramming of construction activities.

Complexity of restrictions (C2.2)
For construction restrictions mentioned above, TDD must analyse specific project planning implications by looking at the uncertainty in methods with which the restrictions can be addressed. For example, while the use of innovative prefabrication methods or special concrete mixtures may enable the continuation of works at low winter temperatures, any commercially unproven technology has been shown as less desirable from a debt-financing perspective (Laishram & Kalidindi, 2009).

Dependence on external stakeholders (C2.3)
Construction projects can be delayed due to external stakeholder pressure. The number and variety of stakeholders the project depends on have been shown as a source of complexity from a project management perspective (e.g. Bosch-Rekveldt et al., 2011 & 2018; Vidal et al., 2011; Nguyen et al., 2015). In project-financed infrastructure, the contracting authority normally ensures a project is in public interest and retains the risks related to major public opposition (Yescombe, 2018). However, many specific external stakeholders may influence the progress of a construction project, and more externally oriented project implementation has been recommended to enhance the overall success of PPP projects (Verweij, 2015). This complexity indicator highlights the extent to which project planning and delivery are dependent on cooperation with any stakeholders external to the project.

Factor C3: Solution complexity
This factor considers the substance of what needs to be constructed by looking at the complexity indicators related to the design solution available at the time of TDD.

Level of design completion (C3.1)
At the time of TDD, the level of detail to which the designs are prepared by the potential borrower may be very preliminary, necessitating detailed designs to be prepared in parallel to ongoing construction. This can influence the reliability of borrower’s cost estimates available before financial close. The cost and scheduling uncertainty in case of such preliminary nature of designs must therefore be assessed in TDD to support the lenders’ risk-based decision-making models.

Design verifications by client (C3.2)
There are different degrees to which project agreements may transfer design risks to the borrower, which is important in TDD analyses. A very simple situation would see final, detailed designs provided in bidding
documentation by the contracting authority, or borrower’s proposed designs verified prior to construction. A contracting authority as a client thus retains partial responsibility for the design’s appropriateness, reducing the risks of operational underperformance. In an opposite case, no intermediate or final design verifications are provided by the contracting authority, and thus all design risks rest with the borrower.

Structure uniqueness (C3.3)
Design solutions that are unconventional or innovative in nature are an indicator of a project’s increased complexity from a lenders’ distinctly risk-averse perspective (Yescombe, 2018; Fitch, 2018; Moody’s, 2016; S&P, 2014). Well-proven design solutions are therefore normally seen in PPP projects, while increased complexity would relate to a project whose design has a highly unique character in terms of its dimensions, structural or architectural features, for which limited precedents are available.

Interdependence of sub-projects (C3.4)
The construction phasing solution is reviewed in TDD to examine its flexibility and overall achievability of plans. Dependencies between tasks, technical processes and disciplines have been shown as a source of project complexity (Bosch-Rekveldt et al., 2011) and scheduling challenges can affect the desirability of projects from a debt-financing perspective (Laishram & Kalidindi, 2009). A complex project on this indicator is characterised by a design with a very monolithic nature that needs to be implemented in a fixed sequence of interdependent tasks with relatively low overall flexibility and limited room for speeding up the project.

Technology and materials (C3.5)
Debt providers are cautious with regard to unproven construction technologies and building materials (Yescombe, 2018; Laishram & Kalidindi, 2009). This indicator focuses on risks arising from the project’s reliance on technology or materials with limited or negative track record in similar applications.

Factor C4: Ramp-up complexity
Following the completion of the main construction works and before beginning the revenue-generating operations the constructed facility must be fine-tuned to fully meet its performance requirements. Four identified complexity indicators refer to technical risks in this final phase of project implementation.

Amount of systems & equipment (C4.1)
Amounts of electrotechnical, mechanical and IT equipment receive can cause technical performance risks relevant from a credit risk perspective (Moody’s, 2016). This may be related to interfaces between different disciplines and lack of experience with the technology employed, which have been shown as sources of project complexity (Bosch-Rekveldt et al., 2011). The variety of different installations systems that must be installed and tested in combination after the main construction works are completed may cause compatibility issues and cause or deteriorate construction delays in the final stages of the construction phase.

Complexity of systems & equipment (C4.2)
Lack of experience with unproven or innovative installations systems whose installation and fine-tuning in accordance with specified performance standards may only be realised late in the construction phase. This can give rise to the likelihood of additional delays incurred in the final stages of the construction.

Completion requirements complexity (C4.3)
Before a facility is certified as complete, completion requirements must be met. These can be more or less demanding, and the final optimisations can sometimes take place while the project is already available to its users and thus potentially eligible for full availability payments.

Testing time needed (C4.4)
The time required for final testing of the installed equipment before the project is complete may give rise to the performance risks and add to construction complexity from a debt-financing perspective (Moody’s, 2016).
Factor O1: Scope of O&M obligations
The complexity of a project’s operational phase depends on the character of services that need to be delivered to continuously meet the output specifications and performance standards required for availability payments. The specific obligations borne by the borrower according to the project agreement may vary and affect the likelihood of the project successfully meeting its requirements over the concession period. The regular maintenance and facility management services that need to be provided can be distinguished from major lifecycle investments and asset renewals. TDD focus is on technical and organisational risks related to these obligations borne by the borrower according to the project agreement.

Nature of FM / routine maintenance obligations (O1.1)
The character of the borrower’s obligations related to regular maintenance and other service provision may be more or less labour intensive, pose technical risks and uncertainties in scope. These obligations are typically divided into soft and hard facility management (FM) for buildings, and routine and major maintenance for road projects (Yescombe, 2018). This complexity indicator can assess the complexity of regular services obligations borne by the borrower according to the project agreement.

Scheduling complexity (C1.2)
The project agreement must allow sufficient downtime for the performance of maintenance activities (Yescombe, 2018), which can be related to complexity from a debt-financing perspective. This complexity indicator can consider the extent to which the regular obligations enable the performance of maintenance activities while keeping the asset available.

Amount of asset renewal responsibility (O1.3)
Various degrees of responsibility for major asset renewal expenditure may be allocated to the borrower. Where these are prescribed by the project agreement, downtime provisions are usually included (Yescombe, 2018). However, asset renewal obligations in the availability period can constitute a major lifecycle cost, and such project may be considered more complex and require additional focus on this area in TDD.

Predictability of asset renewal needs (O1.4)
Major asset renewal works may have uncertainties in exact timing and scope and affect the reliability of the borrower’s lifecycle costing assumptions. Where the timing, scope and cost of major investments into the asset are unpredictable, a higher complexity may be perceived from a debt-financing perspective.

Technical specialisation required (O1.5)
Highly specialised technology and skills needed to carry out major asset renewal can be considered as indicative of a more complex project.

Factor O2: Performance regime
The project agreement defines the performance criteria, required response and rectification times and performance penalties which are directly related to the project’s cash flows and thus naturally important to lenders.

Onerousness of performance regime (O2.1)
The performance regime must be assessed in terms of its sensitivity to minor fluctuations in the asset’s performance, i.e. how punishable the borrower becomes in case of poor performance. High complexity from a debt-financing perspective may be considered where the performance regime stipulations are very onerous, and credit risk analyses rely on LTA opinion regarding the risk of deductions (Moody’s, 2016).

Factor O3: Technology outlook
As already mentioned, senior debt providers are especially wary of any innovative technology the project relies on. This factor considers the inherent uncertainties as to the adequate long-term performance of the technology installed on the project-financed asset. The technology track record, long-term availability of spare parts and the
built-in redundancy were identified as specific technical features of concern to lenders that may thus act as potential complexity indicators.

**Technology track record (O3.1)**
For key technology on which the asset’s operations rely, the track record in comparable circumstances must be evaluated with a view to predicting its long-term reliability and performance. A technology with extensive positive track record in similar projects is considered as indicative of a lesser inherent risk in credit risk analyses (Fitch, 2018; S&P, 2014).

**Availability of parts and consumables (C3.2)**
This indicator is more forward-looking and assesses the long-term access to spare parts and consumables needed to maintain the operating condition of the technology. For standardised, widely deployed technologies for which off-the-shelf spare parts are available from various suppliers, a low complexity score may be assigned in this indicator, and specialised or innovative technologies at an early phase of deployment would be assessed as very complex.

**Built-in redundancy (C3.3)**
Assets with built-in redundancies are considered to have a lesser technical risk related to the likelihood of underperforming vis-à-vis the operational requirements (Fitch, 2018; S&P, 2014), and could thus be considered simpler. This indicator may capture the extent to which the asset’s operation can resort to built-in redundancies to continue normal operations in case of major downtime of primary equipment.
C1 – Site complexity
C1.1 Reliability of site information
The available information on site condition is very scarce and of questionable quality/reliability and therefore not considered representative of the specific site area. As such, the available information does not provide a good basis for realistic methodology, budget and schedule planning due to serious and critical uncertainties regarding the precise location and scale of unfavourable subsoil phenomena; the solution included in the bid is therefore likely subject to changes following further exploration and mitigation measures after financial close.

C1.2 Complexity of site condition
Site area is known to contain a very diverse set of different site conditions and/or the site encompasses some very difficult, unconventional parts for the project type. AND/OR: Overall industry experience of this type of construction in such environment is limited, exposing the project to technological challenges in dealing with site conditions.

C1.3 Preparatory works needed
Needed preparatory works (e.g. utilities relocation, removal/treatment of contaminated soil, blasting, excavation, pre-loading, tunnelling, waterproofing) are substantial and require specialised methods that have previously caused similar projects’ delays or cost overruns early on in the construction phase.

C1.4 Permits & rights of way
Some key legal procedures regarding permits/rights-of-way are outstanding and need to be completed under the borrower’s responsibility before construction can commence, and the related delays are very likely.

C1.5 Logistical complexity
Very remote and/or physically constrained site clearlylicting major logistical challenges on planning, which are considered unusual for the project type and thus require highly tailored and unconventional approaches.

C2 – Interfaces with environment
C2.1 Amount of construction restrictions
Numerous project-specific restrictions that need to be respected during construction in addition to the basic regulatory restrictions pertaining to construction projects, including e.g. timing of works, nuisance limitations, environmental sensitivities, HSSE rules, etc.

C2.2 Complexity of restrictions
To overcome the project-specific restrictions identified in indicator C2.1, innovative or unproven methods must be used.

C2.3 Dependence on external stakeholders
The borrower’s project planning and implementation is strongly dependent on a high number of various external stakeholders that need to be coordinated actively.

C3 – Solution complexity
C3.1 Level of design completion
The key designs are at a very preliminary level of detail. As such, they allow very limited accuracy of budget planning and construction scheduling which both mainly rely on previous similar designs. This necessitates high cost contingencies and schedule buffers to be included in the plans.

C3.2 Design verifications by client
According to the project agreement, no intermediate or final design verifications are provided by the client, and thus all design risks rest with the borrower.

C3.3 Structure uniqueness
The design has a highly unprecedented character in terms of its dimensions, structural or architectural features.

C3.4 Interdependence of sub-projects
The overall design solution has a very monolithic nature that needs to be implemented in a fixed sequence of very interdependent tasks without opportunities for fast-tracking.

C3.5 Technology & materials
The proposed design relies on one or more construction technologies and/or building materials with a lacking or negative track record in similar projects, posing significant construction risks.

Appendix C – Qualitative complexity scoring scales

Table 15: Applied qualitative complexity scoring scales

<table>
<thead>
<tr>
<th>Complexity factor</th>
<th>Complexity indicator</th>
<th>S = Very complex</th>
<th>3 = Somewhat complex</th>
<th>1 = Very simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 – Site complexity</td>
<td>C1.1 Reliability of site information</td>
<td>The available information on site condition is very scarce and of questionable quality/reliability and therefore not considered representative of the specific site area. As such, the available information does not provide a good basis for realistic methodology, budget and schedule planning due to serious and critical uncertainties regarding the precise location and scale of unfavourable subsoil phenomena; the solution included in the bid is therefore likely subject to changes following further exploration and mitigation measures after financial close.</td>
<td>Available information on site condition is somewhat deficient in terms of either amount or quality of information and does not completely cover the entire surface area of construction site(s). Although it provides a sufficient basis for risk-based methodology, budget and schedule planning, important uncertainties remain regarding the location and scale of some unfavourable subsoil phenomena.</td>
<td>Available information on site condition is of high quality and the scope of underlying investigations rigorously covers most of the surface area of the construction site, providing a well-understood, solid basis for budget and schedule planning taking into account some typical remaining uncertainties. DR: Any and all risks related to unforeseen site condition are comprehensively covered by the grantor/contracting authority as per the project agreement / concession.</td>
</tr>
<tr>
<td>C1.2 Complexity of site condition</td>
<td>Site area is known to contain a very diverse set of different site conditions and/or the site encompasses some very difficult, unconventional parts for the project type. AND/OR: Overall industry experience of this type of construction in such environment is limited, exposing the project to technological challenges in dealing with site conditions.</td>
<td>The site condition has some difficult elements, but these are limited to certain locations with well-defined boundaries and industry-standard methods can be used to address the challenges.</td>
<td>The site condition is simple, uniform and well understood across the whole area concerned. To implement the project, industry-standard methods need to be employed. DR: Any and all risks related to site condition are clearly and objectively covered by the grantor/contracting authority as per the project agreement / concession.</td>
<td></td>
</tr>
<tr>
<td>C1.3 Preparatory works needed</td>
<td>Needed preparatory works (e.g. utilities relocation, removal/treatment of contaminated soil, blasting, excavation, pre-loading, tunnelling, waterproofing) are substantial and require specialised methods that have previously caused similar projects’ delays or cost overruns early on in the construction phase.</td>
<td>Needed preparatory works are substantial (e.g. utilities relocation, removal/treatment of contaminated soil, blasting, excavation, pre-loading, tunnelling, waterproofing) and some may require specialised techniques that have previously led to similar projects’ schedule delays and cost overruns.</td>
<td>Preparatory works needed are very straightforward, nearly negligible in scale, and carried out using exclusively well-known and simple methods.</td>
<td></td>
</tr>
<tr>
<td>C1.4 Permits &amp; rights of way</td>
<td>Some key legal procedures regarding permits/rights-of-way are outstanding and need to be completed under the borrower’s responsibility before construction can commence, and the related delays are very likely.</td>
<td>For acquiring the key permits and rights of way, no responsibility is allocated to the borrower, though some important delays may occur in processing the borrower’s delay and compensation events. Any responsibilities allocated to the borrower are related to limited and straightforward administrative and permitting procedures.</td>
<td>No responsibility for acquiring permits and rights of way is allocated to the borrower. Though delays in the procedures may occur, any related delay and compensation events are expected to be processed in a timely manner based on past experiences with the party responsible.</td>
<td></td>
</tr>
<tr>
<td>C1.5 Logistical complexity</td>
<td>Very remote and/or physically constrained site clearly inflict major logistical challenges on planning, which are considered unusual for the project type and thus require highly tailored and unconventional approaches.</td>
<td>Somewhat remote and/or physically constrained site with moderate logistical challenges solvable with conventional approaches.</td>
<td>Site does not pose logistical challenges neither with respect to its remoteness nor its physical constraints.</td>
<td></td>
</tr>
<tr>
<td>C2 – Interfaces with environment</td>
<td>C2.1 Amount of construction restrictions</td>
<td>The project is subject to several project-specific restrictions that can have a bearing on the schedule or cost of the required tasks, including e.g. timing of works, nuisance limitations, environmental sensitivities, HSSE rules, etc.</td>
<td>During construction, only industry-wide regulatory restrictions apply i.e. those expected to be found in any construction project.</td>
<td></td>
</tr>
<tr>
<td>C2.2 Complexity of restrictions</td>
<td>To overcome the project-specific restrictions identified in indicator C2.1, innovative or unproven methods must be used.</td>
<td>Any project-specific restrictions identified in indicator C2.1 can be overcome using methods that have previously been used successfully to overcome the same type of restrictions in comparable circumstances.</td>
<td>No project-specific restrictions requiring complex solutions.</td>
<td></td>
</tr>
<tr>
<td>C2.3 Dependence on external stakeholders</td>
<td>The borrower’s project planning and implementation is strongly dependent on a high number of various external stakeholders that need to be coordinated actively.</td>
<td>The borrower’s project planning and implementation is dependent on external stakeholders that need to be coordinated actively during construction.</td>
<td>The borrower’s project planning and implementation is not importantly dependent on any external stakeholders.</td>
<td></td>
</tr>
<tr>
<td>C3 – Solution complexity</td>
<td>C3.1 Level of design completion</td>
<td>The key designs are at a very preliminary level of detail. As such, they allow very limited accuracy of budget planning and construction scheduling which both mainly rely on previous similar designs. This necessitates high cost contingencies and schedule buffers to be included in the plans.</td>
<td>The designs are moderately advanced to enable reasonably reliable predictions of costs and schedules provided that adequate contingencies and buffers are included.</td>
<td>The designs are mostly completed and provide a lot of certainty with regards to cost estimates. Key works contracts are already prepared based on these designs whereby the contractors are prepared to take over all major design risks.</td>
</tr>
<tr>
<td>C3.2 Design verifications by client</td>
<td>According to the project agreement, no intermediate or final design verifications are provided by the client, and thus all design risks rest with the borrower.</td>
<td>Most design risk rests with the borrower but initial design inputs and/or intermediate detailed design verifications are provided by the client who thus retains some design risk via clear contractual mechanisms included in the project agreement.</td>
<td>Final, detailed designs are provided as inputs or unequivocally approved by the client prior to construction, and the client thus retains all responsibility for its accuracy and appropriateness using clear mechanisms included in the project agreement.</td>
<td></td>
</tr>
<tr>
<td>C3.3 Structure uniqueness</td>
<td>The design has a highly unprecedented character in terms of its dimensions, structural or architectural features.</td>
<td>The design has some unique elements that make it less conventional for the underlying sector concerned. To implement the project, industry-standard methods need to be employed. DR: Any and all risks related to unforeseen site condition are comprehensively covered by the grantor/contracting authority as per the project agreement / concession.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3.4 Interdependence of sub-projects</td>
<td>The overall design solution has a very monolithic nature that needs to be implemented in a fixed sequence of very interdependent tasks without opportunities for fast-tracking.</td>
<td>The overall design solution is divisible into sub-projects but their interdependence allows only limited opportunities for further fast-tracking and on-the-go flexibility of implementation.</td>
<td>The overall design is easily divisible into independent sub-projects which can be fast-tracked through parallel execution or their repetitiveness throughout the project enables e.g. on-the-go optimisation, (partial) prefabrication, economies of scale, etc. (e.g. all floors with the same layout in a high-rise building, standard bridge design on the whole highway section, etc.)</td>
<td></td>
</tr>
<tr>
<td>C3.5 Technology &amp; materials</td>
<td>The proposed design relies on one or more construction technologies and/or building materials with a lacking or negative track record in similar projects, posing significant construction risks.</td>
<td>Some construction technologies and/or building materials, though simple and standard in construction industry, are not entirely well known as they were not previously tested in the same circumstances.</td>
<td>All construction technologies and building materials have an extensive positive track record in exactly the same circumstances and thus do not pose material risks.</td>
<td></td>
</tr>
</tbody>
</table>
Table 15 (continued): Applied qualitative complexity scoring scales

<table>
<thead>
<tr>
<th>Complexity factor</th>
<th>Complexity indicator</th>
<th>5 – Very complex</th>
<th>3 – Somewhat complex</th>
<th>1 – Very simple</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 – Ramp-up complexity</td>
<td>C4.1 Amount of systems &amp; equipment</td>
<td>Substantial amounts of systems &amp; equipment need to be installed and calibrated after the construction works are completed and before the asset can be fully commissioned.</td>
<td>Somewhat high amounts of systems &amp; equipment need to be installed and calibrated after the construction works are completed and before the asset can be fully commissioned.</td>
<td>No or very limited amounts of systems &amp; equipment need to be installed and calibrated after the construction works are completed.</td>
</tr>
<tr>
<td></td>
<td>C4.2 Complexity of systems &amp; equipment</td>
<td>The equipment that needs to be installed, tested and calibrated on fully built asset is unexceptionally complex for project type, both individually and in terms of interdependencies between different components of the overall system.</td>
<td>Some equipment that needs to be installed, tested and calibrated on the fully built asset is somewhat unexceptionally complex for project type, either individually or in terms of its interdependencies between other components of the overall system.</td>
<td>The equipment that needs to be installed, tested and calibrated on the fully built asset is considerably less complex than what is typically found in similar projects, both individually and in terms of its interdependencies between different components of the overall system.</td>
</tr>
<tr>
<td></td>
<td>C4.3 Completion requirements complexity</td>
<td>Requirements that have to be met to start operations are more stringent and unique than usual for the project type, and/or the requirements are not objectively specified.</td>
<td>Requirements that have to be met to start operations are either not entirely normal for the project type or contain some more stringent elements; the criteria are specified in a clear and measurable way.</td>
<td>Requirements that have to be met to start operations are limited in scope and simpler than usual for the project type and the relevant criteria are specified clearly.</td>
</tr>
<tr>
<td></td>
<td>C4.4 Testing time required</td>
<td>Unusually extensive time required for testing before completion.</td>
<td>Relatively long time required for testing before completion.</td>
<td>No or very short testing time required before completion.</td>
</tr>
<tr>
<td>O1 – Scope of O&amp;M obligations</td>
<td>O1.1 Nature of FM / routine maintenance obligations</td>
<td>Most FM obligations are complex and require specialised skills; or FM services obligations’ success depends on the condition of legacy equipment for which there are material risks which are fully allocated to the borrower as per project agreement. Most FM services are considered critical as the asset’s normal operation directly depends on them.</td>
<td>Some of the borrower’s FM services obligations are complex and require specialised skills or equipment; legacy equipment is very limited and its condition is well understood. Some FM services are critical to the asset’s normal operation.</td>
<td>Services to be provided by the borrower are limited to very basic and foreseeable operation and maintenance. All FM services are simple as the asset’s normal operation is not directly dependent on them.</td>
</tr>
<tr>
<td></td>
<td>O1.2 Scheduling complexity</td>
<td>FM services have very challenging timing requirements and/or the asset’s use/occupation patterns offer very limited timing windows for the required services.</td>
<td>Some FM services have somewhat challenging timing requirements such as 24/7 service provision; or the asset’s use/occupation pattern offers somewhat limited timing windows for some of the required FM services.</td>
<td>No challenging timing requirements (e.g. 24/7 O&amp;M services) for any of the FM services to be provided.</td>
</tr>
<tr>
<td></td>
<td>O1.3 Amount of asset renewal responsibility</td>
<td>Borrower assumes all asset renewal obligations which constitute a major lifecycle cost item, and/or the project agreement has very stringent handback criteria.</td>
<td>Part of obligations related to asset renewal needs is allocated to the borrower in the project agreement and/or the project agreement has somewhat stringent handback criteria.</td>
<td>All obligations related to asset renewal needs are retained by the off-taker as clearly indicated by the project agreement.</td>
</tr>
<tr>
<td></td>
<td>O1.4 Predictability of asset renewal needs</td>
<td>The timing, scope and cost of asset renewal obligations are highly unpredictable due to the unexceptionally complex design or high presence of acquired asset components.</td>
<td>Somewhat unpredictable asset renewal obligations related to a somewhat complex newly built and/or some acquired asset components.</td>
<td>Newly-built asset with very simple and well-proven design solution, consequently highly predictable timing, cost and scope of asset renewal needs.</td>
</tr>
<tr>
<td></td>
<td>O1.5 Technical specialisation required</td>
<td>Asset renewal will require highly specialised technology, works and services across the supply chain.</td>
<td>Somewhat specialised technology or skill required for asset renewal.</td>
<td>Any reasonably expected asset renewal requires very limited technical specialisation.</td>
</tr>
<tr>
<td>O2 – Performance regime</td>
<td>O2.1 Onerousness of performance regime</td>
<td>Performance regime is onerous in that any poor performance is punished substantially, and performance requirements are difficult to meet.</td>
<td>The performance regime contains requirements seen as possibly challenging to a less experienced contractor.</td>
<td>Performance regime is very benign in that poor performance is unlikely to result in deductions.</td>
</tr>
<tr>
<td>O3 – Technological outlook</td>
<td>O3.1 Technology track record</td>
<td>Poor technology track record in similar applications; or technology is too new to reliably predict its long-term performance required in the specific asset.</td>
<td>Technology track record is generally positive but raises some limited but specific concerns regarding the longevity of technology or its performance in specific circumstances.</td>
<td>Extensive, positive technology track record in similar applications with comparable asset operational life.</td>
</tr>
<tr>
<td></td>
<td>O3.2 Availability of parts and consumables</td>
<td>Specialised and not widely deployed technology giving rise to uncertainty regarding the future availability of spare parts and consumables.</td>
<td>For some of the asset’s non-key spare parts and consumables, future availability is somewhat uncertain.</td>
<td>All technology being standardised and widely applied in similar assets; availability of parts and consumables is and will remain high from both original manufacturers and third-party suppliers.</td>
</tr>
<tr>
<td></td>
<td>O3.3 Built-in redundancy</td>
<td>The asset has no built-in redundancies and realistic failure paths would lead it into serious performance deficiencies.</td>
<td>The redundancies built into the asset are standard for the industry offering no additional reassurance for meeting performance in case of failures.</td>
<td>Extensive redundancies are built in the asset offering reassurance that operation in line with requirements can continue in case of technology failures.</td>
</tr>
</tbody>
</table>
Appendix D – Structure of the BWM-based questionnaire

Instructions for filling out the questionnaire

At each of the following eight sheets, one of the subsets of factors and/or indicators (see table in the Figure below) is displayed first. You are then asked four multiple-choice questions regarding this subset of complexity indicators.

On all sheets, the four questions are marked in yellow. The cells where you must select your answer from the drop-down menu are marked in green.

In Question 1 and Question 2, you are asked to select the factor/indicator you consider the most and least important, respectively, based on your sector experience.

Select the green cell with your mouse.

Click on the arrow to show drop-down menu and select a predefined answer.

In Question 3, you are asked to indicate the importance of the selected “most important” item (that appears in the left column) as compared to each of the “other” items listed in the right column.

Here, the green cells again indicate where your input is required. All green cells contain a drop-down menu when they are clicked; you can select one option from the drop-down menu. Please note that all non-green cells in Question 3 are filled out automatically based on your choices in Questions 1 and 2.

Your input, using the drop-down menus, is needed in each of these cells.

In Question 4, you are asked to indicate the importance of each of the “other” items listed in the left column as compared to the selected “least important” item that appears in the rightmost column.

Here, the green cells again indicate where your input is required. All green cells contain a drop-down menu when they are clicked; you can select one option from the drop-down menu. Please note that all non-green cells in Question 3 are filled out automatically based on your choices in Questions 1 and 2.

Your input, using the drop-down menus, is needed in each of these cells.

Some information on the underlying method:

In this study, we use a state-of-the-art Multi-Criteria Decision Making method called “Best-Worst Method” (developed by Dr. J. Rezaei, 2015, see links below) to calculate the weights indicating the relative importance of the various factors included in the complexity evaluation model. The strength of the method compared to similar methods is in substantially reducing the amount of needed pairwise comparisons while improving the consistency of the results; your time needed to fill out the questionnaire is therefore kept to a minimum. The method is applicable for various uses where multi-faceted concepts need to be quantified. For more information, follow the links below:

http://bestworstmethod.com/

Figure 18: Instructions to BWM-based questionnaire users.
**Pre-completion phase complexity**

Pre-completion phase complexity consists of four complexity factors as shown in the table below. Each of the four factors is further subdivided into 3-5 complexity indicators as shown in the next Sheets.

<table>
<thead>
<tr>
<th>Complexity in pre-completion phase</th>
<th>Indicator</th>
<th>Preparatory works needed</th>
<th>Complexity of site condition</th>
<th>Reliability of site information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistical complexity</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Preparatory works needed</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Complex site condition</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Reliability of site information</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**Problem complexity**

Solutions complexity involves five indicators as shown in the table below.

<table>
<thead>
<tr>
<th>Solution complexity</th>
<th>Indicator</th>
<th>Preparatory works needed</th>
<th>Reliability of site information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure uniqueness</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Interdependence of sub-projects</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Technology &amp; materials</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Technology &amp; materials</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Technology &amp; materials</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**Site complexity**

The factor ‘Site complexity’ entails five indicators as shown in the table below.

<table>
<thead>
<tr>
<th>Site complexity</th>
<th>Indicator</th>
<th>Preparatory works needed</th>
<th>Reliability of site information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness of site condition</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Preparatory works needed</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Completeness of site condition</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Preparatory works needed</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Completeness of site condition</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**Ramp-up complexity**

The factor ‘Ramp-up complexity’ entails four indicators as shown in the table below.

<table>
<thead>
<tr>
<th>Ramp-up complexity</th>
<th>Indicator</th>
<th>Preparatory works needed</th>
<th>Reliability of site information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of systems &amp; equipment</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Completion requirements</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Interdependence of systems &amp; equipment</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Testing time needed</td>
<td>Interfaces with environment</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**Figure 19: Examples of individual sections of the questionnaire**
Appendix E – BWM inputs analysed per respondent

<table>
<thead>
<tr>
<th>Complexity element</th>
<th>Answer 1</th>
<th>Answer 2</th>
<th>Answer 3</th>
<th>Answer 4</th>
<th>Answer 5</th>
<th>Average weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOST vs. OTHERS</td>
<td>0.48</td>
<td>0.30</td>
<td>0.26</td>
<td>0.29</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>MOST vs. LEAST</td>
<td>0.30</td>
<td>0.25</td>
<td>0.26</td>
<td>0.29</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>OTHERS vs. OTHERS</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Figure 20: Respondents' inputs and BWM analysis results for project type "highways"

<table>
<thead>
<tr>
<th>Complexity element</th>
<th>Answer 1</th>
<th>Answer 2</th>
<th>Answer 3</th>
<th>Answer 4</th>
<th>Answer 5</th>
<th>Average weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOST vs. OTHERS</td>
<td>0.10</td>
<td>0.06</td>
<td>0.06</td>
<td>0.02</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>MOST vs. LEAST</td>
<td>0.05</td>
<td>0.02</td>
<td>0.02</td>
<td>0.07</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>OTHERS vs. OTHERS</td>
<td>0.07</td>
<td>0.02</td>
<td>0.02</td>
<td>0.07</td>
<td>0.02</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Figure 21: Respondents' individual inputs and BWM analysis results for project type "buildings"