International Transport Forum

Collaborative Infrastructure Procurement in Sweden and the Netherlands

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Foreword

Transport infrastructure is a major enabler of economic development. In the drive to refurbish or build, governments worldwide have turned to the private capital market for financing. The primary narrative behind this push is the huge stocks of private capital that are available, while public financing capabilities are said to be limited and insufficient.

The almost exclusive vehicle of private investment in transport infrastructure, including social infrastructure, is public-private partnerships (PPPs). In the context of PPPs, two important aspects have received little attention.

First, sufficient attention has not been given to the role of suppliers. The focus of governments and Intergovernmental Organisations has been on resolving the challenges to private investment from the viewpoint of investors: reducing the uncertainty they face and enabling them to price risk more efficiently by establishing infrastructure as an asset class.

However, looking only at investors gives an incomplete view of the total cost of the risk transferred from the public to the private sphere. In PPPs, investors transfer some of the major risks they are not comfortable bearing to design, construction, maintenance, and operations contractors.

Suppliers, too, face uncertainties and are unable to efficiently evaluate price risk. In such cases, the base cost of the initial investment – and of subsequent services – may be much higher than they might have been, and not just the cost of their financing.

Uncertainty arises from the difficulty of accurately estimating the cost of construction, maintenance, operations, and financing. But it also stems from "unknown unknowns" (the so-called Knightian uncertainty). For instance, changes in weather patterns or paradigmatic technological shifts, the timing and impact of which are unclear, will influence what infrastructure is needed and where.

So what can policy makers do to reduce the cost of inefficient risk pricing of suppliers? Where does this put PPPs? How can public decision makers reconcile long-term uncertainty with private investment in infrastructure? Who should bear long-term uncertainty in projects: the public or the private sector?

These were some of the guiding questions for a Working Group of 33 international experts convened by the International Transport Forum (ITF) in September 2016. The group, which assembled renowned practitioners and academics from areas including private infrastructure finance, incentive regulation, civil engineering, project management and transport policy, examined how to address the problem of uncertainty in contracts with a view to mobilise more private investment in transport infrastructure. As uncertainty matters for all contracts, not only those in the context of private investment in transport infrastructure, the Working Group's findings are relevant for public procurement in general.

The synthesis report of the Working Group was published in June 2018. The report is complemented by a series of 19 topical papers that provide a more in-depth analysis of the issues. A full list of the Working Group's research questions and outputs is available in Appendix 2.

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Abbreviations and acronyms

BAM	Royal BAM Group (Netherlands)
CD	competitive dialogue
DB	design-build
DBB	design-bid-build
DBFM	design-build-finance-maintain
DBM	design-build-maintain
ECI	early contractor involvement
EIB	European Investment Bank
EMVI	*economisch meest voordelige inschrijving* (most economically advantageous tender)
EPC	engineering, procurement and construction
ICE	Integrated Concurrent Engineering
IPM	Integrated Project Management
LCC	life-cycle costing
NPV	net present value
R&D	research and development
PBO	project-based organisation
PPP	public-private partnership
RAB	regulated asset base
RWS	Rijkswaterstaat (the Netherlands)
SPC	special-purpose company
STA	Swedish Transport Administration
TCE	transaction cost economics
TEST	track, electricity, signalling and telecommunication
ToR	terms of reference
TQM	total quality management

Executive summary

What we did

Traditional contracting procedures in construction involve competitive tendering based on detailed fixed-price contracts and subsequent control and monitoring of conformance, often referred to as *arms-length* relationships. However, because change is inevitable in large-scale complex infrastructure projects, traditional procurement strategies may often be ineffective. Hence, relational contracting and collaborative procurement strategies may be more suitable to facilitate collaboration and manage unforeseen events in complex projects. The purpose of this paper is to investigate and compare how different types of collaborative procurement strategies may enhance project actors' collaboration and their possibilities and incentives for improved efficiency and innovation in infrastructure projects. It also identifies and discusses challenges and perceived barriers to implementing these strategies.

Four types of procurement strategies have been investigated, described and compared: 1) collaborative design-build (DB) contracts, 2) early contractor involvement (ECI), and 3) long-term integrated contracts based either on design-build-maintain (DBM) contracts or 4) design-build-finance-maintain (DBFM) contracts. In total, ten infrastructure projects in Sweden (two DB, two ECI and three DBM) and the Netherlands (three DBFM) are investigated and compared. Empirical data is primarily based on interviews with managers and other key actors (foremost clients and contractors).

What we found

Collaboration is a multi-dimensional phenomenon that can be described through four dimensions: scope, depth, duration and intensity. *Scope* encompasses the number of companies and actors involved in collaboration. *Depth* refers to how many hierarchical levels and different functions and roles within the companies are involved in collaboration. *Duration* relates to how long the actors collaborate. *Intensity* regards how much and how actively the actors collaborate. Our findings indicate that the collaborative procurement strategies influence the four dimensions of collaboration in different ways, which in turn affects efficiency and innovation.

We found that increased collaboration *scope* can have positive and negative effects on both efficiency and innovation. Broader collaboration in terms of involvement of key actors, such as design consultants and central subcontractors, may improve efficiency-related aspects, such as joint decision-making and problem-solving, in all types of contracts. Furthermore, involving a private funder in DBFM improves efficiency in terms of more robust and verified material and technical solutions to reduce risk. A stronger focus on revenues from the private funder also puts pressure on keeping the time schedule and encourages early project delivery. However, the involvement of a private funder in DBFM may also hamper more radical innovation, since this actor is often reluctant to accept higher levels of risk.

Findings linked to the *depth* dimension indicate that collaboration among different internal functions and hierarchical levels may be difficult to achieve but, if successful, may result in improved and quicker decision making and more innovation. In our projects, it proved to be valuable to include not only managerial staff, but also technical experts and operational staff. A specific example is the integration of contractors' maintenance competences in the design stage of DBM and DBFM contracts, which improves

maintainability. However, a significant amount of experience with these integrated project types is often required in order to establish an organisational culture that supports this way of working.

Prolonged collaboration *duration* was mainly achieved through early involvement of contractors and/or long-term maintenance responsibilities. Findings from all four types of contracts indicate that early involvement of contractors in the design stage may improve efficiency by improved constructability, but it can also reduce delivery time due to parallel design and construction processes. Early involvement also provides contractors with improved possibilities for innovation, because of fewer restrictions in the tendering documents and more time for development efforts before construction starts, in comparison to traditional design-bid-build (DBB) contracts. A drawback of early involvement in DB, DBM, and DBFM contracts is that it generally increases costs for contractors' tendering (due to extensive design and cost estimation), whereas very early involvement in ECI contracts may reduce tendering costs. Long-term maintenance responsibilities have both pros and cons. On the one hand, they encourage a stronger focus on quality and life-cycle costing (LCC) and enable innovation that reduces LCC and contractors' maintenance costs. On the other hand, they deter radical innovation due to the risk of malfunctions and costlier maintenance. Furthermore, DBM and DBFM contracts often reduce efficiency and economies of scale during maintenance, compared with large-scale maintenance contracts. None of the cases studied included long-term contracts over a series of projects, and in the interviews it was indicated that exploitative inter-project learning and knowledge-sharing across similar projects was relatively limited. Many of the studied projects can be regarded as pilot projects, where the strategies and the resulting behaviours and processes were new to the project actors and the organisations. Still, knowledge transfer was not systematised and there was a lack of continuous improvements, hampering efficiency.

Collaboration *intensity* was positive for both efficiency and innovation. Specifically, collaboration based on co-location of project actors in joint office premises results both in faster development processes and faster and improved joint decision making. Furthermore, open-book administration and joint performance management systems increase the quality of communication while decreasing the administrative load. However, improving collaboration intensity, as well as scope and depth, costs time and money. Hence, investments in collaborative activities and technologies must match project size and needs.

What we recommend

Adopt a long-term learning perspective when developing and implementing new strategies

Integrated contracts enabling collaboration and flexibility have important advantages and may sometimes be the only option. All the models studied also have limitations and entail risks, however. In particular, implementing new procurement strategies involves organisational change and learning for all the main actors, not least the client organisation. Public clients of infrastructure projects often need to improve their knowledge about how procurement strategies can be selected, designed and implemented to enhance efficiency and innovation.

Establish routines for inter-project learning and knowledge sharing

Major potential efficiency improvements and innovation are possible depending on the chosen procurement strategies. These improvements are not automatically achieved, however. It may be very challenging to reap all potential benefits of collaboration – and all actors thus need to continuously improve their processes, routines and capabilities for managing collaborative projects.

Introduction

This paper discusses and compares how four different types of collaborative procurement strategies may enhance the possibilities and incentives for improved efficiency and innovation in the infrastructure sectors of Sweden and the Netherlands. The paper draws on empirical data collected in a multiple-case study of 10 infrastructure projects in those countries.

Background

The socio-economic importance of well-managed investments in infrastructure projects is well understood and can hardly be overstated (OECD, 2011, 2015; WEF, 2012). Many reports have allegedly highlighted an "infrastructure gap"; that is, the current and planned investments in infrastructure do not cover future needs (e.g., OECD, 2011; 2015). The potential gap is associated with two main challenges: 1) raising and allocating sufficient investment funds to increase the rate of infrastructure construction, and 2) getting greater value from the invested money by improving efficiency and innovation. The first challenge may be addressed by bringing private investments into the infrastructure sector through public-private partnership (PPP) projects. This topic is discussed in several papers of this ITF working group (see Appendix 2), including a synthesis document (ITF 2018). The present paper, however, focuses on the second challenge, that is, how to improve efficiency and innovation in infrastructure projects, although private investments are discussed and present in some of the studied projects.

Many previous studies have shown that infrastructure projects are often plagued by efficiency problems in terms of cost and time overruns (Cantarelli et al., 2012; Flyvbjerg, 2009; Han et al., 2009; Winch, 2013). Other studies have indicated a lack of innovation and adoption of new technology in the infrastructure sector (Rose and Manley, 2012, 2014; Tawiah and Russell, 2008). In project-based organisations (PBOs), such as client and contractor organisations in the infrastructure sector, innovation may be pursued either in separate research and development (R&D) projects and/or in regular business projects (Keegan and Turner, 2002; Bosch-Sijtsema and Postma, 2009; Eriksson, 2013). In general, and in comparison to other industries, the R&D expenditures are low in the construction industry (Miozzo and Dewick, 2004; Reichstein et al., 2005). Hence, there is a risk that the need for innovation is not addressed fully through R&D projects. Accordingly, many clients may need to pursue innovation in their regular infrastructure projects too (Eriksson, 2013).

In an extensive report, the World Economic Forum emphasises that the infrastructure sector (and the construction industry as a whole) needs to go through a transformation to deliver more sustainable development, based on both continuous development to enhance short-term efficiency and more radical innovation to increase long-term productivity (WEF, 2016). Similar to these arguments, the Swedish government has given the Swedish Transport Administration (STA) the strategic task of improving productivity and innovation in the infrastructure sector. STA has therefore been going through a strategic change process (called *Renodlad Beställare*, directly translated as "Pure Client") that was initiated 2012, in which the client organisation, i.e. the procuring entity, strives to leave more responsibilities and freedom to the supply market (Ek Österberg, 2016).

Problem discussion

The core characteristics of the infrastructure sector (and its supply market) are that it is project-based and fragmented, often resulting in short-term and arms-length relationships among key actors in temporary projects. However, due to the inter-organisational nature and inherent complexity of infrastructure projects, innovations are often systemic and require knowledge integration and collaboration across different actors and their activities (Kähkönen, 2015; Rose and Manley, 2012). Furthermore, short-term and arms-length relationships result in learning curves, which are disruptive or detrimental to efficiency (Eriksson, 2013). Many reports have therefore recognised that inter-organisational collaboration is a core mechanism for improving efficiency and innovation (WEF, 2016; Egan, 1998; Latham, 1994).

Traditional contracting procedures involve competitive tendering based on detailed and strict contracts and subsequent control and surveillance of conformance in arms-length relationships (Gil, 2009). However, change is inevitable in complex infrastructure projects. Recent studies accordingly advocate that complex projects need new types of project management practices, promoting flexible management of change by collaborative teams rather than *ex ante* planning and control by a project manager (Gransberg et al., 2013; Koppenjan et al., 2011; Williams, 2005). Gil (2009) therefore argues that the traditional procurement strategies based on competitive tendering and extensive control are ineffective in large-scale complex infrastructure projects. Contrastingly, relational contracting based on collaborative procurement strategies is more suitable because it enhances the collaboration and flexibility required to manage unforeseen events in complex projects (Gil, 2009). Accordingly, it seems relevant to increase our knowledge about how collaborative procurement strategies may improve collaboration among project actors – and, in turn, multiply their opportunities and incentives to improve efficiency and innovation in infrastructure projects.

Purpose and research approach

The purpose of this paper is to investigate and compare how different types of collaborative procurement strategies may enhance project actors' collaboration and their possibilities and incentives for improved efficiency and innovation in infrastructure projects. Furthermore, challenges and perceived barriers to implementing these strategies will be identified and discussed. Four types of collaborative procurement strategies will be investigated, described and compared: 1) collaborative design-build (DB) contracts, 2) early contractor involvement (ECI) based on consultancy contracts during the design stage, and 3) long-term integrated contracts based either on design-build-maintain (DBM) contracts or 4) design-build-finance-maintain (DBFM) contracts. In total, 10 infrastructure projects in Sweden and the Netherlands are investigated and compared. The three first types of strategies are used by the Swedish Transport Administration (STA) and the fourth type, which is a type of PPP contract that includes private financing, is used in the Netherlands by Rijkswaterstaat (RWS), the executive agency of the Ministry of Infrastructure and the Environment.

Theoretical frameworks

Efficiency and innovation from an organisational learning perspective

Since the publication in 1991 of a seminal article by J. March, the organisational learning literature has typically distinguished between two main learning modes: exploration and exploitation (March, 1991). Eriksson et al. (2017a) emphasise that *explorative* learning involves a distant search for, and assimilation of, new knowledge and technologies to enhance creativity and to achieve innovation and radical development of new solutions. *Exploitative* learning instead involves a local search for familiar knowledge and technologies to deepen the current knowledge set and achieve efficiency through incremental development and continuous improvements to existing solutions (Eriksson et al., 2017a). Accordingly, exploration is generally associated with terms such as adaptability, flexibility, risk-taking, distant search, experimentation, long-term orientation, radical development, and innovation. In contrast, exploitation is associated with refinement, control, local search, efficiency, short-term orientation, and incremental development (Andriopoulos and Lewis, 2010; Junni et al., 2013; March, 1991).

Due to their inherent differences, these two learning modes are difficult to combine and manage together, especially in organisational settings with scarce resources (Gupta et al., 2006), such as project organisations. However, prior research has indicated that in projects both short-term efficiency based on exploitation and more-radical innovation based on exploration can be facilitated by inter-organisational collaboration (Eriksson, 2013; Eriksson et al., 2017a). Construction projects are often complex and uncertain endeavours that require explorative learning to manage innovation and adaptation challenges. In addition, the systemic nature of innovations and technology development in construction entails the coordination of numerous interdependent components and sub-systems. Various project actors, therefore, need to collaborate in joint development processes (Bosch-Sijtsema, 2009; Ozorhon, 2013). Construction projects also benefit from exploitative learning to achieve efficient use of limited resources. Enhanced efficiency through exploitation may result from both 1) continuous improvements and fine-tuning of existing solutions and 2) knowledge-sharing and diffusion of technical solutions across projects. In construction, knowledge is often context-specific, which makes it difficult to transfer across projects due to varying personal, professional and organisational interests (Bresnen et al., 2003).

Construction procurement from a transaction cost economics perspective

The literature on inter-organisational relationships and procurement has been strongly influenced by transaction cost economics (TCE) (e.g., Williamson, 1985, 1998). Transaction costs are costs for specifying, monitoring and enforcing contracts in order to prevent supplier opportunism. According to TCE, the greater the transaction uncertainty and uniqueness and the lower the transaction frequency, the higher the transaction costs. The main argument in TCE is that procurement and contracting strategies should be tailored to transaction characteristics in order to minimise the sum of transaction and production costs.

Transactions can mainly be governed within three different structures: market, hierarchy, and an intermediate hybrid structure. *Hierarchy* means that the transaction is performed in-house (i.e., intra-organisational transaction), which is suitable for transactions with high frequency and uncertainty that

demand very high and specialised knowledge or other transaction-specific investments that cannot be used for other purposes. In such cases, potential economies of scale through market-based competition are limited and there is, therefore, no point in procuring from external suppliers (Williamson, 1975).

In contrast, *market* governance implies procurement from an independent supplier where low production costs based on economies of scale are achieved by competition. This is most suitable for simple transactions with low uncertainty where standardisation and mass-production make adaptation and transaction-specific investments redundant (Williamson, 1975). In market governance, the identities of the suppliers are assumed to be irrelevant because all suppliers have comparable competences, technologies and products (Macneil, 1978).

The *hybrid* form of governance includes a wide range of semi-hierarchical and collaborative arrangements, such as long-term contracts, networks, partnerships, and alliances (Blois, 2002; Eriksson, 2006). The hybrid structure may be divided into two main forms: bilateral and trilateral hybrids. Of these, the *trilateral* hybrid involves contracts based on detailed specifications of how a range of possible future contingencies should be handled. These contracts rely on third-party assistance to determine performance and resolve disputes, while the *bilateral* (or relational) governance is based on private ordering, considering how the relationship has evolved over time, not only the original contract (Macneil, 1978; Williamson, 1998). Accordingly, the bilateral hybrid is more collaborative than the trilateral, because conflicts are managed jointly in bilateral relationships. The hybrid is most efficient for transactions that require rather high and specific knowledge, for which contractual safeguards are demanded (Williamson, 1991). Trilateral governance chiefly involves short-term relationships in occasional transactions, while bilateral governance involves long-term relationships in recurrent transactions and/or transactions with very long duration (Williamson, 1985; Eriksson, 2006).

TCE has received criticism for being too simplistic and merely describing which governance structure to use, not how to design and implement it at a more detailed level (Eriksson, 2006). Accordingly, it is important to increase the understanding of how procurement strategies can be designed and combined to create a suitable governance structure. The idea of applying different governance structures for different transaction characteristics is relevant also in the construction project context, where every project is considered unique and entails different characteristics. Here, the detailed specifications, close monitoring and frequent negotiations of contractual changes in traditional construction contracts are the main transaction costs. Classic research contributions using a TCE perspective in the construction context are Eccles (1981), Reve and Levitt (1984), Stinchcombe (1985) and Winch (1989). A general conclusion from these studies is that the high uncertainty and unique relations lead to high transaction costs for preventing contractor opportunism. Hierarchy is only an option where there is high transaction frequency, which is why many public infrastructure clients historically have had in-house design and construction departments. Today, however, also these clients procure their construction services from external suppliers based on extensive contracts. From a TCE perspective, where economic self-interest is seen as the main human motivator, transaction costs can be reduced only by increasing the contractor's economic incentives to cooperate. This can be done by increasing relationship lengths, sharing risks and rewards in collaborative agreements, or increasing the importance of reputation and cooperative skills in relation to price in contractor procurement.

Tailoring procurement strategies to project characteristics: A procurement model

In order to provide a simplified framework, practitioners can use to tailor procurement strategies to project characteristics, one of the authors has developed a procurement model (see Table 1), which is based on the TCE framework (Eriksson and Hane, 2014; Eriksson et al., 2017b). The model consists of a three-by-four matrix, where the three-part column structure resembles the three inter-organisational governance structures in TCE, that is, market (here “competition”), trilateral hybrid (“competition and cooperation”), and bilateral hybrid/relational contracting (“cooperation”). The four rows describe four procurement strategy components that can be combined to form a governance structure: 1) the delivery system and the nature (e.g., point in time) of the contractor involvement; 2) the reward system; 3) the contractor selection procedures (bid invitation and bid evaluation); and 4) the collaboration model (i.e. collaborative tools and activities). The different components may be combined in different ways – not only within a certain column but also across columns – in order to achieve a governance structure that fits project characteristics.

Table 1. Procurement model based on four procurement strategy components

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

STA’s client organisation decided to adopt this procurement model, and since 2017 it has underpinned their procurement guidelines for infrastructure projects and maintenance contracts. Because this study focuses on infrastructure projects procured by STA and RWS, this procurement model can serve as a theoretical framework guiding the analysis of empirical data. The model is based on the assumption that in simple and standardised projects with low uncertainty, procurement strategies can be designed to focus on competition in market-like and arms-length relationships (i.e., to the left in the model), whereas more-challenging projects characterised by complexity, customisation, and uncertainty require more-collaborative procurement strategies to coordinate actors and their actions in bilateral relationships (i.e., to the right in the model) (Eriksson and Hane, 2014).

Four procurement strategy components

Delivery system

In recent years, STA has increased their use of design-build (DB) contracts to promote improved productivity and the contractors' opportunities for innovation (Ek Österberg, 2016). The basic idea of DB contracts (as compared to design-bid-build, or DBB, contracts) is that there is no separation between design and construction that hampers constructability and the contractor has more freedom to develop technical solutions that improve time and cost efficiency. DB contracts also result in one less procurement process and allow the contractor to begin construction work before the detailed design is finished, which saves time due to an earlier construction start and parallel processes (Cheung et al., 2001). However, neither DB nor DBB contracts promote collaboration between the client and the contractor as they separate, allocate, and clarify the actors' different responsibilities, which make the contracts more transparent (Eriksson et al., 2017a). In traditional DBB or DB contracts, there is no collaboration during the design stage because either the client or the contractor is responsible for the design.

To promote more client-contractor collaboration in a DB contract, the client may engage more explicitly in the design stage by adopting an advisory role, while the contractor keeps the main responsibility (Eriksson and Hane, 2014). This client involvement enhances joint development and problem-solving, which may be critical to improving customisation and product quality (Eriksson, 2017).

A more collaborative strategy is to use early contractor involvement (ECI), where a two-phase approach is adopted. *ECI* is a term that has been used with different meanings in different contexts and countries. The most influential model is the two-phase contracting model used in the UK and associated with a specific set of standard contracts. In this approach, the contractor is procured early, based primarily on soft criteria, to develop the design in collaboration with the client and consultants in Phase 1. In parallel with the design, a mutually agreed target cost is calculated. After this, the client may choose to activate a contractual option for engaging the same contractor for Phase 2, which is the detailed design and construction stage. Often, the target cost is combined with open books and a gain/pain-sharing incentive mechanism. If the two parties do not agree on a target cost, or if other terms of the option are not met, the client may decide not to proceed to the second phase with the contractor. An ECI project engages the contractor earlier than a DB contract normally would. In the Swedish ECI model, contractors are involved based on cost-reimbursable consultancy contracts in Phase 1; for Phase 2, either a DB or a DBB contract may be used (Eriksson and Hane, 2014). The ECI approach is suitable when the uncertainty is too high to calculate a price in the tendering stage and the client sees important benefits in involving the contractor in very early design stages to integrate design and production knowledge.

DB contracts may also be integrated with maintenance services. Contractors are then responsible for design, building, and maintenance – that is, DBM contracts. Such integrated contracts may also include private funding by the contractor or a consortium, in which the contractor participates. Potential advantages associated with private funding in PPP projects include not only gaining access to additional funding of infrastructure investments but also improving efficiency and innovation (e.g., OECD, 2011; 2015; Leiringer, 2006; Roumboutsos and Saussier, 2014). In the Netherlands, PPP projects are performed through DBFM contracts, in which contractors are responsible for designing, building, financing and maintaining a piece of infrastructure. In recent years, DBFM contracts have become the standard for complex projects at the national level in the Netherlands (Lenferink et al., 2013; Verweij, 2015).

Reward system

Traditionally, fixed-price payment has been most common in both DB and DBB contracts when the client wants to ensure that the lowest price is obtained through competitive tendering (Eriksson et al., 2017b). A fixed price is suitable when uncertainty is low and it is possible for 1) the client to provide bidders with complete and detailed tendering documents and 2) the contractors to calculate bid prices with low-risk premiums (Bajari and Tadelis, 2001). In simple projects with low uncertainty, fixed-price payment gives the contractor an incentive to be cost efficient and to innovate with the purpose of saving costs. However, this reward system is a poor basis for collaboration as the client has no incentive to support the contractor in cost-saving development work and the contractor has an incentive to lower the quality of the end product if it reduces costs (Ballebye Olesen, 2008; Eriksson and Hane, 2014). In addition, any changes the client wants to implement are priced in a monopoly situation and may result in difficult discussions or even conflicts about price adjustments, ultimately resulting in distrust (Kadefors, 2004; 2005).

Strategies that are based on cost reimbursement together with economic incentives connected to a target cost enhance a focus on both competition and cooperation (Eriksson and Hane, 2014). Incentive-based payment can enhance project actors' motivation for joint innovation work and is therefore suitable when contractors are procured early and involved in the design stage (Rose and Manley, 2012). However, failure to incentivise contractors for other aspects than project cost savings can result in sub-optimisations, such as poor quality and increased life-cycle costs (Rose and Manley, 2012). Hence, it is important to connect bonuses to other aspects than merely the project's target cost. Although incentive-based payment is a better basis for early involvement than fixed price, it is not suitable when the uncertainty is too high to calculate a valid target cost. In such cases, and when clients want to implement changes, difficult discussions on target cost adjustments may arise, similar to those in fixed-price contracts (Boukendour and Hughes, 2014; Kadefors and Badenfelt, 2009).

Because cost reimbursement provides the client with strong opportunities for flexibility and change in project scope and content, it is, therefore, suitable when uncertainties are very high and the client wants to involve contractors and their production competences very early. To provide the contractors with incentives for improvements regarding other aspects than pure cost efficiency, cost reimbursement may be used together with bonus opportunities connected to "softer" aspects such as quality, collaboration, milestones, work environment, and environmental impact (Love et al., 2011). Such bonus opportunities set the basis for collaborative work regarding these aspects.

Contractor selection

Lowest-bid competitive tendering is based on the idea that a large number of bidders who compete on the basis of price will ensure that the client can minimise its investment costs for the project. This procurement strategy may work satisfactorily in rather simple and straightforward projects with low uncertainty, where 1) the competences and experiences of the contractors are of little importance and 2) the bid price will remain close to the end price due to lack of changes. However, public clients often use this strategy also in more complex projects due to a fear of appeals when using "softer" criteria (Eriksson et al., 2017b; Sporrong and Kadefors, 2014). A drawback of focusing on the lowest price is that "it generates an emphasis on short-term benefits by taking into account investment costs rather than long-term life cycle costs and innovation" (Eriksson, 2017: p. 217).

In more complex and uncertain projects, the identities and capabilities of the bidders become more important, because all potential bidders may not be capable of carrying out the project. From a relational contracting perspective, bidders then need to be pre-qualified and/or evaluated based on their

competences and capabilities, not only their bid price. A strategy that is based on pre-qualification of a lower number of capable contractors and subsequent bid evaluation that also takes into account “softer” criteria (e.g. organisation, experience, reference projects, etc.) may enhance a focus on both competition and cooperation (Eriksson et al., 2017b). Such partner selection may also promote joint innovation work because the client can select a contractor that is capable and willing to engage in such joint development (Volker, 2012). Another alternative is the *competitive dialogue procedure*, in which a limited number of contractors compete for a contract through a multiple-stage approach including design and cost estimates.

An even stronger focus on cooperation is achieved when the client directly negotiates with only one contractor, and/or a bid selection based more on soft criteria than on price (Volker, 2010; Eriksson and Hane, 2014). A negotiated contract with only one contractor is rather common among private construction clients, while it is an exception for public clients (Bajari et al., 2014). However, a rule of thumb is that the higher the uncertainty and the earlier the procurement, the less focus on lowest price is suitable (Eriksson and Hane, 2014). Accordingly, when contractors are procured early and expected to participate in joint design work, bid evaluation based on soft criteria is especially important (Bosch-Sijtsema and Postma, 2009; Eriksson, 2017). For public clients, it is critical to follow European procurement regulations, which stipulate that the evaluation of soft criteria is as transparent and objective as possible and that all bidders are treated equally during the selection process.

Collaboration model

In arms-length, market-like relationships, a specific collaboration model is not required because the contract clearly specifies and distinguishes between the actors’ respective responsibilities. However, in challenging projects characterised by complexity, uncertainty, technological newness, etc., interaction and knowledge integration become critical to joint problem-solving and joint development efforts. From a relational contracting perspective, it is then essential to establish strong collaborative norms based on socialisation. An important element of collaborative procurement strategies is therefore to utilise a collaboration model that includes integrative activities and technologies; the more the activities and technologies used, the more extensive the collaboration model. Examples of integrative activities and technologies are co-location in a joint project office (Bresnen and Marshall, 2002; Alderman and Ivory, 2007; Gil, 2009), joint IT tools (Eriksson, 2015), formulation of joint objectives and continuous follow-up meetings (Bayliss et al., 2004), and team-building activities (Crespin-Mazet and Ghauri, 2007; Martinsuo and Ahola, 2010). Such activities and technologies strengthen the socialisation of partners so that they can establish a collaborative climate that serves as a foundation for joint development efforts. In infrastructure projects, such collaboration models may be used also in traditional DBB fixed-price contracts, thereby indicating the need for relational governance to complement the contractual trilateral governance under conditions of uncertainty.

Four dimensions of collaboration

As outlined earlier in Table 1, collaborative procurement strategies can be defined in terms of four components that in turn affect the nature of collaboration in the project at hand. Collaboration, in turn, is a multi-dimensional concept that can be divided into and explained by four dimensions: scope, depth, duration, and intensity (Eriksson, 2015). Below, these four dimensions and their interconnections with the four components of the procurement strategy are discussed.

Collaboration scope

The scope dimension involves the nature and number of companies involved in the integrated supply chain (Fabbe-Costes and Jahre, 2007; Flynn et al., 2010). In construction projects, *collaboration scope* refers to the organisations that are involved in and jointly perform the integrative activities and technologies – for example, clients, suppliers, contractors and consultants (Eriksson, 2015). Scope is thus strongly affected by the collaboration model, but also by the reward system, if incentives and bonus opportunities are connected to group performance across contracts rather than the performance of a single actor within a contract. Although there are many important actors (e.g., consultants and sub-contractors) in construction projects, many partnering arrangements include only client and main contractor (Dainty et al., 2001; Humphreys et al., 2003; Hartmann and Caerteling, 2010). However, due to the interdependencies and coordination demands among construction project actors, some prior partnering studies emphasise the importance of integrating other key actors in collaboration (Packham et al., 2003; Bygballe et al., 2010).

Collaboration depth

The depth dimension is dependent on the integration of various types of professionals and functions at various hierarchal levels within each partner organisation (Eriksson, 2015). Prior research has shown that interaction among individuals at different hierarchical levels and from many functional roles may facilitate inter-organisational collaboration (Moenaert et al., 1995; Barnes et al., 2007). In construction projects, the depth dimension is connected to the collaboration model because it depends on what people are engaged in using the integrative activities and technologies. Previous research on construction projects have found that although partnering arrangements often focus on high managerial levels, the involvement of lower levels (e.g., site workers) may be highly beneficial (Eriksson, 2010; 2015). The depth can thus be increased by involving not only project managers and engineers, but also experts, end-users, and blue-collar workers in the use of integrative activities and technologies. Furthermore, the depth may be extended upwards by involving the project governance group/steering committee in collaborative workshops, etc.

Collaboration duration

The duration dimension is dependent on the length of the time period during which the partners will collaborate and jointly utilise integrative activities and technologies, which may involve integration across subsequent projects and/or project stages (Eriksson, 2015). In this way, collaboration duration is heavily dependent on the delivery system, which decides in what stages of a project the contractor will be involved. Accordingly, a DB contract results in longer duration than a DBB contract, but an ECI contract, which is procured even earlier, results in longer duration than a DB contract. Prior research is mainly positive with regard to the early involvement of contractors in DB or ECI approaches. Findings indicate that early involvement of contractors in the design stage may improve efficiency through improved constructability and reduced delivery time due to parallel design and construction processes (Cheung et al., 2001; Eriksson, 2017; Park and Kwak, 2017). However, early involvement also provides contractors with improved possibilities for innovation, because of fewer restrictions in the tendering documents and more time for development and innovation before construction starts, in comparison to traditional DBB contracts (Caldwell et al., 2009).

Duration may also be prolonged by extending the contract to include not only design and construction but also maintenance in a DBM or DBFM contract. Findings in prior literature suggest that DB(F)M contracts encourage stronger focus on quality and LCC because the contractor has strong incentives to reduce maintenance costs arising from poor quality and inferior technical solutions (Rose and Manley, 2012; Lenferink et al., 2013). Another extension option is the use of long-term contracts spanning a series of

projects, such as in strategic partnering arrangements. However, the uniqueness and low frequency of projects make this challenging (Eriksson, 2015). Even when contractors perform well, the client often switches contractors between partnering projects (Alderman and Ivory, 2007). Strategic partnering arrangements spanning a series of projects are therefore scarce both in theory and practice (Bygballe et al., 2010). Nevertheless, many scholars argue that long-term integration and strategic partnering make it possible to strengthen collaboration over time and enhance the possibilities for continuous improvements (Bresnen and Marshall, 2002; Caniels et al., 2012).

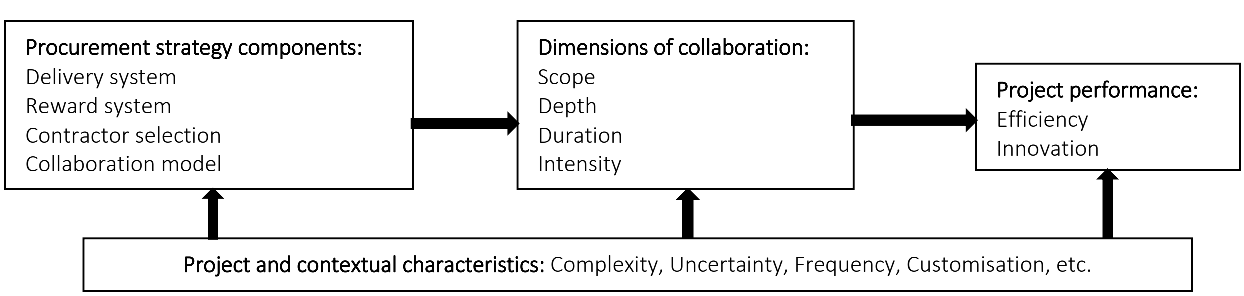
Collaboration intensity

The intensity dimension measures the strength of integration, which depends on the extent to which integrative activities and technologies are utilised (Eriksson, 2015; Fabbe-Costes and Jahre, 2007; Flynn et al., 2010). Prior research on partnering arrangements emphasises the importance of intense or strong collaboration, which is heavily affected by the implemented collaboration model (e.g., Bayliss et al., 2004; Eriksson, 2015). Hence, the more extensive the collaboration model, the stronger the collaboration intensity, other things being equal. However, the intensity is also influenced by the contractor selection procedures, since bid evaluation based on multiple criteria is a better basis for collaboration than pure lowest-price selections. Also, the reward system is important because cost reimbursement coupled with bonuses and/or incentives is a better basis for collaboration than fixed-price rewards (Eriksson and Hane, 2014).

Analytic framework for structure and analysis of empirical data

The analytic framework (Figure 1) underpinning this study is based on the assumption that the four procurement strategy components relate to the four dimensions of collaboration, which in turn influence project performance in terms of efficiency and innovation. In addition, the characteristics of the project and its context affect procurement strategy decisions and the achievement of collaboration and performance.

Figure 1. Analytical framework



Method

The empirical data presented and analysed in this paper were collected through a multiple-case study of 10 infrastructure projects (see Table 2 below and Appendix 1 for more detail) employing four different types of collaborative procurement strategies. Below, we summarise the case study projects and how we collected and analysed the empirical data.

Sample of projects

We chose to study 2-3 projects of each type of procurement strategy: two DB projects, two ECI projects, three DBM projects, and three DBFM projects (Table 2). As mentioned in the previous chapter, the STA adopted new procurement guidelines in 2017 (the *Common National Strategy for Procurement*). The procurement strategies of all the case-study projects were, however, designed and implemented before these new guidelines were adopted. Still, most of the case-study projects may be considered as pilot projects, in the sense that they represent procurement strategies that were novel to both clients and suppliers, who were used to the traditional DBB contracts. Due to the pilot nature of the projects, it is especially interesting and relevant to study and learn from them, and to consider their experiences as useful input for further developing these procurement strategies and the organisational competencies for designing and managing them.

Table 2. Overview of case study projects

Case project	Contract sum/ Estimated cost	Delivery system	Reward system	Contractor selection	Collaboration model
DB 1: Road 252 Hallstahammar-Surahammar Construction: 2016-2017	SEK 210 million (~EUR 21 million)	DB contract	Fixed price, bonus opportunities worth maximum 6 million SEK	Open bid invitation and bid evaluation based on lowest price	Basic collaboration model. A few collaborative activities and technologies
DB 2: Railway Strängnäs – Härad Construction: 2014-2018	SEK 1.9 billion in total, railway project SEK 1 billion (~EUR 190 million)	DB contract, including all five main parts of a railway project	Fixed price, except for cost reimbursement and a target cost for the tunnel	Open invitation procedure and bid evaluation based on lowest price	Basic collaboration model. A few collaborative activities and technologies
ECI 1: West Link sub-project Olskroken Construction: 2018-2026	SEK 2.5-3.5 billion (~ EUR 250-350 million)	ECI based on consultancy contract in Phase 1 with option for DB contract in Phase 2	Cost-plus in Phase 1; cost-plus coupled with incentive connected to target cost in Phase 2	Restricted procedure with pre-qualification; bid evaluation based on multiple criteria	Extensive collaboration model. High level of collaboration in line with STA's guidelines

ECI 2 West Link sub-project Centralen Construction: 2018-2026	SEK 4.0-4.5 billion (~EUR 400-450 million)	ECI based on consultancy contract in Phase 1 with option for DB contract in Phase 2	Cost-plus in Phase 1; cost-plus coupled with incentive connected to target cost in Phase 2	Restricted procedure with pre-qualification; bid evaluation based on multiple criteria	Extensive collaboration model. High level of collaboration in line with STA's guidelines
DBM 1: Norrortsleden Construction: 2005-2008 Maintenance: 2008-2023	SEK 575 million (~EUR 58 million) investment cost, SEK 140 million maintenance	DBM contract	Fixed price for investment, except for cost-plus and a target cost for the tunnel, and yearly payments for maintenance	Restricted procedure with pre-qualification. Bid evaluation based on multiple criteria, but mostly lowest price	Basic collaboration model. A few collaborative activities and technologies
DBM 2: Väg 50 Motala-Mjölby Construction: 2010-2013 Maintenance: 2013-2033	SEK 1.3 billion (~EUR 130 million)	DBM contract	Fixed price, bonus opportunities worth maximum SEK 16 million for early completion	Restricted procedure with pre-qualification. Bid evaluation based on lowest price	Basic collaboration model. A few collaborative activities and technologies
DBM 3: E4 – Sundsvall Construction: 2010-2014 Maintenance: 2014-2034	SEK 1.1 billion (~EUR 130 million)	DBM contract	Fixed price, bonus opportunities worth maximum SEK 30 million for early completion	Restricted procedure with pre-qualification. Bid evaluation based on lowest price	Basic collaboration model. A few collaborative activities and technologies
DBFM 1: Road N31 Wâldwei Construction: 2003-2008 Maintenance: 2004-2023	~ EUR 135 million (SEK 1.4 billion)	DBFM contract	Fixed price with payment for investment and yearly payments for maintenance	Restricted procedure with pre-qualification. Bid evaluation based on lowest price	Limited collaboration model. Limited collaborative activities and technologies
DBFM 2: Road N33 Assen-Zuid Construction: 2012-2015 Maintenance: 2015-2034	~EUR 120 million (SEK 1.2 billion)	DBFM contract, with some elements of early contractor involvement	Fixed price with payment for investment and yearly payments for maintenance	Competitive dialogue, awarding based on price/quality ratio	Limited collaboration model. Limited collaborative activities and technologies
DBFM 3: the Coen Tunnel Construction: 2008-2013 Maintenance: 2013-2037	~EUR 700 million (SEK 7 billion)	DBFM contract	Fixed price with payment for investment and yearly payments for maintenance	Competitive dialogue based on three stages. Bid evaluation based on best price/quality ratio	Limited collaboration model in rather formal structure, plus system-based contract management

Data collection and analysis

The empirical data collection was mostly based on interviews with respondents representing the main parties (client, consultant and contractor) in the ten chosen projects. Also, project documents, such as

organisation schemes, contracts, tendering documents and project reports, were investigated to triangulate the interview findings. The DBM and DBFM cases were studied retrospectively, whereas the DB and ECI cases were ongoing at the time of the study. Due to the early phase of the studied ECI contracts, findings from those cases are limited to the design stage and are rather tentative in nature.

The empirical data were structured and analysed according to the analytical framework shown in Figure 1 (in the previous chapter). The within-case analysis is presented in the case descriptions in Appendix 1. The within-case analysis describes the four procurement strategy components and how they relate to the four dimensions of collaboration in each case, and furthermore how efficiency and innovation were affected by the four dimensions of collaboration. The findings of the cross-case analysis, which are presented in the next section of this paper, focus on comparing how the four dimensions of collaboration affected efficiency and innovation in the four different types of procurement strategies.

Findings from cross-case analysis

This section discusses how the four dimensions of collaboration influence various aspects related to efficiency and innovation in the studied projects. The examples that are analysed, compared and discussed come from the empirical findings of the conducted multiple-case study. A more-detailed presentation of the empirical results can be found in the case descriptions in Appendix 1.

Efficiency aspects influenced by collaboration

Collaboration scope influences efficiency

Collaboration *scope* involves the nature and number of companies (actors) involved in the integrated supply chain, and apart from the client and contractor, the main participants are subcontractors and design consultants. In the DB 2 project, all five main parts of the railway project were included in the DB contract, making it especially important to involve key subcontractors in the collaboration. Several subcontractors were therefore co-located in the same joint project office with the client and DB contractor, which facilitated informal communication and collaboration among them. For the ECI projects, too, this broader scope of collaboration (compared to traditionally procured railway projects) improved the efficiency of the project, mostly by enabling faster joint-decision-making and clearer communication.

The DB and ECI projects indicate that the design and implementation of the co-location premises are critical for collaboration scope. The size and design of the joint project office will determine not only how many actors can be co-located, but also how these actors are physically placed within the office building. Findings indicate that it is important to have buildings that are large enough to accommodate all key actors and that they should be as integrated as possible – for example, by avoiding different floors or sections for different actors. Co-location was perceived as central for enhancing collaboration and communication among different actors, which in turn facilitated joint problem-solving and decision-making.

Findings from DBFM 1 and DBFM 3 indicate that the inclusion of a private funder may result in a more economically sound tender strategy and solid technical solutions with lower risks. In both cases, to avoid

unnecessary risks, the private funder strongly steered on quality control and assessment of the viability of chosen solutions. Furthermore, the private funder's focus on revenues put pressure on keeping the time schedule and encouraged early delivery of construction work. The sooner the construction was finished and the traffic could be released, the sooner the private funder could start earning money. Accordingly, the broader scope of collaboration in PPP projects, compared to contracts without the involvement of private funders, may improve efficiency in the design and construction stages.

Collaboration depth influences efficiency

The collaboration *depth* refers to the integration of different types of professionals and hierarchical levels within the companies involved in the project. Findings from DB 1 and DB 2 indicate that the depth of collaboration may contribute to an effective decision-making process and joint solution of daily problems arising at the construction site. In DB 1, the construction process has seldom been stopped, because minor problems have quickly been solved at a low hierarchical level. In contrast, larger problems have been raised to the executive level, allowing the daily work to continue. This highlights the importance of matching project organisations and establishing strong collaboration at all hierarchical levels so that each level can make joint decisions and solve difficult problems or even conflicts without interrupting the value-adding work processes. In DB contracts the client has a site controller, a consultant who monitors the ongoing work at the construction site. In DB 2, the BPU took a more collaborative approach than what is considered normal. Instead of merely monitoring the contractor, the BPU discussed different solutions and methods directly with the contractor. In this way, the BPU provided support and advice, although the contractor still had the responsibility for the solutions and methods discussed. These discussions were much appreciated and resulted in better solutions for both parties when combining their competencies.

Findings from several cases show the importance of sufficiently large project organisations at the client side, in terms of both the amount of people involved and the number of different roles and competencies involved. Especially in the DBM 1 project, the client organisation had a lot of human resources and was thereby able to provide strong support to the contractor, which was highly appreciated. Contrastingly, in the DBM 3 and all ECI contracts, the client organisations were perceived to lack sufficient human resources, especially in the beginning, which severely hampered collaboration and in turn efficient decision-making.

In all DBFM cases, the project organisation comprised at least a dozen different parties. Since all these parties and hierarchical levels needed to approve the business case of the proposal, transaction costs in the procurement phase were high. During the execution of the contract, approval for significant changes (e.g. the implementation of an innovation) needed to be sought from several layers of responsible officers, which took time. On the other hand, a project organisation of such a large and complex contract requires considerable preparation and is often taken very seriously by the actors involved. Risk allocations, incentive structures and project governance are generally discussed in detail before final award decisions are made. Accordingly, the complex organisational set-up of the DBFM projects resulted in slower decision-making but the decisions were more carefully made and, therefore, of higher quality.

The involvement of maintenance actors in DBFM projects enabled the implementation of a new type of performance-based maintenance system, stimulated by the availability requirements as agreed on in the procurement phase. The maintenance management system includes all the objects for the road and generates work orders based on maintenance intervals. The system also includes accidents that occur, and the maintenance staff constantly tweaks the system for optimisation. Based on this kind of knowledge on actual performances of materials, the contractors of both DBFM 2 and DBFM 3 are developing more-efficient standardised maintenance processes.

All DBM and DBFM cases showed that collaboration between the design and construction actors and the maintenance actors was challenging to achieve. Accordingly, the increased depth of collaboration was not reaching its potential, which negatively affected the maintainability. In some DBFM cases, the construction team promised the maintenance team that some technical solutions would work during maintenance when that was not the case. The client (RWS) hopes that the maintenance team will manage the contract in the future since they can make trade-offs between construction and maintenance and also build maintenance-friendly installations and constructions. The contractors are still developing this kind of competence in the Netherlands.

Collaboration duration influences efficiency

The collaboration *duration* refers to the length of the collaboration and integration of project stages or sub-projects. Duration can be increased either through early involvement or by prolonging contracts to include maintenance. Findings from all four types of contracts indicate that the prolonged duration based on a rather early involvement of the contractors, compared to DBB contracts, has high time-saving potential. The integration of design and production makes parallel processes possible, which saves time. As an example, early involvement of the contractor was found to increase the speed of the DBFM 1 project significantly, especially in the planning and procurement phases, compared to a traditional sequential approach. For ECI projects, time-related advantages include opportunities to proceed with design before final planning permits are obtained. In the ECI cases, however, Phase 1 was delayed by more than 9 months due to difficulties in agreeing on a target cost before entering Phase 2. Here, the client perceived a lack of incentive for contractors, both to collaborate in producing more efficient designs, and to reduce the costs of the design organisation.

Nevertheless, the early engagement of the contractors enables parties with complementary skills and competences to sit down and discuss solutions and ideas, which creates an understanding of the other parties' roles and drivers. Due to the early contractor involvement in DBFM 2, contractors were able to fill in knowledge gaps in the (draft) Route Decision and engineering solutions. For instance, the length of the process and the risks could be better assessed using the knowledge of the contractors involved in the procurement procedure, which resulted in improved project control. Early contractor involvement was also helpful in negotiations with stakeholders. The contractors helped solve implementation-related issues, e.g. by providing detailed information on the types of available sound barriers. The early involvement and integration of competencies and stages improve the constructability of the design solutions due to the incorporation of production knowledge during design work. This early involvement and integration between design and construction is similar across the four types of delivery systems studied. Hence, all four types have the potential to save time and improve constructability compared to DBB contracts.

Although all four types of strategies studied entail the contractor entering the project rather early, many road/rail corridor plans and permits are already set and approved – thus placing early constraints on the projects. This can limit opportunities for optimising the production processes based on contractor experiences since the corridor chosen by the client might not be optimal from a production perspective, especially when considering the placement and transportation of masses. Accordingly, as experienced in the ECI projects, "early" contractor involvement may not occur sufficiently early to truly enhance efficiency by optimising production in flexible road/railway corridors.

The only disadvantage mentioned with regard to choosing a DB, DBM, or DBFM contract over a DBB contract is the increased cost for contractors to submit tenders. Due to their early involvement, the contractors must perform some of the design and development work during the tender phase, in order to

select technical solutions and calculate their costs. For a large project, this work can be very costly, especially if the client uses a competitive dialogue. In the two DB projects, the losing contractors did not receive any compensation for their tender submissions. This arguably made it difficult for smaller contractors to prepare tenders due to the large expenses involved. These kinds of contracts could, therefore, benefit from compensating contractors that submit an approved bid. This would increase the level of competition, which is vital for the sustainable development of the industry. Both STA and RWS sometimes pay such compensation, although the amount of money is relatively small compared to the incurred costs of tendering. The drawbacks of expensive bid preparations are even greater in DB(F)M contracts because contractors must consider and calculate maintenance costs as well. In fact, findings from DBFM 3 clearly illustrate the challenges of calculating valid bid prices in integrated contracts with long maintenance responsibilities. However, in ECI projects the contractors are procured even earlier, and because they are not supposed to present technical solutions or cost calculations in their bids, the cost of preparing bids is actually much lower in this type of contract. This was perceived as a major advantage by both clients and contractors in the studied ECI projects.

Prolonged collaboration duration in late project stages (i.e., during operations and maintenance) also had major effects on efficiency. Findings from the DBM and DBFM contracts illustrate that the long-term responsibilities during operations and maintenance affect the contractors’ priorities regarding quality. To some extent, the maintenance responsibility prompted contractors to invest in higher-quality materials and technical solutions – which, although often more expensive initially, can reduce the risk of failure and malfunctions, and thus lower life-cycle costs during maintenance. This type of consideration is especially evident when the reward system during the maintenance phase is connected to malfunctions and traffic interruptions. Both contractors and clients believe the potential for fines during the maintenance phase provides a good incentive for improving road/rail availability. The contractor tries to avoid fines during the maintenance phase, as these are not included in the budget. For example, in DBFM 3, a well-functioning organisation was important since the machines used for maintenance are expensive to run and the fines are severe at EUR 20 000 for every 15-minute reduction in availability.

Long-term collaborations also create challenges in relation to the ambiguities in contractual agreements. In DBFM 3, financial problems have arisen during the maintenance period (2014-2034) regarding accidents/incidents that were not clearly defined in the contract. In DBFM 1 the quality standards of the end results require negotiations due to the use of cheaper stabilisation methods than required.

The issue of predicting the operation and maintenance need for such a long period (20 years) was also mentioned by the client in the DBM 3 contract. Long contracts also affect the collective memory of the organisation. Decisions and discussions made 15 years ago are hard to remember and most people will not be there during the whole contract. Hence, it is important to get the documentation right when decisions are taken, in order to prevent ambiguities and conflicts in later maintenance stages.

From a maintenance perspective, DBM and DBFM projects are inefficient when compared to the parallel strategy of creating large performance contracts for maintenance in an entire region. DBM and DBFM contracts create isolated “islands” in the infrastructure network, with specific contractual agreements and specialised people dedicated to each one. This increases the need for administration and dual staff competencies and decreases the economies of scale for the maintenance contractor. Furthermore, any change requires renewed negotiations between all stakeholders related to the objects realised in DBM or DBFM projects, while in other parts of the network the standard regulations apply. Both RWS and STA are therefore considering the option of packaging these types of contracts with adjacent maintenance objects (which was done to some extent in DBFM 3) by adding the maintenance of the parallel existing tunnel.

The fact that few of the projects studied were part of a long-term contract spanning a series of projects seems to have hampered efficiency in terms of inter-project exploitative learning, especially where the DBM projects are concerned. This is somewhat disappointing as many of the projects served as pilot or test projects (i.e. the first of their kind) for the client organisations. In DBM 1, the client's project organisation made strong attempts to enhance inter-project learning and knowledge sharing by codifying experiences and knowledge into documents and manuals so that future projects could learn from mistakes and successes. To our, or the respondents', knowledge, these experiences have not been picked up by subsequent DBM projects. In the ECI projects, our findings indicate that learning and knowledge sharing across the West Link projects (see Cases ECI 1 and ECI 2 in Appendix 1) was limited. However, in subsequent ECI projects STA improved inter-project learning by adapting the organisation-level ECI strategy based on the experiences from West Link. Furthermore, RWS more recently has taken a similar proactive role in transferring knowledge and experience from project to project, which has resulted in continuously improved DBFM contracts and procurements over time.

Collaboration intensity influences efficiency

Collaboration *intensity* relates to the degree or strength of the integration. Intense collaboration can enhance efficiency since important decisions can be made together and better solutions could be chosen. As a result of the intense collaboration in DB 1, a file system for the quality and environment work was jointly developed to increase the efficiency of meetings. Although the list of client requirements related to quality and environment was rather extensive, the meetings became more efficient by structuring the requirements into various categories reflecting the different competences and actors. This is a solution that the contractor in DB 1 will use in other projects, especially those with extensive client requirements.

In several of the studied projects, the project actors were co-located in a joint project office that contributed to a collaborative climate. The improved collaboration prevented small issues, both personal and task-related, from becoming major issues. Furthermore, co-location improved communication and joint problem-solving. Of the various components of the collaboration model, co-location in a joint project office seems to be the most important. In the DB and ECI projects, which utilised joint project offices, project actors highlighted the importance of being co-located and some of the problems that occurred were connected to deficiencies in the joint project office.

However, the extensive collaborative activities that were performed in several of the studied projects must be considered in relation to the contract size. DB 1, for example, was almost considered to be too small a project by STA for this type of extensive effort. A delicate balance exists between positive outcomes and expenses that must be considered before deciding on a collaboration model that fits the individual project. In addition to the size of the project, time pressure may also affect the implementation of the collaboration model, and thus also the collaboration intensity. If time pressure becomes too strong, project actors may be tempted to skip proactive collaborative activities and instead focus on reactive problem-solving. This was experienced in DBM 3, in which bonuses for early completion forced an early production start for suppliers and provided an incentive for fast decision-making rather than joint decision-making. Further, one reason for not following through with the implementation of the planned collaboration model in ECI 2 was that the already-limited timeframe had been further shortened by the court appeal process. Hence, project actors perceived that they lacked sufficient time for collaborative activities, which contributed to the poor collaboration later in Phase 1 of the ECI contract.

Due to the risk allocation and fully integrated task division in DBFM projects in the Netherlands, the client and contractor remained rather distant from each other in these projects. They implemented a performance-based quality-management system, which required the contractor to set up an open system

to monitor project progress with respect to the performance-based contractual targets. This enabled the client to keep track of the contractors' progress without being on site. Every four to six weeks, formal meetings were held to discuss deviations from the agreements. Additionally, external audits took place once a year, also because of the high level of financial risk assumed by external lenders. Because this sometimes resulted in an artificial collaboration and lack of trust, the more recent DBFM projects tend to include collaborative measures such as co-location.

Innovation aspects influenced by collaboration

Innovation efforts varied among the projects, and there are some explicit examples of both product and process innovations. Overall, however, the level of innovation seems to be rather limited. An important aspect to discuss is the *type* of innovation that is encouraged in these project environments. Although there are some quality-enhancing product innovations, it seems that cost-reducing process innovations are more common. In the ECI projects, for example, innovation and improvement initiatives were strongly focused on the goal of reducing investment costs. Innovations that lead to increases in quality – such as improved city logistics, lower life-cycle costs, or lower environmental impact – are to a large extent accepted only if they also reduce investment costs.

Collaboration scope influences innovation

The findings indicate that increased scope of collaboration may enhance some innovation efforts, where different actors and competences are required. In DBM 1, the intense collaboration between the client, the consultants and the contractor served as a main driver and enabler for innovation. This broad collaboration was perceived as especially valuable when the project actors together managed to develop a completely new traffic solution – a crossing that divided the traffic into two levels, instead of a solution based on a roundabout – for which they need new permits. The intense collaboration and integration of different competence sets enabled faster development and permit processes; many respondents highlighted that this must be a Swedish record in terms of quick changes of permits and design solutions. A similar example was found in ECI 1, where the collaboration between the consultant and the contractor resulted in a major design change. The project actors developed a technical solution (which entailed eliminating a bridge) that carried considerable environmental benefits and important cost reductions.

Findings from the DBFM projects indicate that the increased scope of collaboration in terms of involvement of the private funder also affected innovation. Increased quality control and the risk-averse perspective of the private funder leave minimal room for radical innovation in the DBFM projects that were included in this study. Due to the high risk connected with innovation, the private funder is very sceptical towards new and untested solutions. On the other hand, the increased focus on quality (i.e. the use of robust and verified solutions) offered the client more certainty in terms of the feasibility of the few innovations proposed during the tender phase. In these projects, the broader scope of collaboration seems to have resulted in fewer radical innovations but improved verification of the innovations that were selected and implemented.

Collaboration depth influences innovation

In general, the influence of collaboration depth on innovation was not explicitly discussed in the interviews. However, in DBFM 3 it was found that the initial project organisation vertically separated the installations from the rest of the construction, which hindered innovation and caused problems in terms of project control and system engineering. The contractor successfully solved this by fully integrating both parts,

including the financial streams. According to the project managers, the project organisations should be "mirrored" so that similar roles and tasks are present on both sides of the project team (the client and the contractor) in order to facilitate good communication. From the client side, the Integrated Project Management (IPM) structure was therefore applied, resulting in a project director, a project controller, a project manager, a stakeholder manager, a technical manager and a contract manager. Further, it is important that each role is empowered and can make decisions in his or her specific area of expertise. In ECI 1, the innovative solution was suggested by a consultant rather than by someone at a higher design management level, indicating that it is important to involve the technical experts directly in the process.

Collaboration duration influences innovation

The early involvement of contractors in all four types of contracts enhanced innovation in several of the projects. The early involvement of the contractor in DB 1 served as a basis for making some minor innovations possible in the project, including some related to product quality. Because of the longer duration of the warranty period (10 years), it was desirable for both actors to improve product quality to decrease the risk of major maintenance work. Similar findings were made in DBM 2, where the contractor developed both product and process innovations that were beneficial for both the client and the contractor. In the ECI 1 contract, the large design change (elimination of a bridge) was only possible to implement at an early stage.

Findings from several projects (e.g., ECI 1, ECI 2, DBM 1, DBM 3) show that lack of time is a major barrier, both to collaboration and to innovation. Accordingly, even when contractors are procured early, sufficient time must be allowed for joint design and development efforts. When time pressure is too high, contractors will stick with their existing solutions to avoid time-consuming development work, which may or may not produce implementable solutions. As experiences from DBM 1 and DBM 3 show, clients may sometimes consider time savings to be the main purpose of innovation.

Findings in all four types of contracts indicate that the early involvement of contractors, compared to traditional DBB contracts, may not be sufficiently early to facilitate more radical and larger innovations. Too many restrictions are already set during the initial planning and permit processes that are conducted before the involvement of contractors. This appeared in all projects but was especially evident in railway projects (e.g., DB 2, ECI 1, and ECI 2), in which restrictions are more rigid than in road projects. Although the contractors in DB 1 and DB 2 were procured rather early, the fact that many requirements and constraints were already set and fixed when the contractors were procured limited the contractors' ability to affect design, development and use of innovative production solutions. Similar findings were identified in the DBFM 2 project, where the early contractor involvement did not result in substantial technical innovations. Because the draft Route Decision had already been made, the contractors could not influence the development of alternatives or the scope of the project.

In the DBM and DBFM contracts, the long duration in terms of maintenance responsibilities enhanced several development efforts. In DBFM 3 an innovative asphalt development was realised, enabled by the duration of the contract. Asphalt is normally renewed every eight to ten years, but an innovative chemical spray that makes the layer last another eight years was successfully implemented in this project. The sub-contractor providing this innovation (who was not involved in the beginning) has assumed part of the risk for this method. The spray is cheap and will, therefore, be applied more often than every eighth year to make sure the asphalt meets the requirements.

A similar innovation was seen in DBM 3, where the asphalt on the bridges was replaced by concrete. This solution was initiated by the contractor to decrease maintenance costs for the large number of bridges along the road. For the DBFM 2 project, a new way of handling the traffic on the adjacent lane was used

by the contractor. Also, wider asphalt machines were developed to be able to lay both lanes at the same time and avoid the edge between the lanes, making the road more durable. In DBFM 3 a new maintenance machine has been developed that can work in the emergency lane. It can operate during the day, parallel to the traffic lane, without requiring lane closure (which would result in a fine). The contractor has a long pay-back time on the machine for the development cost, which is possible in this type of contract. The types of tasks performed by the machine include grass mowing, changing the lights, emptying sewers, and cleaning the strip between the roads. The machine is also rented out to other companies, resulting in extra income for the contractor. This was stimulated by the fact that the DBFM project contracts required a solution for keeping traffic lanes open but did not specify the solution. Furthermore, in this project, the NEN 15288 standard was used, which requires the contractor to show how risk management and safety issues are organised as well as to evaluate incidents. This standard has been incorporated into contracts in recent years and appears to be very successful.

Contrasting findings from DBM 2 and DBFM 3 indicate the client's importance for innovation. An ongoing discussion regarding a change to LED lights in DBFM 3 shows that increasing the number of innovative insights can change the value of an agreement in time. The contractor of DBFM 3 has no incentive to change the rather new lights into LED lights due to financial reasons, while the client desires this change for environmental reasons. Because the contract is performance-based, negotiations on the replacement of the lights have now turned towards an exchange on another issue which does not seem to deliver the right kind of value anymore while agreed upon at contract closure about 10 years ago. Contrastingly, in DBM 2, the client explicitly demanded new light technology in the tendering documents, and because of the long maintenance responsibility, the contractor awaited the development of LED lighting before implementing the latest technology in order to fulfil client requirements and reduce the energy costs during the operation and maintenance phase.

However, findings from the DBM and DBFM contracts also show that the long duration in terms of maintenance responsibilities may deter innovation. The contractor will be less inclined to develop new solutions, with less verified robustness, when it is responsible for maintaining the road for 15-30 years. New technical solutions that eventually prove to be of inferior quality may be costly to maintain. Hence, more radical innovations will be avoided and more robust and verified solutions will be favoured.

Collaboration intensity influences innovation

Some findings indicate that collaboration intensity is central to innovation, or at least to those innovations that are difficult for a single actor to develop by itself. In interviews, the project managers of DB 1 stressed that many (minor) creative ideas that are needed to solve problems arising during production are easily handled through intense collaboration due to the joint project office. They found that working tightly and intensively (in the joint project office) creates an environment where everyone feels it is their "duty" to contribute to the best interest of the project (see Case DB1).

It is not enough, however, to provide contractors with possibilities to innovate through early involvement; they must also have appropriate incentives to innovate. In this regard, the reward system is central. Although fixed-price payment or target cost connected to a 50/50 gain/pain-sharing mechanism give contractors a strong incentive to develop cost-reducing innovations, these reward systems may place too much risk on the contractor. Findings from the ECI projects show that a sharing of gains and pains made contractors risk-averse in Phase 1 (this was also the case with an 80/20 split). In effect, the contractors had weak incentives for innovation in Phase 1, when the potential for innovation is the highest. Findings from DB 2, where the fixed-price contract and the design responsibilities deterred the contractor from making uncertain innovation efforts, also pinpoint the importance of risk and reward allocation. In DB 2, the client

made a few suggestions for simpler and cheaper methods to the contractor during the design work. However, as these alternative methods were new to the contractor, it asked the client to take partial responsibility for them. The client refused, referring to the DB contract. The contractor, therefore, chose to stay with the initial plans and solutions rather than try the suggested simpler and cheaper methods. Increased risks are a major barrier to changing and developing new alternative solutions. Due to the fixed-price contract, the client lacked an incentive to take responsibility for this risk. Taken together, these findings highlight the importance of designing appropriate contractual risk and reward allocations so that actors can share gains and pains from innovations in suitable ways.

However, findings from the ECI projects also indicate that individuals and teams are driven to be more innovative by factors other than formal contracts and risk/reward allocations. Instead, engineers are motivated primarily by a creative environment and the opportunity to collaborate with skilled experts in various fields. Hence, at the individual level, collaboration intensity may serve as an important driver of innovation efforts.

Findings from the Netherlands show that the strength of collaboration increased somewhat over time in the DBM and DBFM projects, as the actors gained experience in operating under this type of integrated contract. Ten years ago the DBFM contract was a new experience for both clients and contractors, and the same goes for ECI. The main challenge raised by the respondents was working together and understanding each other. Because the procurement phase was driven primarily by legal and financial discussions, the technical assignments and contract management system were not fully addressed upfront. Project managers indicated that staff should simply try to be nice to one other – especially during the initial phases, which require a substantial amount of "give and take". Both sides should be able to win when innovations are applied and changes are required.

Concluding discussion

Summary of main findings related to efficiency and innovation

The four dimensions of collaboration (i.e., Scope, Depth, Duration and Intensity) had both positive and negative effects on efficiency and innovation in the case-study projects. Several examples were identified in our multiple-case study, and these are summarised in Table 3, each preceded by either a "+" (positive) or "-" (negative) symbol. Positive effects marked in parentheses – "(+)" – were identified but not realised to their full potential due to challenges during implementation. The table also comments on the type(s) of contract(s) to which the identified effects are most relevant (some effects are relevant to all four contract types, whereas others are especially relevant to only one).

Table 3. Summary of findings of efficiency and innovation in the case study projects

Collaboration dimension	Impact on efficiency	Impact on innovation
Scope	+ Involvement of private funder in DBFM results in selection of more robust and verified material and technical solutions + Involvement of private funder in DBFM results in more focus on revenues, putting pressure on keeping the time schedule and encouraging early delivery of project (+) Involvement of design consultants and key sub-contractors in collaboration may bring improved joint problem-solving and decision-making in all four contract types, but was difficult to achieve	+ Collaboration with design consultants enhances development efforts in all four contract types + Involvement of private funder in DBFM results in more robust and verified innovations with lower risk - Involvement of private funder in DBFM hampers more radical innovations that entail greater risk
Depth	+ Collaboration at many different hierarchical levels results in improved and quicker decision-making in daily work in all four contract types + Mirrored project organisations facilitate fast and easy decision-making in daily work in DB and DBM contracts (+) Sufficiently large project organisations on the client side improve collaboration and efficient decision-making, but human resources are often scarce (+) Integration of clients' and contractors' internal maintenance competences in the design stage of DB(F)M contracts may improve maintainability, but was difficult to achieve +/- Complex organisational set-up of DBFM projects results in slower decision-making, but the decisions taken may be of higher quality	(+) Vertical collaboration among different internal roles and hierarchical levels may be positive for innovation in all four contract types, but was difficult to achieve. For many innovation areas, it is important to include technical expertise in the collaborative activities, not only managerial levels.
Duration	+ Early involvement of contractor improves constructability in all four contract types + Early involvement of contractor reduces delivery time due to parallel processes in all four contract types + Long maintenance responsibilities encourage stronger focus on quality and LCC in DBM and DBFM contracts - Restrictions from initial planning and permit processes reduce possibilities for efficient production in all four contract types, despite early involvement - Early involvement in DB, DBM, and DBFM contracts results in increased tendering costs for contractor (especially if a competitive dialogue is used), but very early involvement in ECI contracts reduces tendering costs	+ Early involvement of contractor improves possibilities for innovation in all four contract types + Long maintenance responsibilities enable innovation that reduces LCC in DBM and DBFM contracts - Early contractor involvement (ECI contracts) requires suitable risk/reward allocation to provide incentives for innovation - Restrictions from initial planning and permit processes reduce possibilities for innovation in all four contract types, despite early involvement - Long-term maintenance responsibilities deter radical innovation in DBM and DBFM contracts due to risk of malfunctions and costlier maintenance - Long-term maintenance contracts are very difficult to price *ex ante*. Contractors/consortia need to add risk premiums to their tenders. The longer the duration, the more difficult the contracts are to

	- Long-term maintenance contracts (DBM and DBFM) increase the need for documentation, due to lack of organisational memory - DBM and DBFM contracts reduce efficiency and economies of scale during maintenance, compared with large regional maintenance contracts - Lack of long-term contracts over a series of projects hampers exploitative inter-project learning and knowledge sharing	price, and the larger the risk premiums in DBM and DBFM contracts
Intensity	+ Collaboration based on co-location results in faster and improved joint decision-making in all four contract types - Improving collaboration intensity through an extensive collaboration model costs time and money; investment must match project size in all four contract types - Strong time pressure may tempt project actors to skip proactive collaborative activities	+ Collaboration intensity enhances faster development processes in all four contract types + Collaboration enhances creativity and serves as a driver for individuals' development efforts, especially in ECI contracts (+) Contractual incentives may drive joint innovation efforts in the design stage of ECI contracts, but these incentives are difficult to put in place - Lack of time due to high time pressure hampers collaboration and reduces possibilities and incentives for innovation in all four contract types

Discussion of main findings

Collaboration scope in infrastructure projects

In the literature on supply chain integration, the scope of collaboration – which involves the nature and number of companies involved in the integrated supply chain – is a central dimension (Fabbe-Costes and Jahre, 2007; Flynn et al., 2010). Although there are many important actors (e.g., consultants and subcontractors) in construction projects, the collaboration scope often includes only the client and the main (DB) contractor (Dainty et al., 2001; Humphreys et al., 2003; Hartmann and Caerteling, 2010). Due to interdependencies and coordination demands among construction project actors and the systemic nature of many construction innovations, this narrow focus on client-contractor collaboration may often be detrimental to efficiency and innovation. Hence, some prior partnering studies emphasise the importance of integrating other key actors in collaboration (Packham et al., 2003; Bygballe et al., 2010).

Our findings indicate that broader collaboration scope is important for both efficiency and innovation, but it is challenging to achieve this collaboration among many different actors. A key mechanism is to have a sufficiently large joint project office in which key actors can be co-located. Many examples of explorative learning are of an emerging nature, requiring both broad and intense collaboration among different actors with different competences. In order to be prepared for sudden and unforeseen exploration efforts, project actors need to establish a sufficiently broad collaboration scope beforehand, to facilitate quick responses to emerging challenges (Eriksson et al., 2017a).

Furthermore, our findings indicate that the involvement of a private funder in DBFM projects may improve efficiency because it tends to encourage the use of more robust and verified material and technical solutions, thereby reducing risk. This is because the private funder is relatively risk aversive and brings in a strong quality-control competence into the project. This actor also brings a stronger focus on revenues, which puts pressure on the other actors to keep the time schedule and encourages early delivery of

projects. However, the involvement of a private funder in DBFM projects may hamper more radical innovation. Because this actor is often keen on reducing risk, any uncertain innovation efforts are generally avoided (Caldwell et al., 2009; Rose and Manley, 2012). This finding is in line with prior research findings indicating that the private funder tends to "adopt innovations that are incremental and of relatively low risk, as risk relates to the competence of the private funder" (Roumboutsos and Saussier, 2014: p. 359).

Collaboration depth in infrastructure projects

Although there is a general lack of studies focusing on the depth of collaboration (Eriksson, 2015), there are a few previous studies suggesting that interaction among individuals at many hierarchical levels and from many functional roles may facilitate inter-organisational collaboration (Moenaert et al., 1995; Barnes et al., 2007). Previous research on construction projects has, however, found that many partnering arrangements mainly involve high managerial levels, even though involvement of lower-level personnel (e.g., site workers) may be highly beneficial (Eriksson, 2010; 2015). The findings from our cases indicate that collaboration at different hierarchical levels can be difficult to achieve – but, if it is successful, it can result in improved and quicker decision-making and daily problem-solving. The influence on innovation from such collaboration across hierarchical levels is more uncertain, as this aspect was not explicitly discussed to a large extent in the studied projects. When it comes to earlier stages, however, there is a strong relationship between innovation opportunities and the involvement of individual design consultants holding expertise in key areas. An often neglected aspect is the critical importance of establishing sufficiently large project organisations on the client side, in terms of human resources, so that the client is able to support the contractor and engage in collaborative work. These findings support prior literature in that a lack of human resources in the client's project organisation is especially detrimental in collaborative projects, since contractors then have to work in a relatively isolated fashion, instead of together with the client (Eriksson, 2015).

In line with prior research, we found it important but difficult to involve end-users in construction projects (Eriksson et al., 2017a). Findings from the DB(F)M projects indicate the critical importance of involving both the client's and the contractor's maintenance functions in the design stage to facilitate improved maintainability. However, to deepen the collaboration in this way is problematic, because end users (e.g. the client's maintenance department) typically do not belong to the temporary project organisation, but to the permanent line organisation (Eriksson, 2015). Hence, much more effort is required to take them away from their normal work and involve them in collaborative project practices (Eriksson et al., 2017a).

Collaboration duration in infrastructure projects

The low frequency of construction projects and the separation of projects into different stages (which are often executed by multiple actors) make the duration dimension especially important in this empirical context (Crespin-Mazet and Portier, 2010; Martinsuo and Ahola, 2010). Prolonged collaboration duration may mainly be achieved in three ways: early involvement, long-term maintenance responsibilities, and/or long-term contracts spanning a series of subsequent projects. Findings from all four types of contracts support previous literature by indicating that early involvement of contractors in the design stage may improve efficiency through improved constructability, but it can also reduce delivery time due to parallel design and construction processes (Cheung et al., 2001; Eriksson, 2017; Park and Kwak, 2017). Early involvement of engineers and suppliers also provides contractors with greater possibilities for innovation than in traditional DBB contracts, because of fewer restrictions in the tendering documents and more time for development and innovation efforts before construction starts (Caldwell et al., 2009). However,

restrictions from initial planning and permit processes were found to reduce possibilities both for efficiency and for innovation in all four contract types, despite early involvement.

One drawback of early involvement in DB, DBM and DBFM contracts is that it generally results in increased costs for contractors' tendering (especially if a competitive dialogue procedure is used), whereas very early involvement in ECI contracts appears to reduce the tendering costs. Hence, the client may consider paying losing tenderers for participating in the tendering stage – which both STA and RWS have done in some of the case projects studied, although the sums were very low and did not cover the contractors' costs.

Long-term maintenance responsibilities may have both pros and cons. On the one hand, our findings support prior studies suggesting that DB(F)M contracts encourage stronger focus on quality and LCC, because the contractor has strong incentives to reduce maintenance costs due to poor quality and inferior technical solutions (Rose and Manley, 2012; Lenferink et al., 2013). Additionally, these contracts may enable innovation that reduces LCC and contractors' maintenance costs. In DB and ECI contracts, the contractor has no incentives for such innovations. On the other hand, long-term maintenance responsibilities may deter radical innovation due to the risk of malfunctions and costlier maintenance. Hence, the contractor is generally hesitant to test new solutions that are not verified. It seems that STA tried to encourage innovation in their DBM contracts, but this was not achieved to a large extent, while RWS did not explicitly encourage innovation in their DBFM contracts. Recent research in the railway sector indicates that many European clients (e.g., ProRail, Network Rail, and Deutche Bahn) do not encourage innovation in their infrastructure projects; instead, innovation is pursued in separate R&D projects (Eriksson et al., 2017b). This matter of origin and placing of innovation efforts is of strategic importance. Because R&D spending is generally low (Miozzo and Dewick, 2004; Reichstein et al., 2005), it may not be sufficient to pursue innovation only in separate R&D projects (Eriksson, 2013).

Another drawback of long duration is that it is difficult for contractors to price maintenance work *ex ante* in the tendering stage, due to the long duration of the contract. All five studied DBM and DBFM cases were based on fixed-price contracts, which according to Bajari and Tadelis (2001) are most suitable when the contractors can calculate bid prices with low-risk premiums. Prior research has found that the larger and longer the contract in DBFM projects, the higher the risks for cost overruns (Anastasopoulos et al., 2014). This is because the longer the contract duration, the more difficult it is to foresee all future contingencies and calculate an appropriate price. Hence, it can be anticipated that long contracts result in a lack of information about future contingencies and therefore larger risk premiums in tenders (Makovšek and Moszoro, 2017). This is arguably a larger problem in DBFM contracts than in DBM contracts because of the longer contract duration. To avoid unreasonably high-risk premiums, DBM contracts could be limited to 10-15 years; however, such a shorter period of time is often too short for DBFM contracts, where the client typically wants to spread out its costs over as long a period as possible.

Furthermore, DB(F)M contracts reduce efficiency and economies of scale during maintenance, compared with large regional maintenance contracts. This fact is difficult to address, but one way is to add adjacent maintenance objects to the DB(F)M contract – as exemplified in RWS's DBFM 3 project, where the maintenance of an existing parallel tunnel was added. (STA is currently also considering this strategy.)

In line with previous research, we found that collaboration mainly enhances inter-project learning related to both exploration and exploitation, whereas increased efficiency (through improved inter-project learning related to continuous improvements over time and across projects) is more difficult to achieve (Eriksson et al., 2017a). Implementation of these types of collaborative procurement strategies involves organisational change for all key actors, not least the client organisation. Hence, it is critical to adopt a long-term learning perspective when developing and implementing new strategies. Many of the studied projects can be regarded as pilot projects because the strategies and the resulting behaviours and

processes were new to the project actors. This study identified vital potential improvements in efficiency and innovation as a result of the chosen procurement strategies. It is, however, important to emphasise that these improvements are not automatically achieved. In fact, it seems very challenging to reap all the potential benefits of collaboration, and all actors, therefore, need to continuously improve their processes, routines and capabilities for managing collaborative projects. In line with arguments highlighted in prior studies, it seems critical for participating organisations to establish routines for inter-project learning and knowledge sharing (Eriksson and Leiringer, 2015). Both STA and RWS have during recent years realised the importance of establishing such routines and they are now, at least to some extent, able to learn from their experiences and improve their procurement strategies over time.

Collaboration intensity in infrastructure projects

In literature on supply chain integration, the intensity of collaboration – addressing both the strength and extent of the actors' collaboration – is a central dimension (Fabbe-Costes and Jahre, 2007; Flynn et al., 2010). In a construction project context, prior research on partnering arrangements emphasises the importance of intense or strong collaboration (e.g., Bayliss et al., 2004; Eriksson, 2015). An integrative mechanism that is often highlighted is a joint project office that enhances face-to-face communication (Bresnen and Marshall, 2002; Alderman and Ivory, 2007; Gil, 2009). Our findings illustrate that collaboration intensity was identified as positive for both efficiency and innovation. Specifically, collaboration based on co-location of project actors in joint office premises results both in faster development processes and in faster and improved joint decision-making. Furthermore, open-book administration and joint performance-management systems may increase the quality of communication while decreasing the administrative load.

However, improving collaboration intensity costs time and money. Hence, investments in an extensive collaboration model that involves many collaborative activities and technologies must match the project's size and other characteristics; the larger and the more complex the project, the more extensive the collaboration model. Because it takes time to engage in proactive collaborative activities, project actors may be tempted to skip them when facing strong time pressure. Findings from several of our cases illustrate that this tempting strategy is a short-term solution that may backfire in the longer run, because collaboration may be required for efficiency and innovation.

Furthermore, collaboration intensity may be influenced by contractual incentives (Bayliss et al., 2004). A challenge with ECI contracts is to design and implement contractual incentives that spur contractors to engage in joint innovation efforts to reduce costs already in the design stage, where the possibilities for innovation are the greatest. However, given that there is a sharing of gains and pains in Phase 2, the contractor has an incentive to inflate the target cost during Phase 1. There are no economic incentives to innovate before the target cost is agreed, and then it may be too late for major design changes. This, in turn, causes mistrust on the part of the client. It is also important to provide incentives for key aspects that may be unrelated to reducing investment costs. Prior research indicates that failure to incentivise contractors in areas other than project cost savings can result in sub-optimisations, such as poor quality and increased life-cycle costs (Rose and Manley, 2012). Hence, the strong focus on cost reductions in target cost contracts may be detrimental for other, more long-term aspects.

Conclusions and recommendations

A key assumption of this study is that the client's procurement strategies need to be tailored to the project characteristics and the circumstances at hand. A general rule of thumb, from the perspective of transaction

cost economics, is that the more challenging the project characteristics (e.g., complexity, uncertainty, customisation) the more collaboration is required among the project actors. Because many infrastructure projects are complex and uncertain endeavours, it is critical to establish collaboration that enhances flexibility, joint problem solving, joint risk management and knowledge sharing in project organisations. However, investments in collaborative activities and integrative contractual arrangements must also match project size and complexity in order to balance out the transaction costs.

It is not only the procurement strategy choice that is important, but also the understanding of how different aspects of the chosen strategy affect efficiency and innovation in infrastructure projects through four dimensions of collaboration – scope, depth, duration and intensity. Implementing these types of collaborative procurement strategies entails organisational change and learning for all actors involved. This change requires investments in routines, resources and capabilities for collaboration and organisational learning, both at the project level and at the firm level. Accordingly, public clients of infrastructure projects need to improve their knowledge of how collaborative procurement strategies can be designed and implemented in order to enhance efficiency and innovation. This study has therefore aimed at identifying, describing and discussing examples of efficiency and innovation and how they are connected to the four dimensions of collaboration. In this report, we have analysed and discussed four types of collaborative procurement strategies, integrating various combinations of actors. There are pros and cons to all four strategies, and there is no best strategy for all occasions. Hence, the examples presented and discussed here can give public clients guidance as to what positive and negative aspects may be encountered when implementing collaborative procurement strategies. In this way, this study aims to provide an improved understanding of the benefits and challenges inherent in different strategies and how they may influence efficiency and innovation through the four dimensions of collaboration.

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Appendix 1. Case descriptions

Case DB 1: Road 252 Hallstahammar-Surahammar

Summary

Construction period: 2016-2017

Contract sum/Estimated cost: SEK 210 million

Delivery system: Design-build (DB) contract

Reward system: Fixed price, bonus opportunities worth maximum SEK 6 million

Contractor selection: Open bid invitation and bid evaluation based on lowest price

Collaboration model: Basic collaboration model including a few collaborative tools and activities

Table 4. Procurement strategies in case DB 1

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

The existing road (Väg 252) had major flaws and is in need of both renovation and a new stretch due to a watercourse along the current road. While not a major road (only about 3 000-4 000 vehicles per day), it is an important link between two highways. The idea is to build a new road to replace the worst stretch of the current road. The project includes 8 km of new road, a 120-meter-long bridge over a small river, and a 2-km-long connection route to a smaller village.

The project was described as a typical road project where the need for innovation is rather low and the project size is too small for any major development efforts, e.g. of new coating types. The complexity of

the project was mainly due to the construction of the large bridge, which is built in a rather sensitive environment. Consequently, much work has been put into the design to solve both aesthetic and environmental issues, such as the water flow. The new road stretch also passed two moss areas that must not be drained, which increases the complexity. Nonetheless, the project can be characterised as having rather low complexity and there have not been any major changes during the project that will affect the outcome in any significant way.

Procurement strategies

Delivery system and contract type

The project was based on a design-build (DB) contract that was procured using conventional methods and procedures. The contract specifications were based on a mix of functional requirements and technical demands developed by a technical consultant and the client during the preliminary design stage. The contract includes a 10-year warranty period during which the contractor is responsible for the technical functions. The tendering documents regarding the large bridge include substantial technical requirements since it is built in a sensitive environment that requires environmental permissions. The client was actively involved in the design process managed by the contractor – not for control purposes, but rather to provide support and create good clarity for the contractor during the design stage.

Reward system

The reward system was based on a fixed price for the whole contract. However, the contract also included a smaller incentivisation section featuring bonus opportunities linked to a pre-determined list of criteria (based on criteria specified in STA's supplier evaluation system) addressing nine areas of varying importance. The most important area for this particular project was collaboration, for which an SEK 1 million bonus was available, followed by risk management and work environment. Innovation was one of the nine areas but, due to the project's characteristics, it was assigned a low importance – meaning the contractor's bonus for achieving innovation was less than for the abovementioned areas. The contractor could receive a maximum bonus of SEK 6 million if all criteria were met. There was also a traditional penalty based on time and quality.

Contractor selection

The procurement process was rather quick, due to a favourable market situation that was identified during market analysis. This quick procedure led to some challenges during the procurement of the contractor, since not all environmental and water permits were in place. The procurement was based on a conventional open bid procedure. Some basic requirements regarding the project's organisational settings existed but, due to their elementary nature, all contractors could easily fulfil them. During the tendering phase, the client arranged a dialogue process to reduce the uncertainty connected to the tendering documents. The bidders were allowed to book a meeting with the client, during the tendering phase, to discuss the documents. All questions asked and answered during these meetings became public as required by the public procurement legislation. Four contractors submitted tenders. The bid evaluation was based on price only, so the contractor with the lowest bid also won the contract.

Collaboration model

The contract assumed a rather ambitious level of collaboration between contractor, consultant and client in line with STA's current guidelines for basic collaboration (*samverkan bas*), although this project was procured before the current guidelines were put in place. Several collaborative tools and activities have been utilised: co-location in a joint project office, joint project planning and goal discussion, joint risk management workshops, and a conflict resolution model in case disputes arise. The conflict resolution model specified how different conflicts should be solved at different hierarchical levels.

Discussions were held from the outset the contract about key words and phrases that reflect the desired culture and how participants should act towards each other. Although the words and phrases chosen had no legal significance, they formed the basis of a partnering charter document, with a number of phrases that served as a guide for the actors' relationship, which all project participants signed.

Four dimensions of collaboration

None of the formal project objectives involved the achievement of a high degree of collaboration. Nevertheless, collaborative tools and activities, together with collaborative attitudes among the project participants, have contributed to the establishment of strong collaboration. Positive effects, such as minimal disagreements and the ability to adapt and solve problems at the construction site, can be seen as positive outcomes of the achieved collaborative climate.

Collaboration scope

The collaboration model with its tools and activities mainly included the client and the main contractor, due to their contractual agreement. This arrangement meant that it is their (client and contractor) responsibility to forward information to other involved actors. However, because the atmosphere has been open, the collaboration has (apart from formal activities) not been limited exclusively to the two main actors. Surveys about the collaboration and work environment are regularly sent not only to the client and main contractor but also to other involved actors, such as sub-contractors and consultants. The result reflects and confirms the substantial ambition for, and broad scope of, collaboration in this project.

Furthermore, the consultant (contracted by the contractor) has sometimes been involved in collaborative activities, since it shared the joint project office on a part-time basis. The contractor's design manager, however, states that "*it would have been preferable to have had the consultant located in the joint-office on a more regular basis since a lot of the problems that occurred could have been solved more easily*."

Collaboration depth

The collaboration reached from top management all the way down to the blue-collar workers that conduct the actual work on site. The client's project manager emphasised that the project "*promotes open communication and that everyone has a responsibility to contribute with their own experience*." Collaboration meetings were not exclusive to management, and several other hierarchical levels are represented. These representatives are responsible for bringing the information forward and spread it throughout the project organisation. Furthermore, the abovementioned surveys were replied to not only by managers but also by blue-collar workers of the main contractor and sub-contractors.

Collaboration duration

Because this project was based on a DB contract, the contractor was procured earlier than in a traditional DBB contract. The collaboration between the client and the contractor started at the outset of the DB contract and the client was significantly involved in the design stage. Due to continuous meetings and co-location, the collaboration has continued during the whole project duration. Although the contractor was procured rather early, it was not involved in creating the initial plans or securing the required permits for the road and its route (*vägplanen*), which limits the collaboration duration to some extent. Another aspect affecting the duration is that the contract had a prolonged warranty period of ten years, compared to the normal five years. The client often prescribes a longer warranty period for major road projects to decrease the risk of extensive maintenance work due to poor quality. Hence, the contractor has responsibility for the quality and function of the road for a longer period than is considered normal.

Collaboration intensity

The collaboration could be seen as rather intense and continuous, especially due to the co-location, which facilitated informal encounters and communication. Small talk in the joint coffee room contributed to collaborative problem-solving of complications arising at the construction site. Moreover, the signed agreement regarding a collaborative and open culture informed everyone about the kind of atmosphere expected during the project.

Both sides of the contract took part in creating this creative atmosphere from the outset of the project by conducting joint project planning and goal discussion. This activity created a common understanding of what the outcomes of the project should be and ensured that everyone was “aboard the same ship”. Another activity that has helped maintain the creative and open atmosphere was the continuous collaboration meetings during which the main actors discuss possible solutions to increase efficiency, quality, and other performance-related topics.

Project outcomes

Efficiency

The depth of the collaboration and the open atmosphere contributed to an effective solution process for the problems that arise daily at the construction site, i.e. the construction process has seldom been stopped due to minor daily problems. Minor problems have been solved at a low hierarchical level whereas larger problems have been brought up to management level.

Both the contractor’s and the client’s project management argued that the prolonged duration (based on the rather early involvement of the contractor) has been time-saving, due to the integration of design and production. This integration makes parallel processes possible and improves the constructability of the design solutions due to the involvement of production knowledge during design work.

However, although the actors are positive towards the early involvement of the contractor, the client states that the contractor did not conduct the work in an efficient way in the initial phase. This inefficiency resulted in a loss of time compared to the time schedule. However, this was followed up and discussed by the client and contractor during the project duration and the contractor made a strong effort to speed up the work. In the end, the project was completed on time and the road was opened several weeks ahead of schedule. The rather forced last part of the production stage was initiated by the contractor and contributed to a rather negative cost result for the contractor. The forced work in the last part of the

project was mostly due to a need to move the production personnel to other construction projects as quickly as possible.

The only mentioned negative side of choosing a DB contract, instead of a DBB contract, was the increased cost for contractors to submit tenders. Due to the early involvement, the contractors must perform some design and development work during the tender phase, in order to select technical solutions and calculate their costs. The contractors receive no compensation for submitting tenders, which makes it difficult for smaller contractors to prepare tenders due to the large expenses involved. The client's project manager expressed the opinion that these kinds of DB contracts could benefit from compensating contractors that submit an approved bid. This would increase the competition, which is vital for the sustainable development of the industry.

Even if the contractor enters the project early, the initial planning (*vägplanen*), including road corridor and permits, is already set and approved – which places many constraints on the project. This can limit the opportunities for optimising the production processes based on contractor experiences since the chosen road corridor made by the client might not be optimal from a production perspective.

Furthermore, the project managers argued that intense collaboration could be more efficient since the decisions can be made together and better solutions could be chosen. As a result of the intense collaboration, a file system for the quality and environment work was developed, in collaboration between the two actors, to increase the meeting efficiency. The list of client requirements in these areas was rather extensive. By structuring the requirements into various categories reflecting the different competencies and actors, the meetings became more efficient. This is a solution that the contractor will use in other projects, especially those with extensive client requirements.

The joint project office has contributed to a collaborative climate where small issues, both personal and task-related, seldom become major issues. The signed "collaborative agreement" was placed at the centre of the office, where everyone was constantly reminded of it. However, the extensive collaborative activities that are performed can be considered as rather expensive (due to the rather small contract size) and the managers mentioned that this project is almost too small for this type of effort. This difficult balance – between positive outcomes and cost – must be considered before deciding on the collaboration model that best suits the individual project.

Innovation

The project managers argued that this is a conventional project where the need for innovation was rather low. Although a collaborative climate can boost innovation, the project's relative simplicity (i.e. low task complexity and lack of extensive technical demands) does not drive participants to innovate.

Although the contractor was procured rather early, the fact that many requirements and constraints were already set and fixed when the contractor was procured limited the contractor's ability to affect the design, development and use of innovative production solutions. However, the contractor's early involvement did serve as a basis for making some minor innovations possible in the project. First, a new type of fast-growing vegetation (a type of wheat) that enhances the quality of slope vegetation was tested during the first year. This innovation was initiated by the contractor in the first year to reduce the destruction of slopes by heavy rain. The client was open to testing this solution because it was intended to increase slope quality and reduce the need for maintenance work by the contractor. Another innovation was a new, harder type of stone (porphyry) used in the asphalt to increase the road's lifespan. Road maintenance is often expensive and difficult to perform due to the ongoing traffic, which makes this type of innovation desirable to test. This solution was introduced during a creative discussion between actors in the project organisation.

Bringing the production knowledge into the collaboration at early stages made it possible to jointly develop the solution parallel to the early construction stage. Both of these innovations are related to product quality. Because of the longer duration of the warranty period, it was desirable for both actors to improve product quality to decrease the risk of major maintenance work.

The project managers stress that many (minor) creative ideas that are needed due to problems arising during production are easily handled through collaboration facilitated by the use of a joint project office. The client PM stated: "*We have experience, the contractor has experience, and working so tight and intensively [in the joint project office] creates a commitment where it is everyone's duty to actually contribute to the best of the project*."

General conclusions

The project has performed well in accordance to the client's pre-determined cost and quality goals and was finalised before the pre-determined time schedule. The collaboration between actors has worked satisfactorily. The project managers believe the procurement strategy and contract used were the right choices. The managers appear to invite openness and collaboration and everyone seems to enjoy working in the project, according to regular evaluation surveys. However, it is important to acknowledge the central role of individuals. In this project, the project management contains a well-functioning team that support each other and always put project outcomes before individual satisfaction. This is something that has less to do with procurement strategies than with the key participants' desire to perform well. The DB contract for this project was based on a mix of technical solutions and functional requirements, so the contractor's ability to be innovative can be considered as rather limited. However, major innovations were not required for the project to be a success due to the conventional project characteristics and low task complexity.

Case DB 2: Railway Strängnäs - Härad

Summary

Construction period: 2014-2018

Estimated cost: SEK 1.9 billion in total, of which railway project SEK 1 billion

Delivery system: Design-build (DB) contract, including all five main parts of a railway project

Reward system: Fixed price, except for cost reimbursement and a target cost for the tunnel

Contractor selection: Open invitation procedure and bid evaluation based on lowest price

Collaboration model: Basic collaboration model including a few collaborative tools and activities

Table 5. Procurement strategies in case DB 2

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

The Swedish Transport Administration (STA) was building double railway tracks between the towns of Strängnäs and Härad as the final component of "*Kraftsamling Mälardalen*", a program that seeks to increase traffic capacity on the *Svealandsbanan* (the Svealand Railway), which is a vital part of the transport infrastructure system in Sweden's *Mälardalen* (Mälaren Valley). The tracks were built and refurbished during the 1990s and are now electrified; however, a large part of the line only includes a single track, which does not fully meet the need for easy and fast transportation in this region. This double-track railway project was intended to increase punctuality as well as capacity, thus promoting regional development.

Public transport authorities in the region were to acquire new trains, and the plan was that this will facilitate commuting between the cities of Eskilstuna and Stockholm.

The Strängnäs-Härad project was divided into three sub-projects – railway, travel centre (i.e. train and bus station), and noise reduction plank for nearby residents. The case study mainly entails the railway part of the project, but since the travel centre is situated next to and above the railway tracks it has sometimes been difficult to separate those two; hence some overlaps between the sub-projects have occurred. The studied sub-project consists of civil engineering and groundwork (including a tunnel), tracks, electricity, signal system and telecommunication.

Procurement strategies

The Strängnäs-Härad project was divided into three main procurements, one for each sub-project. The client decided not to procure the travel centre and the railway in the same contract due to different legal handling of permits and documents. Although there could have been potential benefits associated with procuring the railway and travel centre together, the risk of delay for the plan and permits for the travel centre made the client procure the railway first so it would not be delayed by the time schedule for the travel centre. This study is focused on the procurement and construction of the railway sub-project.

Delivery system and contract type

The delivery system of the railway sub-project is based on a design-build (DB) contract, including all five main parts of railway work: construction work, tracks, electricity, signal system and telecommunication. These five parts are usually procured and contracted separately; notably, this was the first time that the approach of procuring all parts in a single DB contract had been used in Sweden. The procurement procedure was performed in 2012 and the DB contract was signed in 2013. Initially planned as a design-bid-build (DBB) contract, the sub-project was converted into a DB contract halfway through the design planning phase, when the project was selected by the client as a pilot. As a consequence, the client had more documents than needed for this type of procurement. Many of these abundant documents were submitted as information to the contractors with the tendering documents, but they did not have contractual status.

Reward system

The reward system is a combination of fixed price for the railway and cost reimbursement coupled with incentives (linked to a target cost) for the tunnel. The client used a target cost for the tunnel (due to the substantial uncertainty involved in underground and tunnelling work) to transfer some of the risk from the contractor to the client. The target cost was set by the client in the tendering documents, with a possibility for the bidding contractors to comment on the target cost (if it was unreasonably high or low) during the tendering phase. None of the tenderers commented on the target cost. The incentives involved a gain/pain sharing mechanism set at 70/30, that is, the client will take 70% of the gain/pain and the contractor will take 30%. The cost reimbursement part required open books. Hence, the client had access to the contractor's financial system and could, therefore, see all costs related to the tunnel. The target cost was increased during production due to unknown initial conditions.

Contractor selection

The contractor selection was based on an open invitation procedure and the bid evaluation was based on lowest price. Due to the unique set-up of the DB contract – which includes all five parts of a railway project and was the first DB contract used for a railway – the client had to start from scratch when developing the tendering documents. This resulted in a project specification containing several uncertainties and unclear descriptions. During the tendering phase, the client, therefore, held tendering dialogues with the bidding contractors. The long and extensive question-and-answer process (there were more than 200 questions) resulted in revised tendering documents that gave a much clearer picture of project requirements. The client subsequently received four bids that varied very little in terms of the submitted prices.

Collaboration model

Because the procurement documents did not specify any formal requirements for collaboration, the client was able to initiate a basic collaboration model. It contained various collaborative tools and activities – such as formulation of joint objectives, a partnering facilitator, regular surveys to measure collaborative climate, and a joint project office. The collaboration model was perceived to function well, especially the joint project office was considered valuable for collaboration to emerge.

Four dimensions of collaboration

The parties decided early in the project to focus on establishing a collaborative climate because this kind of contract had not previously been used for building railways in Sweden. The need for collaboration arose both from the new contract type and from the lack of earlier knowledge regarding how to realise the objectives. The collaborative tools and activities contributed to the establishment of a strong collaborative climate. Positive effects, such as few disagreements and high ability to adapt and solve problems at the construction site, seem to be results of the collaborative climate.

Collaboration scope

The collaboration mostly involved the client and the main contractor. However, because the DB contract included all five main parts of the railway project, it was important to include key sub-contractors in the collaboration. Accordingly, the scope of the collaboration was wider than in a traditionally procured railway project. The fact that subcontractors were co-located in the same joint project office facilitated informal collaboration between STA and subcontractors, for instance regarding safety issues, and the close proximity of the parties generally improved the efficiency of the project.

Collaboration depth

The two project managers (client and contractor) worked to set a collaborative tone for the project. All personnel of both the client and the contractor had access to the joint project office and saw each other on a daily basis, which enhanced the depth of collaboration.

After completion of the project, the client's maintenance department was to assume the maintenance responsibility for the new track. However, there was a lack of mutual planning between the construction project and the client's maintenance department, and this results in outcomes that are beneficial to the project but is less positive for maintenance. According to the client's project manager, although attempts

to invite the maintenance department were made at various stages of the planning phase, the initiative has failed, resulting in a low degree of involvement from maintenance personnel.

Collaboration duration

The contractor was procured earlier than usual due to the switch from a DBB contract to a DB contract. The collaboration duration, therefore, began earlier than usual and has been maintained throughout the project, thanks to the joint project office. At the beginning of the project, the collaboration started with a workshop led by a facilitator to set up the mutual goals for the project. Halfway through the project, a new workshop was held to revise the goals and motivate the actors to finish the project on time. "Goalkeepers" were appointed and made responsible for the continuous activities performed during project execution, which are required to meet set goals.

Collaboration intensity

The collaboration outlined in the contract was based on a mutual agreement to collaborate. The mutual goals, collaboration workshops, and joint project office have resulted in a positive collaboration climate and therefore a lower threshold to discuss different issues. The formal handling of issues through the use of notification has still been used to correctly document the ongoing project. The mix of informal and formal discussions has affected the outcome of the project in a positive way. However, some respondents expressed a preference for collaboration to be contractually mandated, so that the project could receive assistance and resources from the client's organisation. The informal collaboration model used in this project could perhaps have been at risk if any conflicts or other problems had arisen in regards to the "gentlemen's agreement" to implement the collaboration model.

The client and the contractor have jointly handled risk using this informal collaboration model. Usually, the risk assessment is dealt with separately by the parties and discussed during periodic meetings. In this project, however, the risks that are in the other party's domain are pointed out to create mutual awareness. The parties also engage in a mutual, direct handling of matters so that both benefit from solving efficiently – for instance, jointly seeking permission from a public authority, where both parties act to the benefit of the project and submit the application together.

External communication has been handled by a communications specialist employed by both parties. The specialist dealt with all complaints, which enabled key personnel to focus on the core tasks of the project.

Project outcomes

Efficiency

The project must accommodate standard train traffic running in the work area on the existing track. This affects both the work environment and the production planning, which needs to be made minute by minute so that the train-free time in the schedule is used as efficiently as possible. At the time of the study, the project has caused no disruptions or delays for the railway traffic. The contract states that the contractor has three weeks per year for a full train stoppage, but the contractor must apply 18 months in advance for this. Both planning and efficiency are affected when the contractor must either speed up the work to be able to use the planned stop or find other tasks for the workforce if the stop is scheduled later than needed.

In traditional DBB contracts, the client's construction supervisor has an active role in deciding how to conduct the work in this kind of project. In DB contracts the client has a person (consultant) with a monitoring role ("BPU") who instead monitors and follows up the ongoing work at the construction site. For DB contracts this BPU role is clear – no interference with the contractor's way of planning, designing or executing the work. However, in this project, the BPU has taken a more collaborative approach and has discussed different solutions and methods directly with the contractor. The responsibility for the solutions and methods discussed still lies with the contractor, but the discussions between the parties have been much appreciated and have resulted in better solutions for both parties when combining the competencies from both the client and the contractor. The depth of collaboration, based on interaction between the BPU and the contractor's site personnel, has therefore improved efficiency.

When asked what has affected the efficiency most in this project, the contractor's project manager mentioned the joint project office. The client's project manager and the contractor's design manager also emphasised the importance of the joint office to the project results and efficiency. The project office acts as the key mechanism for widening the scope of collaboration, enhancing informal encounters and discussions among all actors located in the office building.

The overall efficiency of this project does not appear to be higher than expected, but the time schedule seems to have been kept. The efficiency obtained must, of course, be regarded in the light of the pilot nature of the project and the initially poor and deficient tendering documents. The rather intense level of collaboration has helped even out the lower quality of the tender documents and has allowed the actors to avoid disputes arising from different interpretations of the deficient specifications.

Innovation

The client's project manager stated that the BPU has been more driven toward innovation and development of new work methods than the contractor. This could be because the client in this contract was not responsible for the chosen methods (DB contract), nor their budget effects (fixed price), and therefore can be more free-minded. In general, there seems to have been little focus on innovation.

The client suggested simpler and cheaper methods to the contractor during the design phase, with the result that the contractor wanted the client to take partial responsibility for the construction in question (the client refused, referring to the DB contract). Despite the fixed-price contract, the contractor has chosen to follow the original plan for the railway construction (which is based on well-known solutions) rather than trying the suggested simpler and cheaper methods.

At the beginning of the project, the contractor thought that it could find better and simpler solutions in all parts of the project, but this has not been the case. All the simple solutions demanded extra workload and more funding, leading the contractor to revert to the original plans.

One minor innovation was, for instance, a new type of noise reduction plank that was recently developed and replaced the six different types of plank originally designated for use in the project; this will have an impact on the client's maintenance later on, as they will only need spare parts for one plank instead of six different types.

Innovation in this project must be discussed in the light of the tasks that need to be performed. Railway construction is highly regulated and there is little room for variation. Railway tracks, height, switches, and so on are impossible for the contractor to change. That said, innovation could take place in the planning stage, or when considering work methods and materials (except for the switches). As the first design-build contract for a railway in Sweden, this project has, despite the narrow possibility for innovation, still contributed towards the practice of using design-build contracts in railways in Sweden.

General conclusions

The overall outcome of this project in regard to financial outcomes seems to have been positive for both client and contractor. The estimated cost of the entire sub-project was SEK 170 million below budget. There have not been any serious work injuries and the summarised survey responses have been positive. A key factor in this positive outcome appears to have been the mutual agreement to focus on solutions and to build a positive atmosphere of collaboration between the parties. However, the project was probably negatively affected by the poor quality of the tender documentation.

Cases ECI 1 Olskroken and ECI 2 Centralen in the West Link Project

Summary

ECI 1: West Link sub-project Olskroken

Construction period: 2018-2026

Contract sum/estimated cost: SEK 2.5-3.5 billion (EUR 250-350 billion)

Delivery system and contract type: ECI based on consultancy contract in Phase 1 with contract option for DB contract in Phase 2

Reward system: Cost reimbursement in Phase 1; in Phase 2, cost reimbursement coupled with an incentive mechanism connected to a target cost and a contractors' fee of 7%

Contractor selection: Restricted bid invitation procedure with pre-qualification, bid evaluation based on multiple criteria

Collaboration model: High level of collaboration in line with STA's guidelines

ECI 2: West Link sub-project Centralen

Construction period: 2018-2026

Contract sum/estimated cost: SEK 4.0-4.5 billion (EUR 400-450 billion)

Delivery system and contract type: ECI based on consultancy contract in Phase 1 with contract option for DB contract in Phase 2

Reward system: cost reimbursement in Phase 1; in Phase 2, cost reimbursement coupled with an incentive mechanism connected to a target cost. A gain/pain share ratio of 80/20 and a contractors' fee of 7%

Contractor selection: Restricted bid invitation procedure with pre-qualification, bid evaluation based on multiple criteria

Collaboration model: High level of collaboration in line with STA's guidelines

Project overview

The West Link project comprises a railway tunnel and three underground stations in the city of Göteborg, Sweden's second-largest city. The facility will serve commuter trains for public transport and the planned railway stretch is approximately 8 km, of which 6 km is underground. The new tunnel will increase the total capacity of the central station, which also serves long-distance traffic, and create two additional stations. It will reduce the vulnerability of the railway system and reinforce the local transport system.

The West Link is one of STA's main investments and is being carried out by its Major Projects division. The project is perceived as extremely technically advanced from a structural engineering point of view. The depth and width of the excavations, in combination with an underground that consists partly of loosely

compacted clay, are unique by Swedish standards. Further, the tunnel is being constructed in an inner-city environment and considerable attention has to be given to cultural heritage, city logistics and the natural environment.

When developing the procurement strategy for the West Link project, the project management team performed extensive market research in order to decide how to partition the contracts, and also what delivery system, reward system and collaboration model would be best for each contract. In line with STA's strategy of attracting international tenderers, the Project Director and the purchasing manager met with 23 suppliers from 11 countries during 2013. They also made study visits and exchanged experiences with similar projects in Sweden and six other countries. This market dialogue and research established that contracts should be worth at least SEK 3 billion in order to be of interest to international suppliers not yet present on the Swedish market, and also that the contractors were in favour of collaborative contracting models.

Table 6. Procurement strategies in cases ECI 1 and ECI 2

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

The West Link can be considered a "megaproject" with a total estimated project budget of SEK 24 billion (EUR 2.4 billion) and is divided into six sub-projects: four very large projects, one smaller but complex project, and one TEST (track, electricity, signalling and telecommunication) project for the whole stretch. The ECI contract model was selected for two of the large civil engineering projects, while DB contracts were used for the other three civil engineering projects and a DBB contract for the TEST project.

The West Link contracts described here are the two ECI contracts, Olskroken (ECI 1) and Centralen (Central Station, ECI 2), which were the first large contracts in the megaproject to be procured. Both contracts, while complex, were originally planned to have a shorter time-span than the other contracts. With ECI it was possible to engage the contractor for the design stage before the final permits had been obtained.

Olskroken (ECI 1) encompasses a railway area northeast of the central station where five tracks meet. The purpose of ECI 1 is to create new tracks at different levels and separate freight and passenger traffic. The

project involves the construction and reconstruction of 7 km of rails as well as a large number of switches and 17 new bridges for trains, road traffic and pedestrians. Since the traffic will be running during construction, extensive temporary provisions are included. Important challenges in this project are related to logistics and rail traffic control. The contract was signed in December 2015 and the project activities started in spring 2016. Phase 1 was planned to end in June 2017 and production start was planned for 2018.

ECI 2 comprises the construction of a new underground station for commuter trains, below the existing Central station and bus terminal, as well as a tunnel section for berthing tracks. The geological conditions for ECI 2 require large constructions in clay, which will be performed by the cut-and-cover method. The contract was not signed until May 2016 due to a court review procedure in February of that year. The project activities started in autumn 2016 and Phase 1 was planned to end in June 2017. Start of production was planned for 2018.

Procurement strategy

The West Link project was the first STA project to use an approach where collaboration ambitions affected much more than the collaboration model. The procurement strategy included a delivery system, a reward system, and a contractor selection procedure that were adapted to encourage collaboration. Similar models were used for ECI 1 and 2.

Delivery system and contract type

In the delivery system used by STA for the West Link ECI contracts, two separate contracts are set up for Phase 1 and Phase 2. In Phase 1, the contractor is engaged by a consultancy contract, which is regulated by the Swedish General Conditions of Contract for Consulting Agreements (ABK 09). In Phase 2, the contractor is re-engaged by a design-build (DB) contract, which is regulated by the Swedish General Conditions of Contract for Design and Construct Contracts (ABT 06). A “collaboration contract” connects the two contracts. In Sweden, this type of model has been supported by the Swedish Construction Clients Federation and is common in the building sector but not for infrastructure.

Reward system

In Phase 1, the contractors were reimbursed based on incurred costs, i.e. salary and sub-consultants’ fees plus the agreed contractor’s fee (i.e. a cost-plus contract). The reward system for Phase 2 was a cost-reimbursable contract connected to a target cost with a gain/pain arrangement, plus a fee covering risk, overheads and profits. This fee was set as a percentage of the construction costs and the sharing ratio was initially established at 50/50, but later adjusted to 80/20. The target cost was to be set during Phase 1 in collaboration between the parties.

Contractor selection

A restricted procurement procedure with prequalification was used. The award mechanism was designed to select the most economically advantageous tender, where quality criteria and price were weighted with a maximum of 70% and 30%, respectively.

Quality was evaluated on the following three criteria:

1. Competence in collaboration, based on:
   - A collaboration plan for Phase 1 and 2, describing how collaboration will be established and maintained – including 1) how to integrate the organisations of the client, the DB contractor and other suppliers; and 2) how the parties will collaborate in risk management, purchasing, cost control, and conflict management. (10 pages)
   - References for two individuals within the proposed team, with previous experience from collaborative contracts. (10 pages)
2. Proposed means of implementation for Phase 1, based on an implementation plan (10 pages) describing:
   - Organisational structure, identifying key individuals, the reason why they were chosen for this project, and their expected contribution. (15 pages)
   - A maximum of five critical areas, identified by the tenderer, including suggestions for how they should be handled in Phase 1. (10 pages)
   - The process for ensuring that the parties would arrive at a jointly agreed target cost. (5 pages)
3. Proposed means of implementation for Phase 2, based on an implementation plan (10 pages) describing:
   - A maximum of five project-specific areas critical to the construction stage, identified by the tenderer, and suggestions for how they should be handled in Phase 1. (10 pages)
   - Organisational structure for Phase 2, including how the transfer of knowledge from Phase 1 to Phase 2 will be ensured. (10 pages)

The price criterion consisted of a proposed contractors' fee, where 30 points were assigned to offers of 7% or less, and any proposed percentage over seven incurred a decrease in points – up to 12%, where no points were awarded.

The tenderers were also invited to present their tenders for three hours. The presentations were to be made by individuals intended to have key positions in the contract. The jury consisted of the Project Director, the project manager for the sub-project, one STA member of the steering group for the West Link project, and one external member from academia specialised in collaborative contracting.

For each contract around ten contractors submitted tenders for pre-qualification; of these, five were selected. Three contractors submitted final tenders for Olskroken/ECI 1 (two Swedish construction companies and one Italian-Swedish-British consortium) and four for Centralen/ECI 2 (two Swedish construction companies, one Swiss-German-Swedish consortium, and one Italian-Turkish-Swedish consortium).

For ECI 1, one of the Swedish contractors – Peab – won the contract. In this case, the price criterion was decisive: Peab proposed a 7% fee, which was lower than the other Swedish contractor NCC, which scored higher on the quality parameters, especially on collaboration. For ECI 2, all tenderers proposed a fee of 7%, and this time NCC was awarded the contract. However, one tenderer filed a court appeal. Although the appeal was unsuccessful, the sub-project ECI 2 was delayed during the review process.

Collaboration model

The collaboration model was defined on a general level in the tendering documents and the Collaboration contract, where it was stated that the project activities should be carried out by a Collaborative organisation involving the client, the contractor and key suppliers. A few processes and organisational aspects were specified in more detail: that there should be a Collaboration management group comprising two members from the client and two from the contractor, that this group should develop a goal document for the contract (in a process involving the wider Collaborative organisation), that a routine for conflict management should be established to prevent disputes, and that the Collaborative organisation should be located in joint office facilities close to the future construction site. The contractor was supposed to find and establish these premises.

Since STA's Project Director and his group believed that the tenderers would be more experienced in collaborative contracting than the client, and also wanted to use the collaboration plan as a selection criterion, STA chose not to develop the collaboration model in more detail before procuring contractors. Instead, the collaboration model for each contract was proposed by the contractors in their tenders and was to be further developed in collaboration between the parties.

Four dimensions of collaboration

Collaboration scope

The ECI contract was established between the client and the design-build contractor, but the intention was that Phase 1 should involve all project parties with relevant knowledge in a collaborative design and planning process as well as in collaboration activities. These included design consultants and specialist contractors as well as client staff. Engineering design consultants were extensively involved, since Phase 1 takes place during the design stage, but key sub-contractors were as well. In ECI 1, Olskroken, the participation of the railway subcontractor was important. The intention is that both design consultants and sub-contractors will take an active part in the collaborative organisation also during the construction stage.

Collaboration depth

In the STA's Major Projects division, there are restrictions on how large the client organisation for a project can be. The size of the client organisation in the ECI 1 and ECI 2 contracts did not differ from that in a normal project of a similar size.

The Project Director of the West Link project had the overall responsibility for all six sub-projects. The client organisation was of a matrix type. Here, the majority of the STA employees were stationed within central functional (specialist) units, directly under the Project Director. Only a few STA representatives (around six in the ECI projects) were stationed in each sub-project. The project manager of each individual contract had to request resources from the central project administration and finances unit. Thus, responsibilities that the sub-projects normally would have handled internally (overall budget, resources, etc.) in the West Link project were handled by the functional units.

According to the Project Director, a matrix organisation enables a more efficient use of STA resources and a better overview of the megaproject. Further, work practices will vary less between the sub-projects. The matrix's organisation, however, implied that STA members from the functional units were not automatically involved in the collaborative activities.

In both contracts, contractors perceived the client resources during Phase 1 to be insufficient, and the client as well had expected broader participation from contractor and consultants.

Collaboration duration

The aim of Early Contractor Involvement (ECI) is that the contractors are involved early enough to bring their knowledge of construction methods and costs to the design process. The model engages contractors earlier than in design-build (DB) contracts. In the prior design stage of the West Link project, the STA project management had urged the design consultants not to be too detailed in their designs in order to allow for input from contractors. However, the Swedish planning and permit processes for infrastructure projects require many parameters to be set in the preceding planning and conceptual design stage, which limits the degree of freedom.

Collaboration intensity

As already mentioned, the development of the collaboration models began when the contractors were engaged. Thus, the collaboration models – and consequently the intensity of collaboration – varied between the two contracts.

ECI was a new type of collaborative arrangement for both STA and the other parties, which implied many organisational challenges. An important aspect influencing collaboration intensity was that both projects experienced difficulties in defining integrated processes for jointly producing a target cost. Given the sharing of gains and pains, the contractors had an incentive to inflate the target cost. This, in turn, caused mistrust on the part of the client and an important issue was to clarify what open books mean and how the STA could get insight in the estimation process despite their limited resources. The sharing ratio was adjusted to 80/20 to reduce contractors' risks, but the process of setting the target cost still hampered collaboration during Phase 1 in both contracts. For ECI 2, the Central Station, the contract for Phase 2 was eventually signed in March 2018, a delay of 9 months.

ECI 1

The winning contractor for the ECI 1 contract did not have a company-level collaboration model and had not fully defined the collaboration model in the tender. Thus, the model was developed in collaboration with STA after the contract was signed. The parties also jointly agreed to appoint an external partnering facilitator. The collaboration started with discussions and a start-up meeting led by the partnering facilitator. The parties formulated mutual objectives which were documented in a partnering declaration. A joint office was established, although it took a few months for the contractor to find suitable premises. Further, there was no project studio and the office space could only accommodate the project management team and not the design consultants and sub-contractors. Thus, key participants were left out of the co-location for lack of space.

The collaboration worked out well from the start, but soon it was found that the initial organisation scheme and meeting structure were not optimal. Thus, after a few months, a new joint forum was established where the different areas of activity could meet regularly in order to facilitate and speed up decision-making. According to interviewees, however, the formalised activities and partnering facilitators were perhaps not most important in getting a working organisation in place; rather, it was the fact that the parties got to know each other through co-location. Thus, the lack of space was perceived as a significant obstacle.

ECI 2

The contractor of ECI 2, as a company, had a high profile in collaborative contracting and extensive experience of working in partnering projects. They had a standard collaboration model, and the parties saw no need to adjust it jointly. The option of appointing an external partnering facilitator was discussed, but the parties decided to use the contractor's internal facilitator, who had been involved in developing the tender. In ECI 2, co-location was in place fairly soon, about a month after start-up. The office space was larger than for ECI 1 and could accommodate the personnel resources needed as well as big meetings. A project studio was installed, where key project functions were to meet once a week to jointly plan the project activities. The project studio can be described as a key mechanism enhancing Integrated Concurrent Engineering (ICE) and the scope of collaboration since design consultants who were not co-located could be involved in the project studio activities.

However, the project did not follow through the ambitious collaboration plan outlined in the tender. A few partnering activities took place (such as discussions to establish roles and work models), and an initial workshop to establish joint objectives was held some months after the project start. However, the project studio was not used fully as intended. One reason for not following the planned collaboration model was that the already limited timeframe was further shortened by the appeal to the court. It also turned out that some key managerial staff on both sides did not consider relationship-building activities to be important. Thus, when the review procedure was concluded, the parties focused on starting up design activities. However, although roles and relationships on the managerial level were quite traditional, a functional interdisciplinary collaboration was established between engineers on the operational level.

The attitudes and relational problems were reflected in how the shared office space was used. STA's sub-project manager did not use the joint office, and staff members from each organisation were placed together in separate clusters. After some months, the contractor's Project Director was replaced and the partnering activities were then reinitiated. The STA Project Director further instructed his staff to mix with the staff from the contractor and the design consultants in the shared office. However, relationships did not improve much until the contract for Phase 2 was signed. At this point, the STA Project Director perceived a significant change in the collaboration climate, which he attributed primarily to the contractual aspects. At the same time, a few more staff that had been resisting collaboration were transferred from the project.

Project Outcomes

Efficiency

The ECI model increases efficiency by economising in the procurement processes since the contractors tendering for an ECI contract do not need to develop and calculate the cost of a full design, which they have to do in a DB contract. In the West Link contracts, tenderers had to propose collaborative processes and identify and submit suggested solutions for critical areas. According to the contractors, this required about 10% of the resources needed for a design-build project of similar size and complexity.

The rationale for STA's ECI approach relies heavily on efficiency aspects. The early engagement of the contractor enables parties with complementary skills and competences to sit down and discuss solutions and ideas, which facilitates an understanding of the other parties' roles and drivers. Several respondents within the studied projects emphasised that the mix of professions and competences stimulated and enhanced innovative solutions for the projects. The project studio was seen as important in this respect. More generally, co-location was stated as a key enabler of collaboration: that partners meet regularly

means that they get to know each other and interact outside of formalised activities such as meetings. This leads to a daily interaction where problems or questions may be sorted out immediately, preventing the issue to delay the project. Accordingly, the abovementioned shortcomings with the project offices in both projects somewhat hampered collaboration, in terms of both intensity and scope. Furthermore, project participants emphasised that the client has an important role in "greasing the wheels" of the decision machinery and facilitating the work done by other parties. However, especially in ECI 1, where collaboration was established as intended, the lack of sufficient client resources was perceived to be a major obstacle to efficient decision-making.

In ECI 1, there was a continuous development of roles and working processes to increase efficiency in decision-making. However, in both contracts, there have been some questions related to the internal efficiency of driving the design and planning work in Phase 1. One aspect was the cost of the design organisation, where STA perceived that the incentives for contractors to optimise the total project organisation in Phase 1, including the contractors' own staff, were too weak. Also, STA perceived that they needed to clarify the leading role of the design-build contractor in relation to the design consultants in the design process. In a traditional project, STA leads the design process and the design consultants, but the contractors had less experience in design management in a design-build ECI contract, where this responsibility falls mainly on the contractor.

There are as of yet no data covering the construction phase in in the two projects studied. In an ECI contract, however, efficiency in the construction phase (Phase 2) is expected to increase compared to a traditional DBB project since the contractor has reviewed and adjusted the design to increase constructability. Further, many compensation events and the associated negotiations and potential conflicts are eliminated. The jointly agreed target cost will only be adjusted for major changes, and joint risk management should enable more efficient risk prevention.

Innovation

Both efficiency and innovation were more prominent in the ECI 1 contract, where the collaboration was more developed than in ECI 2. In terms of innovation, STA had only expected adjustments to the original design, mainly because the railway corridor was already set along with numerous other restrictions. In the ECI 1 contract, however, a design consultant came up with an idea for a major design change that solved several problems in the original design. The new solution included the elimination of one bridge and the opportunity to avoid entering a nature area of national interest, and was possible to implement only because the proposed design fit within the legally binding rail corridor. It carried considerable environmental benefits as well as important cost reductions. Thus, the wider collaboration scope, involving also consultants, in combination with the early involvement, enabled a high degree of innovation. In addition to this major change, there were numerous design-based improvements of a smaller magnitude, such as reducing dimensions of construction components, thereby also contributing to environmental sustainability. However, innovation and improvement initiatives were strongly focused on the goal of reducing investment costs. Although this was not explicitly stated, innovations that lead to increases in quality, for example, improved city logistics or lower environmental impact, were only considered if they also reduced costs. This applied also to solutions associated with lower life-cycle costs.

Regarding drivers for innovation, several project members stated that the engineers were strongly motivated by a creative environment and the opportunity to collaborate with skilled experts in various fields. For the design consultants, for example, direct contact with contractors with production knowledge had been inspiring. A "best for the project" attitude was perceived as important in order to establish an open environment where all competences could meet and contribute. Interviewees also emphasised,

however, that an important condition for such value-enhancing collaboration is that there is enough time available to question and reconsider existing solutions. Consequently, lack of time was identified as a major obstacle to creativity and innovation in the two contracts.

As already mentioned, the financial aspects of the ECI contracts created a complex incentive structure which caused discussions; this was also the case in ECI 1, where collaboration otherwise worked well. In effect, there were no financial incentives for innovation in Phase 1, when the potential for innovation is the highest. Many innovations have a short window of opportunity – if an idea is not acted upon quickly, it is lost. Also, it was perceived as unfair that the contractor in ECI 1 could not be rewarded for the important innovation in Phase 1.

General conclusions

This type of ECI arrangement was new to many organisations and individuals participating in the West Link project. ECI 1 and ECI 2 were the first two contracts that STA procured of this kind, which makes them somewhat of a "test round" where difficulties and unforeseen consequences will undoubtedly arise. That said, ECI 1 and ECI 2 were described by the STA project management as paving the way for further ECI contracts. Similarly, the national and international market dialogues conducted by the STA to establish the procurement strategy clearly showed that the industry is requesting more collaborative contracting models and believes that such models would be more common in the future. The high-level contractor managers interviewed perceived the two West Link ECI contracts as game-changers of national importance and said that failure was not an option for these first contracts.

The two cases show that the STA application of the ECI model has its potential benefits in complex and uncertain projects, but also challenges. The major design change in ECI 1 demonstrates the value of bringing in the contractors and their design teams early, and the lower tendering cost is an important advantage compared to a traditional DB contract. Most employees appreciated working in a more collaborative way and perceived that their competence increased through closer contact with other disciplines. Collaboration is also better suited to making use of new communication technology such as Building Information Modelling (BIM) and Virtual Design and Construction (VDC). However, there is an important improvement potential in designing and preparing the client organisation, fine-tuning contracts, and organising co-location and project studio work.

Several other STA projects plan to use the ECI strategy after the two West Link contracts are procured. A category manager at the central purchasing unit was responsible for developing the ECI concept, and a range of adaptions was introduced based on both the experiences of the West Link project and discussions with other STA project managers and contractors. First, it was decided that the sharing ratio should be 80/20 (with 80% of the risk and reward going to the client). Further, STA has now clearly defined what is included in the fixed percentage fee, which reduces uncertainty for contractors; the minimum fee is now 8%. In the most recent project, STA has disclosed its own target cost and introduced a maximum bonus of 3% of this sum to reward contractors that come up with improvement suggestions during Phase 1. Another suggested possibility, which has been used in the building sector, is not to have a gain-share/pain-share mechanism at all, rather only a fixed part and a cost-reimbursable part.

Additional future development areas were also identified. One regarded the need for STA to have sufficient competence for cost estimation – a jointly agreed target cost requires such resources. Also, a structure and process for matching internal competence with project needs was requested.

Another aspect is what kinds of innovation are encouraged in this project environment. It could be argued that innovations sought in the ECI projects were innovations that could reduce cost in production and shorten production time. On a higher level, STA will need to consider how innovations that are more costly but positive for sustainability, general public (disturbances, accessibility) or lifecycle costs can be encouraged.

Case DBM 1: Norrortsleden

Summary

Construction period: 2005-2008

Maintenance period: 2008-2023

Estimated cost: SEK 575 million in investment cost, SEK 140 million in maintenance

Delivery system: Design-build-maintenance (DBM) contract

Reward system: Fixed price for the investment, except for cost reimbursement and a target cost for the tunnel, and yearly payments for maintenance

Contractor selection: Restricted procedure with pre-qualification, and bid evaluation based on multiple criteria, but mostly lowest price

Collaboration model: Basic collaboration model including a few collaborative tools and activities

7. Procurement strategies in case DBM 1

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

This case study focuses on a DBM contract that was part of a larger Norrortsleden project in which the STA aimed to increase traffic capacity east of the E4 highway. The Norrortsleden project involved more than 20 km of new roads and was divided into several parts, of which the DBM contract was the largest. The

DBM contract included a 7 km stretch of new road, of which 1 km was tunnel. All technical systems in the tunnel were included in the DBM contract, which also involved 15 years of maintenance.

Norrortsleden is STA's first DBM contract and was therefore viewed as a pilot project. In the early preparation stage of the project, PPP arrangements, in terms of DBFM contracts, were intensively discussed and Norrortsleden was identified as a suitable project for testing PPP. During this period the political climate changed, which resulted in a political stalemate where private funding of infrastructure was no longer an option. However, the project management group at STA decided they did not wish to give up on the idea of letting the private sector take on more responsibility. Hence, they skipped the "F" in "DBFM" (i.e., the private financing), but kept the "M" (i.e., the maintenance). In this way, it was decided that Norrortsleden was going to be a pilot project where STA would test DBM contracts for the first time.

Procurement strategies

Delivery system and contract type

The delivery system of the sub-project in focus here was based on a design-build-maintain (DBM) contract, including tunnelling and the technical systems in the tunnel. The contract was rather restrictive in that it included over 650 technical requirements (*skall-krav*) in 15 different technical areas. These requirements were of varying nature: some were general and broad (e.g., the landscape architecture), and some were very detailed and specific (e.g., prescribing a certain type of valve). Accordingly, in many respects, the contractor's degree of freedom was very limited.

Reward system

The reward system is a combination of fixed price for the main part of the project and cost reimbursement coupled with incentives connected to a target cost for the tunnelling work. The client used cost reimbursement for the tunnel, due to the high uncertainty involved with underground and tunnelling work, to transfer some of the risk from the contractor to the client. The maintenance part of the contract is also rewarded by a fixed price, but through yearly payments.

Contractor selection

The contractor selection was based on a restricted procedure with a pre-qualification stage. It is very expensive to prepare bids for this type of contract. Hence, the client wanted to limit the number of bidders to attract a few capable contractors rather than many contractors potentially incapable of performing this integrated contract. The client's project director emphasises: "*We started with a prequalification to limit [the number of bidders]. It was a rather big contract and a lot of work to make a bid for such a contract. It was probably considerate to do a prequalification. There were foreign companies who said that if there are ten bidders then there is no point in getting into this because then there is a lot of work and very little chance of getting the job*." The prequalification resulted in the selection of three competent and capable contractors, which were invited to submit tenders.

The subsequent bid evaluation was mostly based on lowest price, but some softer parameters were also evaluated (e.g., organisation and bid presentation). Due to the unique set-up of the DBM contract, the client had to start from scratch when developing the tendering documents. The client's project management team put a good deal of effort into the work, which resulted in a project specification of relatively good quality. During the tendering phase, the client held tendering dialogues with the bidding

contractors to further reduce uncertainties and misunderstandings. The process of questions and answers resulted in some complements to tendering documentation that resulted in even clearer language in the tender with lower uncertainties. The client subsequently received three high-quality bids that varied little in terms of the submitted prices. In the end, the contractor with the lowest bid price was selected.

Collaboration model

The client initiated an extensive collaboration model comprising several collaborative tools and activities, such as formulation of joint objectives, a partnering facilitator, continuous surveys to evaluate the collaborative climate, continuous collaboration workshops, joint risk management, a dispute resolution forum, and a joint project office.

Four dimensions of collaboration

The parties decided early in the project to focus on establishing a collaborative climate because this kind of DBM contract had not been used previously in Sweden. The need for collaboration originated partly because of the new contract type and the lack of earlier knowledge of how to realise the project objectives, and partly because the client wanted to support the contractor in the integration of design, build and maintenance activities.

Collaboration scope

The collaboration mostly involved the client and the main contractor. However, since this was a new type of contract, the contractor did not have internal design competences and resources to allocate to the project. Hence, external design consultants played a major role. The collaboration with the consultants was somewhat problematic at the beginning of the project because they were used to working with the client on DBB projects. Because they were inexperienced in working with the contractor on DB(M) projects, they continued working as if they were working for the client, which was frustrating for the contractor. Over time, however, the collaboration grew stronger and during the second half of the project, the main actors collaborated well. Accordingly, the scope of the collaboration was a bit wider than in a traditionally procured DBB project. However, subcontractors were not co-located in the same joint project office and rarely took part in the collaborative activities.

Collaboration depth

Prior to this contract, STA mostly procured DBB contracts. Hence, this contract can be regarded as a major change, because it not only integrated design and construction in a DB contract but also added the maintenance. Due to the pilot nature of the project, STA decided to allocate the same amount of resources to the project as it would to a traditional DBB project. Accordingly, throughout the project duration, the client's project management team was strong in terms of the amount of people involved and the number of different roles and competences. The client, therefore, had sufficient human resources to fully support the contractor.

The contractor's project manager made no explicit effort to spread the collaborative climate downwards in the organisation to blue-collar workers. However, the project manager highlights that she always tries to involve them in important discussions to get their input and reap the benefits of their production experience. Furthermore, she claims that the blue-collar workers must have felt that the project had a collaborative climate without harmful disputes: "*We always involve our site workers because they have*

very much knowledge and have a great ability to provide input to our discussions. They probably felt that it was a project carried out in harmony without any major conflicts; everybody notices that."

Due to the integration of maintenance in the contract, both the client and the contractor tried to involve their maintenance functions in the project. According to the client's project manager, attempts were made to invite the maintenance department, to help inform the planning stage. However, the initiative was not very successful. Apparently, the client's maintenance department did not support the new DBM approach, in which their traditional maintenance responsibilities were turned over to the contractor. Because the maintenance responsibilities were not in the hands of STA's maintenance department, they were sceptical about engaging with the project. The DBM contracting approach became an excuse to not get involved in the project. The contractor had similar difficulties in trying to involve its maintenance department. Accordingly, although the integrative nature of the contract resulted in somewhat deeper collaboration between the client and contractor organisations, the collaboration depth was not as deep as the project management hoped for.

Collaboration duration

The contractor was procured somewhat earlier than what is considered normal, due to the switch from DBB to DBM contract. The collaboration duration, therefore, began earlier than usual and has been maintained throughout the project, thanks to the joint project office. At the beginning of the project, the collaboration started with a workshop to establish joint project objectives, and throughout the project, there have been collaboration workshops to follow up on the objectives and the collaborative climate.

The integration of maintenance in the contract has a major impact on collaboration duration since the contractor is responsible for maintaining the road for 15 years after project completion. However, although the contractor is responsible, they will not carry out the actual maintenance work. In fact, they have outsourced this service to the company that has the maintenance contract for the surrounding road area. A major problem with this DBM contract is that it is too small: although the technical systems in the tunnel require more maintenance work than a normal road, a stretch of road only 7 km long is too short to obtain any economies of scale. This was highlighted by the contractor's project manager: *"From a maintenance perspective, 7 km is very short; it's nothing that you can build an organisation and a business around."* To remedy this, the client's project manager suggests that DBM contracts may be procured together with maintenance services in adjacent areas: "*In order to get more efficient maintenance work, you need larger objects, so you may want to add a maintenance area in connection with such a project to get a larger volume*."

Collaboration intensity

The rather extensive use of collaborative tools and activities has contributed to the establishment of a strong collaborative climate. Positive effects, such as minimal disagreements and high ability to adapt and solve problems at the construction site, could be the results of the collaborative climate. However, the fact that the reward system was based on a fixed price was perceived as negative for collaboration; there were no incentives for collaborating to improve efficiency and innovation to reduce costs. The contractor's project manager emphasises the importance of the reward system: "*I have worked in real collaborative contracts, and this is not one of them. Here we do not have collaboration in the contract, but there is an appendix regarding enhanced collaboration. But a fixed-price contract can never be a collaborative contract."*

Project outcomes

Efficiency

In general, the client and the contractor perceived that the project was executed with high efficiency, thanks to the good level of collaboration and the absence of disputes. Another aspect that enhanced efficiency and resulted in a robust product was the long duration of the maintenance contract, which facilitated a life cycle perspective and made the contractor somewhat more conscious regarding quality when choosing technical solutions and input material. The client is very pleased with the final product, as highlighted by the project manager: "*We have the feeling that the performance in this contract was very good. The contractor built for themselves. They were, for example, very careful when it came to packing the soil and selecting materials*." The contractor's project manager verifies their concern for LCC and exemplifies this in their choice of coating: "*It is a higher quality of coating than we would have chosen if it had been a traditional contract. We spent more resources and money on making a higher quality of coating to save time and costs during our 15 years [of maintenance]*."

Another factor that prompted this life-cycle perspective and a concern for a robust product was the penalties for closing the road for maintenance work. Because the contractor only has a limited number of occasions (11 nights per year) when they can close the road for performing maintenance, they want a product with high quality and minimised maintenance requirements.

The restricted road plan with a fixed road corridor makes it difficult for the contractor to plan and execute the production efficiently, especially regarding logistics and masses. With a more flexible road plan, the contractor could have adjusted the design of the road to minimise their transport of heavy masses and increase the reuse of blasted rock and gravel in the project. The contractor's project manager highlighted that it is especially important to involve the contractor early in this type of project, where the contractor has so much responsibility: "*In this type of project, you would like to come in earlier to participate in the planning process, because you can influence many things then.*"

In terms of exploitative learning and knowledge sharing, the experiences from this project were not captured and transferred to other projects. Because it was perceived as a pilot project, the client's project organisation made a strong effort to enhance the knowledge transfer to subsequent projects, but the client's project manager did not feel that their experiences were appreciated and absorbed by others: "*There was a lot of work done in documenting this project, a lot of work to develop tools. It took a lot of effort to create a database that was possible to use in other projects. We spent a lot of time developing, documenting, and preparing for others, but to my knowledge, it has never been used by anyone else and I think that's a shame, it was a waste of work for us*."

An illustrative example of the strong collaboration intensity was that the client held "good-advice meetings" in which the client gave important information and input to the consultants and contractor regarding the design solutions. Because of the delivery system, the client was not responsible for the design and could therefore not tell the other actors which solutions to choose. But they could give advice regarding their prior experiences with various solutions, including issues of quality and robustness. Accordingly, they took a supporting role rather than a directive or authoritative one. The client's project director explained: "*Even though the contractor was entirely responsible, we had decided that our specialists and project management should support them. Even if we leave the responsibility [to the contractor], we can still, for example, explain further how we have thought about the functional requirements. So there were no closed doors.*" The contractor perceived this support to be very beneficial and suggested that the client should generally engage more in the design stage of DB(M) projects by taking a more supportive role.

Innovation

The extent of innovation was not very great in the project, and not as great as the client had anticipated when planning the project. The client's project director explained that when their innovation ambitions failed to materialise, they were "*a bit disappointed. In advance, we were envisioning all sorts of things and engaging in totally unconventional thinking*."

A major reason for this was the rather restrictive tendering documents, which provided the contractor with a low degree of freedom. In fact, many of the functional requirements were similar to prescribed solutions. The client's project director explained how this had been a challenge within the client organisation: "*The technology specialists at STA were afraid to let go of the entire maintenance, as they were not sure what result they could expect and would have to rely on someone else. This resulted in the functional requirements becoming far too prescriptive; in practice, they were not functional requirements so much as complete solutions. We worked very much with this cultural aspect within our organisation*."

Another reason for limited innovation efforts was the intense time pressure in the project and, therefore, the limited amount of time that the contractor could spend on innovation work. The contractor's project manager emphasises the importance of time in relation to innovation efforts: "*It is a challenge to dare to take time to think about these technical solutions based on the functional requirements or to choose proven solutions that already existed; it is a challenge to make that choice – should we develop new technology or should we use our existing technology when we design*"? The contractor's project manager had discussed this issue with the client, pinpointing the importance of time for innovation work, but the client was mostly focused on innovations that could save time: "*I talked a lot with STA about having time to be innovative, but they do not really want to see like that. Instead, we should come up with these amazing solutions that will allow us to save time. We must not focus on innovation at the expense of time, but innovation must save time.*"

Another aspect that hindered innovation was the long-term maintenance responsibility. The contractor is less inclined to develop new solutions with less verified robustness, due to their responsibility to maintain the road for 15 years. New technical solutions that later on prove to be of inferior quality may cost more to maintain. The client's project manager understand how the maintenance responsibilities limited the contractor's willingness to innovate: "*With such a long time of responsibility and quite a short time to build, they don't dare to test things that are not proven. You might use proven technology in a new way, but you do not find completely crazy things. Obviously, you do not dare to do that*." The contractor's project manager verifies this concern: "*How innovative should we be and how safe should we be? Should we be safe and build a proven solution or should we be innovative and stick our neck out and come up with something new? We will maintain this road for 15 years, so we can't be too innovative; we must make sure that the solution you choose is safe and robust as well*."

The long duration of the maintenance contract may also be a challenge in terms of technical development during the life cycle of the road. It is important to discuss how new innovations can be incorporated and implemented so that the object, especially the technical systems in the tunnel, does not become obsolete during the contract duration. In this project, the client took a deliberate decision to pay separately for any such potential improvements to update the technology, because it would be impossible for the contractor to envision such potential developments during the tendering stage. As the client's project director stated, *"Another question is how we should handle innovation and technological development over the lifetime. One would like to see that if, for example, new, safer solutions are developed, they will be identified and implemented. However, we cannot ask the contractor to know in advance what it costs to keep up with the latest technology. Instead, we handle that as a regular change order."*

The biggest change in the project was the revised design for a traffic crossing that was based on two levels instead of the planned roundabout. During the first half of the project, the client began to realise that the planned crossroad solution based on a roundabout would not fulfil the traffic capacity requirement. During the second half of the project, the actors, therefore, decided to change this solution, which required new city planning and permits. Respondents from both the client and the contractor spoke enthusiastically about the resulting change process, in which all actors collaborated well to both go through the planning and permit process together and then build the new crossing. Hence, the intensity and scope of collaboration served as important foundations for this creative work. The contractor's project manager explained: "*Together we started a process of changing the city plan (*detaljplan*) with the three involved municipalities and going through a permit process, with all that this entails. We really went all-in – STA, the contractor, the consultants and the municipalities – to drive this planning process to make this change possible, and we succeeded….It was a big challenge but really fun."* The client's project director was also enthusiastic about this joint effort: "*The formal permit process and then the construction succeeded thanks to the excellent collaboration. It must be a Swedish record*."

Another innovative solution involved a traffic separation wall in the tunnel. In Sweden, oncoming traffic is not allowed in tunnels. However, STA lacked the budget and permits necessary to build two adjacent tunnels. Instead, the client decided that the traffic should be separated by a wall in the tunnel. The wall had to be both robust (to guard against fire and explosions) and able to be disassembled if it was decided to build another adjacent tunnel in the future. This technical solution was a big challenge for the contractor because it was the first time such a solution had been built in Sweden. The solution was based on prefabricated concrete elements that were assembled all along the tunnel stretch. The contractor's project manager described the situation: "*The time pressure was critical and we had more than 800 concrete elements spread around the whole region of Mälardalen on railway wagons, so we had to go out every night and count how many elements had come in."* Ultimately, although it was a creative solution that fulfilled the requirements, both the client and the contractor stated that it would have been better to build two tunnels if they had had the required budget and permits.

General conclusions

The project was considered successful by both the client and the contractor; it was finished within the budget and the time schedule and according to specifications. The client and contractor were also satisfied with their collaboration and joint solutions to challenges and changes, especially the new solution for traffic on different levels instead of a roundabout. The collaboration model thus served its purpose of enhancing collaboration, even though the project was based on a fixed-price contract.

However, the maintenance department in STA considers the maintenance costs a bit high and are not pleased that all authority and responsibility has been allocated to the contractor. From a maintenance perspective, the 7 km road stretch is also considered too small an object to maintain efficiently. Hence, the contractor has outsourced the maintenance work to another contractor that maintains the surrounding roads in the area.

Case DBM 2: Riksväg 50, Mjölby-Motala

Summary

Construction period: 2010-2013

Maintenance period: 2013-2033

Contract sum/Estimated cost: SEK 1 300 million

Delivery system: Design-build-maintain (DBM) contract with 20 years of operation and maintenance for road

Reward system: Fixed price, bonus opportunities worth maximum SEK 16 million for early completion

Contractor selection: Pre-qualification and bid evaluation based on lowest price

Collaboration model: Basic collaboration model including a few collaborative tools and activities

Table 8. Procurement strategies in case DBM 2

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

The Riksväg 50 Mjölby-Motala project, which was completed in 2013, included a new road stretch and was a part of "*Bana väg*", which is a major infrastructure investment in Sweden. The road is not a major road but is an important link between a smaller city and a highway. The idea was to build a new road to replace the worst stretch of the existing road. The project included 28 km of new road and connection routes, 39 smaller bridges, and a 600-meter-long bridge built over a city bay.

Although the project was a typical road project, the main difficulty lay in its location, which was rather sensitive to the surrounding natural environment and cultural values. The project, therefore, had certain expectations in terms of innovation. There was also some project complexity due to the construction of the large bridge, which had to be built in an urban environment. Consequently, much work went into the design to solve both aesthetic and environmental issues for both the road and the large bridge.

Nonetheless, the project could be characterised as having rather low complexity, and there was only one major change during the project that affected the outcome significantly: an unexpected groundwater level along part of the new road necessitated a new design for some of the planned bicycle tunnels.

Procurement strategies

Delivery system and contract type

The project was based on a design-build-maintain (DBM) contract, including an extensive operation and maintenance responsibility of 20 years for the road part. The contract specifications, developed by a technical consultant and the client during the preliminary design stage, were based on a mix of functional requirements and technical demands. Besides the extensive operation and maintenance responsibility for the road, the contract includes a ten-year warranty period for the other needed roads and a three-year warranty for bicycle and pedestrian roads, during which the contractor is responsible for the technical functions. The tendering documents regarding the large bridge contained a large number of technical demands since the bridge was to be built in a sensitive environment and would require environmental permissions. For this reason, the client was actively involved in the design process managed by the contractor. The tendering documents also included an extensive design program – including aesthetic criteria for bridges and other structures, which affected the appearance of the road – but at the same time, the client was open for new solutions. As the contractor's project director stated, *"We had good discussions about innovative solutions that had not been tested before, and these were carried out between contractor, consultant and client."*

Reward system

The reward system was based on a fixed price (~ SEK 1 300 million) for the whole contract. However, the contract also included an incentive: a bonus for early completion. The contractor would be awarded SEK 2 million for each week the road was opened ahead of schedule, with a maximum of SEK 16 million if the road was opened eight weeks or more before the scheduled opening – which the contractor succeeded in doing. The contract also stipulated traditional penalty fees based on time and quality.

Contractor selection

Due to the project's size, the procurement was based on a restricted procedure involving a pre-qualification on the basis of basic requirements for contractor revenue. All major contractors could not easily fulfil the requirements and therefore the pre-qualification closely resembled a conventional open-bid procedure. As the client's procurement officer explained, *"Pre-qualification in terms of revenue was established so we would not get tenders from small contractors that did not understand the seriousness of the project and that it was a major procurement."*

During the tendering phase, the client both performed marketing activities and arranged a dialogue process to reduce the uncertainty connected to the tendering documents and the extensive operation and

maintenance responsibility. The marketing activities were also a way to encourage large foreign contractors to submit tenders. Despite the marketing efforts, however, only two contractors submitted tenders. The bid evaluation was based on the sole criterion of lowest price, so the contractor with the lowest bid price also won the contract.

Collaboration model

The contract's envisioned level of collaboration between contractor, consultant and client was fairly low, involving only a few collaboration activities and tools. This set-up was in the lower region of STA's current guidelines for basic collaboration (*samverkan bas*), although this project was procured before the current guidelines were put in place. The collaborative tools and activities utilised were 1) the use of partnering facilitators (one from each organisation) in the early stages of the project and 2) joint project planning and goal discussion. The client's project director highlighted that "*We made no extravagant excursions to foster collaboration, we kept it on a local level"* – meaning that although the client and the contractor met frequently to discuss activities and structures, the collaboration was very limited.

Four dimensions of collaboration

None of the formal project objectives involved the achievement of a high level of collaboration. This, together with the fact that the client preferred to keep the collaboration limited to discussions, contributed to a rather low degree of collaboration from the standpoint of all four dimensions discussed in this section. However, respondents from both the client and the contractor mentioned that there were no major disagreements or conflicts between the two parties. The contractor also mentioned that the solution-oriented mindset of both contractual parties contributed to an open and creative atmosphere within the project organisation. Even though the level of collaboration might have been rather low, the atmosphere in the project contributed to a relatively high degree of innovativeness.

Collaboration scope

The collaboration in this project involved only the client and the main contractor, due to their contractual agreement. This arrangement meant it was their (client and contractor) responsibility to forward information to other involved actors. The client's preference to keep the collaboration on a low and local level further highlighted the exclusion of other actors from collaborative activities.

Collaboration depth

The project's collaboration was not deep in that it took place only at a high managerial level. The collaboration meetings held prior to the regular construction meetings included only the project director and project manager from each of the two contractual parties. This meant that only four people were actively involved in collaboration activities, none of whom were from lower levels in the project hierarchy. These representatives were therefore responsible for bringing the information forward and disseminating it throughout the project organisation.

The *internal* collaboration within the contractor organisation can, however, be seen as deeper, e.g. that between the project organisation and maintenance department. This extensive internal collaboration stemmed from the contract's stipulated long-term operation-and-maintenance responsibility, which required new solutions that focused on life-cycle costs rather than initial costs.

Collaboration duration

Because this project was based on a DBM contract, the contractor was procured earlier than in a traditional DBB contract. The collaboration between the client and the contractor started at the outset of the DBM contract and, due to continuous meetings, continued for the duration of the project. However, because the contractor was not involved in the formation of the initial plans and permits for the road and its route (*vägplanen*), early collaboration was limited to some extent. Nevertheless, the contractor was satisfied overall with the choice of a DBM contract and highlighted that it creates incentives for innovation. The contractor's project director stated: *"We feel that the DBM contract increases our driving force to truly achieve something and it should not be underestimated. The driving force to really work with technical solutions and the greater possibilities to influence; that creates interest."*

The fact that the contract included a long operation-and-maintenance responsibility of 20 years (compared to the normal five-year warranty period) also increased the incentive for both the client and contractor to develop and implement new, higher-quality solutions.

Collaboration intensity

The collaboration intensity was not very strong. There was no signed collaboration agreement (partnering charter) and, since the client removed the assigned partnering facilitators during the execution phase, the collaboration intensity became low. The client had no ambition to achieve a high degree of collaboration, and this affected this dimension significantly since the client is the one that manages the project. However, as stated previously, the strength of the internal collaboration at the contractor was high due to the need and possibility to develop solutions involving life-cycle perspectives. This focus on internal collaboration was consequently created by the DBM contract, based to a large extent on functional requirements including the long operation and maintenance responsibility applied by the client in this project. Co-creation requires intense collaboration, which is difficult to achieve when teams are not located under the same roof. To cite the contractor's project director, *"It has become more and more common to be co-located, and we see the [positive] effect of it – so that is something we could have done better here."*

Project outcomes

Efficiency

The joint goal discussion – that is, the effort made to create a common basis for understanding what to achieve in the project – contributed to efficiency. The joint goals were used as the basis both for follow-up meetings and for necessary adjustments throughout the project; this helped unite the project organisation and created a solution-oriented attitude wherein individual team members placed the project's interests ahead of their own. The DBM contract also made it possible for the contractor to integrate design and construction and conduct them in parallel with each other. This increased the efficiency of the process – and also helped improve constructability since the relevant parties were able to evaluate various solutions throughout the course of the project.

Because the contractor entered the project after the initial planning (*vägplanen*) was approved, the road corridor and permits placed many constraints on the project. This limited the opportunities for optimised production processes based on contractor experiences since the client's chosen road corridor might not be the optimal choice from a production perspective. To cite the contractor project director, *"The client has very high ambitions for DB(M) contracts and they chose this approach because they wish to be a 'pure'*

client and really only control the whole project – [whereas] we [the contractor] sought responsibility for the entire design stage and for managing consultants etc. I think this [separation of roles] is good, but if at the same time you have a system with detailed plans and permits [*the* vägplan]*, this means you as a contractor do not get enough freedom in the contract – you will not get the [desired] effect. This is very important to point out and I think still, the degree of freedom is low in this contract. It's too controlled."*

Another example of this occurred when the contractor asked whether they adjust the design for the 39 small bridges so that the bridge supports could be made straight. This would have facilitated the construction of the bridges significantly by allowing for the sequential manufacturing of the supports, which to a certain extent is a repeatable process. However, the late involvement of the contractor made this impossible to achieve at a reasonable cost and with a reasonable amount of effort. To cite the contractor's project director: *"If one is to achieve an expected result of the DB(M) contract form, then one must provide the conditions for it in the project. [The project needs] less detailed and more functional requirements – you have to let go of the detailed control."*

By contrast, the contractor also frequently mentioned that DBM contracts are positive in that the contractor can generally guide their consultants towards more buildable solutions that are suitable to the contractor's own production competence. The functional requirements that the client applied to many of the structures allowed the contractor to involve some of their own unique solutions. Two examples here are the use of the contractor's own innovative precast bridge design in two locations and also the use of their geotechnical expertise.

The long duration of the DBM contract also enhanced efficiency aspects, due to the life-cycle perspective that was required to handle the long operation and maintenance responsibility efficiently. The maintenance responsibility made the contractor especially aware of quality aspects, thus prompting them to prioritise life-cycle costs before investment costs. To cite the contractor's project director, *"we raised the quality far beyond what the norm [required], just to eliminate cost in the future [during operation and maintenance]."* The extensive operation and maintenance responsibility forced the contractor to involve their own maintenance department in the design, which affected some of the choices made.

One mentioned negative side effect of DB(M) contracts, compared to DBB contracts, is the increased cost for contractors to submit tenders. Due to their early involvement, the contractors must perform a certain amount of design and development work during the tender phase, in order to select technical solutions and calculate their costs. Unsuccessful contractors (i.e. those that did not win the contract) did receive some compensation for submission of an acceptable tender, but it was a small amount that did not cover the actual costs.

Innovation

The respondents argue that the DBM contract was a driving force for innovation, and the contractor had high hopes of achieving extensive innovations in the initial phase of the project. However, the reality became clear to the contractor during the startup meetings where the project goals were discussed. The client stated that, although they were open to innovation, it would not be possible to implement all the contractor's ideas; instead, the contractor would have to decide on a few ideas and really focus on them. To cite the contractor's project director: *"They [the client] probably had to slow us down because we wanted to change a lot and it would lead to extra work for them, so they said on some occasions that we must prioritise what we really want to push; [otherwise we would] turn the whole pre-design [process] upside-down."* This also shows that the contractor was procured rather late; the fact that many requirements and constraints had already been already fixed by the time the contractor was procured necessarily limited the contractor's ability to affect the design and development and use of all of its

innovative production solutions. According to the contractor's project director, it would have been better if the contractor had joined the project prior to the creation of the *vägplanen* (the initial plans and permits of the road and its route), and if the plans had contained more flexibility and fewer restrictions. He highlights that the people working with the initial plans and permits are not aware of the consequences: *"I actually believe that those who sit and optimise the road corridor do not fully understand the consequences – and then we are restricted by something that is not very good."*

Some major innovations did occur due to the DBM contract – innovations designed to decrease costs during operation and maintenance. The main one was an innovative solution for stabilising the road which required new technical knowledge. This solution was developed in response to the lack of suitable ground material along the new route, which traditionally is addressed by the rather expensive and time-consuming transport of material from other sites. The new technique involved mixing cement into the existing raw material to stabilise the material. The solution was initiated and developed by the contractor, which had in-house expertise in this subject, but also with the help of a professor from the Royal Institute of Technology (KTH). Although the technique had previously been used abroad, the Swedish client was initially sceptical because it had not been tested in Sweden before, at least not at this scale. The contractor's upper management therefore required evidence that this technique would work before it could be implemented in the project. The assigned development group collected evidence from previously conducted projects abroad and performed their own tests, after which an internal expert group validated the results. This validation was subsequently communicated to the client, who assigned their own reviewers to investigate it before the technique was finally approved and used in the project successfully.

This solution would have been impossible to perform in a DBB contract and with a client that did not have an open mind and belief in the competence of the contractor. The solution was time-consuming to validate but contributed to lowering both time and costs. The DBM contract made the contractor especially careful to validate that the solution was robust, in order to avoid cost during the maintenance phase.

The long operation and maintenance responsibility also contributed to the contractor's desire to save energy over the 20-year maintenance period (2013-2033). The client also put in some unusual requirements about the use of the latest technology in the tendering document. One solution that had not been used before and was under development during the project's early execution phase was LED lighting. The contractor had continuous discussions with the supplier (the developer of the technique) throughout the execution and knew that the possibility was there and made this a part of the deal. The contractor waited as long as possible before installing lights along the route so that the newest model of LED light could be used. This new technique was finally implemented in the project, which required the active involvement of designers. To cite the contractor's project director: *"It was stated that we [the contractor] shall use the latest technological developments that are possible, e.g. LED."* This requirement gave the contractor an incentive to wait for the parallel development of the LED technology that, in the end, is calculated to reduce the energy consumption by 50% in the operation and maintenance phase.

The DBM contract, together with the constructive dialogue between the client and the contractor, also resulted in the implementation of another innovation that both increased efficiency and decreased operation costs: the precast bridge concept discussed earlier in this case study. This solution was developed long before the project started and had been used occasionally in infrastructure projects before. The contractor suggested the concept mainly to decrease the costs during the extensive operation and maintenance phase, but the result also showed that the construction time decreased significantly. The two latter innovations were related to product quality and were initiated due to the longer duration of the operation and maintenance period. Consequently, it was desirable for both actors (contractor and client) to improve product quality to decrease the risk of major maintenance work. Neither of these systemic

innovations that affect actors throughout the supply chain would have been possible to implement if a DBB contract with pre-defined technical solutions had been used by the client.

General conclusions

The project performed well (i.e. the results were in accordance to the client's predetermined cost and quality goals) and was finished ahead of schedule. The actors had a satisfactory working relationship but there was relatively little collaboration. Both the contractor and the client believe the right choices were made with regard to procurement strategy and contract type. The DBM contract in this project was based on a mix of technical solutions and functional requirements, and the degree of freedom for the contractor to be innovative was relatively small, even though some larger innovations were implemented. It is also important to acknowledge the central role of individuals and their openness to innovation. In this project, the project management contained a well-functioning team that supported each other and always put project outcomes before individual satisfaction.

Case DBM 3: E4 - Sundsvall

Summary

Construction period: 2010-2014

Maintenance period: 2014-2034 (20 years)

Contract sum/Estimated cost: SEK 1 100 million

Delivery system: Design-build-maintain (DBM) contract with 20 years of operation and maintenance of road

Reward system: Fixed price, bonus opportunities worth SEK 30 million

Contractor selection: Open bid invitation and bid evaluation based on lowest price

Collaboration model: Basic collaboration model including very few collaborative tools and activities

Table 9. Procurement strategies in case DBM 3

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

The E4 - Sundsvall project (2010-2014) comprised a new stretch of road for a major highway in Sweden. The purpose of the project was to relocate the highway away from the current urban location to a location outside the Sundsvall city centre. The project included 24 small bridges along the new road.

It was a fairly typical road project that can be characterised as having relatively low complexity. However, it was located in an urban area, and the new stretch of road featured a lot of rock that needed to be blasted

away; also the new stretch had to be connected to a new large bridge over the bay in Sundsvall built in parallel by another contractor.

There was only one major change made during the project that affected the outcome significantly – a change stemming from the unexpectedly large amount of rock material found along the new road. In addition, unclear demands in the procurement documents resulted in a large number of change orders.

A DBM contract was chosen for the project for two reasons: the low project complexity and the fact that the client was trying to increase its usage of contracts that include both design and build components.

Procurement strategies

Delivery system and contract type

The project is based on a design-build-maintenance (DBM) contract. The contract was procured with conventional methods and procedures but included an extensive operation and maintenance responsibility of 20 years for the road part. The contract specifications, composed by a technical consultant and the client during the preliminary design phase, were based mainly on the large number of technical requirements, but also on functional requirements. The client was actively involved in the design process managed by the contractor due to the newness of this kind of contract. The aim of using the extensive operation and maintenance responsibility was to create an incentive for more sustainable solutions, as expressed by the client's project manager: *"It felt like their interest was a bit stronger to do something really good because they [the contractor] knew they would have to take care of the results for so long afterwards."* However, the difficulty of specifying a long maintenance period is that one does not know anything about the traffic situation that exists in the future. To cite the client's project manager: *"We built a road that meets the requirements now, but there will be something else that will use this road in 20 years – especially since the new standards will allow trucks to weigh 74 tons, instead of today's 64 tons."*

Reward system

The reward system was based on a fixed price for the whole contract. However, the contract also included an incentive: a bonus for early completion. The contractor would receive SEK 30 million if the project was completed one year or more ahead of schedule. The contractor's project manager strongly questioned this incentive because it encouraged the organisation to focus on money rather than on soft factors such as quality and the work environment: *"One thing that never should have been included in this contract was the bonus for early completion. It has messed up a lot for us. You cannot say that you prioritise the work environment if you set up such a bonus."* Traditional penalty costs based on time and quality were also included in the contract.

Contractor selection

The procurement was based on a conventional open-bid procedure. Some basic requirements regarding contractor competences/roles existed but, due to their elementary nature, all major contractors could easily fulfil them. The bid evaluation was based on lowest price and no other criteria were assessed when evaluating the tenders, so the contractor with the lowest tender price also won the contract. This strong focus on cost was something that the contractor project manager raised as negative for collaboration and other soft parameters. To ensure receipt of a sufficient number of tenders, the client also compensated the losing contractors for their work on the tenders because of their large expenses. However, the client

demanded certain things from the contractors in order to receive the compensation. To cite the client's project manager: *"We compensated the losing contractors for their tenders, but only under certain conditions; they should, for example, be within 20% of the winning tender [price]. Not everyone made that cut.*" Only two out of four contractors got this compensation from the client. During the tendering phase, the client arranged a dialogue process to reduce the uncertainty related to the tendering documents and the extensive operation and maintenance responsibility.

Collaboration model

The contract's envisioned level of collaboration between contractor, consultant and client was fairly low and involved only a few collaboration activities/tools. This approach was in the lower region of STA's current guidelines for basic collaboration (*samverkan bas*), although this project was procured before the current guideline was put in place. The collaborative tools and activities that were used in the contract were the result of collaboration meetings between the client and contractor during the project as well as joint project-planning and goal-setting discussions. The client's project director remarked that "*We made no extravagant cooperation trips, we kept it on a local level"*, meaning that the client and the contractor held continuous meetings about how to conduct activities and structures but no specific intention to facilitate co-creation.

Four dimensions of collaboration

None of the formal project objectives involves the achievement of a high level of collaboration. This, together with the fact that the client liked to keep the collaboration in the format of limited discussions, only involving high management levels from both contractual parties, contributed to a rather low degree of collaboration from the standpoint of all four dimensions discussed in this section. However, respondents from both the client and the contractor mentioned that there were no major disagreements or conflicts between the two parties because of insufficient collaboration. The lack of collaboration in the early stages of the project was cited by both project managers (client and contractor) as having a negative effect on the rest of the project. As the contractor's project manager put it, *"According to the client, we should work together in collaboration. But you cannot just say that; you really have to mean it."* The project manager continued by saying that it is difficult to collaborate when the project organisation (at both client and contractor) lacks the right competences, will and ability to work in collaboration.

Collaboration scope

The collaboration in this project included only the client and the main contractor, due to their contractual agreement. As such, it was their combined responsibility to forward relevant information to other involved actors. The client's preference to keep the collaboration on a low and local level further highlighted the exclusion of other actors from the collaborative activities.

However, the *internal* collaboration between the contractor and the technical consultant engaged by the contractor was strong and can be seen as an aspect of wider collaboration. This extensive internal collaboration resulted from the contract's stipulated long-term operation-and-maintenance responsibility, which required new solutions that focused on life-cycle costs rather than initial costs. Furthermore, the contractor and the technical consultant shared the same office to some extent, which helped increase collaboration between them. As the contractor's design manager put it, *"I think the internal collaboration worked well but the collaboration with the client was not good."*

Collaboration depth

The collaboration depth was in this project kept on a high management level. The client's project director emphasises that the project had no intention of actively collaborating, and collaboration meetings were held only twice a year, at lunches between the contractor and client management team. This meant that only a few people were actively involved in collaboration activities and none of them was from lower hierarchical project levels. These representatives were therefore responsible for bringing the information forward and spreading it throughout the project organisation, which was achieved to a varying extent.

Both contractual parties also highlighted the low level of involvement from their respective maintenance departments as a shortcoming, since the objective of including the long maintenance responsibility in the contract was to promote better solutions based on a life-cycle perspective. This frustration is expressed by the contractor's project manager: *"It's one thing to design for construction and another thing to design for operation and maintenance."*

Collaboration duration

Because this project was based on a DB contract, the contractor was procured earlier than in a traditional DBB contract. The collaboration between the client and the contractor started at the outset of the DBM contract and, due to continuous meetings, continued for the duration of the project. However, because the contractor was not involved in the formation of the initial plans and permits for the road and its route (*vägplanen*), early collaboration was limited. The contractor also decided to start fieldwork, e.g. cutting trees and uncovering the soil, directly after the contract was signed, which affected the early collaboration negatively since the client project organisation was not yet completely installed. The normal procedure is that the contractor starts with the design, and the fieldwork usually does not start before a couple of months into the project. The early mismatch in project organisation structures between the two contractual parties was something that the client's project manager highlighted as negative for the project: *"….I wanted to allocate staff to the project organisation earlier, but we could not really influence that. If you establish an organisation early on, and then when you have a permit approved (Vägplan) you are able to give the contractor the right support, you can also increase their freedom. Otherwise, if you do not have sufficient skills in the organisation, you are more locked in the pre-established early design solutions."* However, the contractor is overall satisfied with the choice of DB(M) contract since the level of freedom is higher than in a DBB contract.

The fact that the contract included a long operation and maintenance responsibility of 20 years, compared to the normal five-year warranty period, also increased the incentive for both the client and contractor to develop and implement new solutions with better quality, which was the intention of this initiative.

Collaboration intensity

The collaboration can be seen as continuous but rather weak. There was no signed collaboration agreement, and the collaboration intensity became low since the client did not assign a collaboration facilitator for the project. The client had no desire to achieve a high level of collaboration, which affected this dimension significantly since the client manages the project. The client also had early discussions about a joint project office but decided not to co-locate with the contractor. The client's project manager elaborated on the decision to not use a joint office: *"It is a bit difficult if you share the same* coffee room]*. You cannot sit and talk tactics and you can sometimes say too much. [Then there is] the discussion about how friendly you might become if you sit together for several years; it can be difficult to keep your distance."*

A joint project office is an important tool for creating deep collaboration between contractual parties, and the decision clearly indicates that the client did not want to facilitate co-creation activities in the project.

In addition, the contractor's design manager highlights that the client did not collaborate well in terms of accepting new solutions suggested by the contractor: "*The people in the project must have the willingness to cooperate, to help each other find joint solutions; it should not be a war….If you [as client] see that [something] is a good solution economically for the contractor, you [as client] should not be negative against the solution just because it brings an advantage to the contractor."*

Project outcomes

Efficiency

The joint goal discussion – that is, the effort made to create a common basis of what to achieve in the project – was lacking in this project. The rather weak early communication effectively reduced project efficiency since the two contractual parties did not understand each other. One example cited by the contractor's project manager was the lack of understanding from the client in terms of parallel design and construction: *"The long review of drawings made the efficiency lower, as the design took place at the same time as construction."* This is something that the client needs to understand when working in DB(M) contracts where the contractor has the design responsibility and often wants to perform parallel activities. This becomes especially evident if the contractor has an incentive to complete the project due to bonuses, as was the case in this project. Nevertheless, the DBM contract made it possible, to some extent, for the contractor to integrate design and construction and conduct them parallel to each other. This increased the efficiency of the processes and also contributed to improved buildability since the relevant parties were able to evaluate different solutions throughout the life of the project.

However, since the contractor was procured rather late (after the formation of the initial plans and permits of the road and its route, or *vägplanen*), the contractor's freedom was limited to making only minor changes in the client's initial design. The already determined road corridor and permits put many constraints on the project, limiting the opportunities for optimised production processes based on contractor experiences, since the road corridor chosen by the client might not be the optimal one from a production perspective.

Another thing that hampered efficiency was the extensive involvement of the municipality. They had strong opinions on certain issues and the client gave in to some of them. For example, the contractor's design manager said that *"the client tried to keep down the cost but could not resist [the municipality], so eventually it became a very long bridge. I made many suggestions before they [the municipality] were satisfied."*

By contrast, the contractor also frequently mentioned that DB(M) contracts are positive in that the contractor can generally guide their consultants towards more buildable solutions that are suitable to the contractor's own production competence.

Innovation

The respondents argue that the DBM contract was a driving force for innovation, but the contractor had low hopes of achieving extensive innovations due to the route permits (*Vägplan*), which limits opportunities to implement innovation (the route permits include e.g. specific data about the height and the corridor of the new road stretch, which are difficult to change during the project execution).

Some minor innovations occurred despite the rather late entry of the contractor, however. These were due mostly to the life-cycle perspective that was required to handle the long operation-and-maintenance responsibility in an efficient way, but also to the large amount of unexpected rock material along the road. To cite the contractor's project manager: *"We may not have come across these [innovations] if we had not worked like this"* – meaning that the DBM contract forced the contractor to think differently and apply a life-cycle perspective rather than only focusing on initial investment costs. The extensive operation and maintenance responsibility forced the contractor to involve their own maintenance department in the design, which affected some of the choices. In particular, two innovative solutions were implemented to increase quality and decrease costs during operation and maintenance. The main one involved strengthening the road; although this did not require much new knowledge, the result was increased quality from a life-cycle perspective. This solution was developed due to the large access to rock material along the new route. This is traditionally handled by transporting the material from the site, which is expensive and time-consuming. Since the rock material was hard, the contractor instead used it to reinforce the road body, thus minimising the risk of settlements on the road. The solution was initiated and designed by the contractor (together with the technical consultant), which possesses knowledge of this subject. The solution did not require any extensive validation since it is a known technique. Because this solution did cost slightly more than using the initially designed solution, and because it increased the quality of the road throughout the life-cycle, the contractor thought that they could get some compensation for it from the client. However, this did not happen, and the contractor's project manager felt that they should have discussed this matter with the client before they decided on this solution.

The contractor's responsibility for the long operation and maintenance period also prompted the contractor to elaborate on the coating of the bridges along the road. Traditionally, the asphalt coating has a rubber carpet underneath to create a seal for the bridge. Unfortunately, there are often problems with gas bubbles underneath the rubber carpet that destroy the asphalt. In this project, the contractor initiated the use of a concrete coating that itself creates a seal for the bridge structure beneath. The problem with concrete is that one must ensure the surface is very even, especially when the speed limit is as high as 100 km/h. The contractor did, in fact, manage to produce an even surface, first by using a levelling roller (when the concrete was still wet) and then by grinding the hard concrete. To cite the client's manager responsible for the bridges: *"The result was great, so we'll see if it lasts as long as we hope so that you do not have any problems."* The incentive to use this solution is to reduce maintenance costs since concrete is harder and more resistant than asphalt.

Both these innovations were related to product quality and were initiated due to the longer duration of the operation and maintenance period – which made it desirable for both actors (contractor and client) to improve product quality, thereby decreasing the risk of major maintenance work. Neither of these systemic innovations that affect actors throughout the supply-chain would have been possible to implement if a DBB contract with pre-defined technical solutions had been used by the client.

General conclusions

The project performed well (i.e. the results were in accordance to the client's pre-determined cost and quality goals) and was finished ahead of schedule. The actors had a satisfactory working relationship but there was relatively little collaboration. Although both the contractor and the client believe the right choices were made with regard to procurement strategy and contract type, the cost focus did negatively affect the collaboration and choice of solutions. Both the client and contractor also acknowledged the central role of individuals, e.g. their competence and willingness to successfully realise this type of project. This project could have benefitted from including operations and maintenance competences due to the

intention of creating solutions from a life-cycle perspective. To cite the contractor's design manager: *"I imagine that operation and maintenance [specialists] may not be so knowledgeable about construction, but it would certainly have been useful, and I think it would be good for future projects."* However, that might have been difficult since the project management team in this project did not function perfectly and some people had even difficulty in speaking to each other.

Cases DBFM 1 (Road N31) and DBFM 2 (Road N33)

Summary

DBFM 1: N31 Wâldwei

Construction period: 2003-2008

Maintenance period: 2004-2023

Contract sum: EUR 135 million (about SEK 1.4 billion)

Delivery system: Design-build-finance-maintain (DBFM) contract

Reward system: Fixed price with payment for investment and yearly payments for maintenance

Contractor selection: Restricted procedure, with pre-qualification of at least five competitors and then later direct awarding based on a fixed price

Collaboration model: Limited collaboration model including a limited number of collaborative tools and activities (e.g. project start-up, bi-weekly special task force, regular formal joint project meetings); system-based contract management

Table 10. Procurement strategies in case DBFM 1

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

DBFM 2: N33 Assen-Zuid

Construction period: 2012-2014

Maintenance period: 2015-2034

Contract sum: EUR 120 million

Delivery system: Design-build-finance-maintain contract

Reward system: Fixed-price with payment for investment and yearly payments for maintenance

Contractor selection: Competitive dialogue; criteria used for evaluation were the risk management plan, the price, the financing structure and price as well as fulfilment of other criteria

Collaboration model: Limited collaboration model including Project Start-up, regular formal joint project meetings, system-based contract management

Table 11. Procurement strategies in case DBFM 2

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification /competitive dialogue	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview: N31

Rijkswaterstaat (RWS) is working on traffic flow and road safety on three different routes of the N31 in Friesland, a northern province in the Netherlands. One of these routes is national road number 31, locally called the *Wâldwei*. The part of the Wâldwei between Nijega (near Drachten) and Hemriksein (Leeuwarden) is one of the few national roads in our country that has not yet been widened, causing several (fatal) accidents. To address this, RWS has opted for, among other things, the doubling of the road between Nijega and Hemriksein (13 kilometres). The Fonejacht bridge also had to be raised/renewed and an aqueduct built. The management and maintenance of the existing road and new road were contracted from the market for the entire duration of the contract.

Construction, management and maintenance were based on a design, build, finance and maintenance (DBFM) contract awarded to the consortium Wâldwei.com, which included Royal BAM Group ("BAM"), Dura Vermeer Group and Ballast Nedam Infra. All work was carried out between 2003 and 2008. The project was completed three to four months ahead of schedule, and the construction consortium also

delivered on budget. Until December 2023, Wâldwei is also responsible for the daily management and maintenance of an N31 route of 22 km in total. The consortium was paid for the optimal availability of the N31 between Drachten and Leeuwarden.

N31 was the first DBFM contract in the Netherlands and will end in 2022. For this reason, observers are waiting to see what will happen at the end of the contract. The contract was successful in the beginning compared to regular contracts, but the delivery standards for the end of the contract were not specified. The project's overall success depends on what happens with outstanding issues that are currently under discussion in the project, and the financial end result is not known yet.

Project overview: N33

The N33 Assen-Zuidbroek project (2012-2015) was a DBFM contract to widen the existing N33 road in the Netherlands. As with the N31 project, the client is RWS. The project is being carried out by the BAM consortium 'Port of North', a partnership of several BAM contractors. In order to improve road safety, traffic flow, and the accessibility of the region, a 38-kilometre stretch of the N33 is to be upgraded from a two-way road into a dual carriageway with two lanes in each direction. A traffic interchange creating a link with the A28 motorway will be built at Assen-Zuid, while a clover-shaped junction at Zuidbroek creates an optimal connection for the new road with the A7 motorway. At various locations, the connection between the access road network and the N33 will be optimised by the construction of roundabouts. The activities also include the improvement of existing, and the construction of new, wildlife crossings.

The project included 1) a 38 km road from 2x1 to 2x2, including all road-related items such as signposting, lighting, and safety/crash barriers; 2) two main interchanges, including viaducts and underpasses, six exits and access roads, one movable bridge (including all electrical and mechanical installations), and two fixed bridges; and 3) five new viaducts, the lengthening of two viaducts, the widening of two viaducts, one railway underpass, two new pedestrian underpasses, one new underpass and the lengthening of two underpasses, and the assessment and strengthening (if required) of all existing structures.

RWS and BAM signed the DBFM contract on October 1, 2012. Financial close was signed in December 2012, with a Concession Period of 20 years. The work started in 2013 and the project was ready in September 2014, which made it one of the quickest road projects in the Netherlands to date.

Procurement strategies for N31 and N33

Delivery system and contract type

The N31 Zurich-Harlingen was the first project in the Netherlands in which the procurement procedure started before the route determination/EIA-procedure had been completed. The option to involve the contractor earlier than usual in this project became clear after the feasibility study stage was (almost) completed. Both the project quality and the project budget were therefore fixed. A decision was made to procure the contractor consortium very early, because of the time constraints resulting from commitments regarding the project's date of completion. To enable timely completion, parallelisation of the (remaining steps of the) route determination/EIA procedure and the procurement procedure was regarded as the best course of action. Therefore, the main objective of early contractor involvement in this project was to realise time gains.

A particular feature of the DBFM 2 contract is the involvement of pension funds. Although some operational PPP projects in the country were transferred to the innovative joint venture between BAM PPP and PGGM (a pension fund service provider), the conversion of the N33 was the first new project directly acquired by the combination. (The joint venture hopes to build on the success of the N33 and currently offers bids on ten other PPP projects.) Of note is the involvement of ABP, another large pension provider in the Netherlands, which finances 70% of the project's loan capital, and which received compensation pegged to inflation. This is remarkable for two reasons: it is the first time that a Dutch pension fund has provided foreign capital to a Dutch infrastructure project, and it is the first time that the Dutch government has been directly involved in financing with compensation pegged to inflation. Calculations for the contract award indicate a capital gain of 20% (apart from differences in market prices).

Reward system

Both projects have reward systems based on a fixed price, in terms of one payment for the construction and yearly payments for maintenance. BAM uses 10-20% of its own money and 80-90% external money from financiers. The debt with interest is paid back during the contract using the payments from RWS for each step according to the contract. The portfolio manager from RWS estimates that maintenance always constitutes the largest part of the budget; around 20% of the budget is construction and 80% maintenance.

Every month, availability reports are sent from the contractor to RWS describing reasons for disruptions, and the cost is deducted from the bill. For incident management, the first EUR 25 000 is paid by the contractor when there has been damage caused by an accident. For N33 the same figure is EUR 5 000. The idea behind these sums from RWS' perspective was to not have to act on every incident and thereby have less administration. On the other hand, the contractor assumes a certain number of accidents in the tender and the RWS pays for them whether they happen or not. The trend in the newer contracts is to decrease the sum used for accident compensation. This has had an effect on the winning bid, leading to lower annual payments, but on the other hand, it has increased the administration and the discussions in the contracts.

Changes in law and regulations like safety and health are not included in the contract and RWS pays for any changes needed.

Contractor selection

Because the N31 project was not particularly complex, the restricted procedure was applied instead of the competitive dialogue procedure. The procurement started directly after the Draft Route Decision was made, which meant that the procurement procedure therefore occurred in parallel with the end of the feasibility study phase. A necessary precondition for this approach was the approval of a pre-decision on the financing of the project (an internal decision within the Ministry of Infrastructure and the Environment), which enabled funding to be distributed, and the continuation of the process without a definitive Route Decision. In the pre-qualification of the restricted procedure, the (mandatory minimum of) five participants were selected in a lottery. These parties were allowed to make a bid. The project was awarded for the lowest price.

The transaction costs of the N31 project were relatively low compared to the total budgeted costs. Because of the narrow scope of the project and its simple character from a technical/spatial viewpoint, the room for creativity on the part of the contractors was limited. Therefore, one might wonder whether it is justified, from a transaction cost perspective, to have five participants develop solutions. Although a minimum of five participants is required for the restricted procedure (Art. 44 paragraph 3 EU 2004/18/EC),

it could be argued that three participants (which is the minimum for the competitive dialogue procedure) would also have sufficed (Lenferink, Tillema, and Arts, 2011).

The N33 project was procured in a competitive dialogue. This refers to a two-stage procurement process in which only a few parties are selected at each stage, based on the plans they present and the answers they provide during the tender. Despite the label of 'dialogue', the dialogue is strongly formalised in order to retain objectivity, equality and transparency; all information (including the discussions in the parallel dialogues) should be spread equally among the parties that show interest in the project. This challenge grows as the proposals develop in later stages of the tender process and the dialogue becomes more content-based. The award criteria are based on the quality/price ratio. For N33 the criteria used for evaluation were the risk management plan (i.e. the plan for mitigating risk), the price, the financing structure and price, as well as fulfilment of other criteria.

Collaboration model

RWS is now very much aware that collaborative relationships can usefully solve many problems that might otherwise have to be settled in a courtroom. The precise collaborative nature of each project largely depends on the project's complexity and duration as well as the contract type. The N31 project started during a period when the client wanted to keep some distance from the contractor because this was associated with the idea of outsourcing everything to the contractor and only inspecting the results periodically. Therefore, an open, performance-based quality-management system was applied. This means that the contractor is responsible for total quality management (TQM) and the client just sometimes inspects the books and site based on the information in the system.

Both the client and contractor had a separate project team. During the construction stage, discussion of requirements for N33 was done in formal meetings. However, the client and the contractor have buildings next to each other on site, and RWS has identified the benefits of co-location, which is used in another ongoing project. Every four weeks, there were meetings with the contractor regarding technical issues. For N31 a special task force met every two weeks to address the road settlement issue.

Four dimensions of collaboration

Collaboration scope

In general, PPP projects (e.g., DBFM) are based on a wide scope of collaboration because many different organisations are involved in the consortia, not just a main contractor. In practice, this usually still entails different teams per construction stage. Hence, an important effect of being responsible for the whole life cycle of a product is that contractors now have to think for themselves instead of obeying the orders of the client.

The construction stage focuses on such questions as, "Are the specifications right? Is everything going according to plan?" In the maintenance phase, the focus is on the availability and quality of the road and the performance level of the service tasks. Nobody in the project has really worked with the maintenance criteria before the maintenance phase starts. (This was generally the case for N31 except for one person who had worked with the project since its inception; but this is an exceptional situation. For N33 there was a period of overlap in people within the RWS; the contractor, however, made a complete change.) The first two years in the maintenance phase are all about getting used to one another, struggling to uphold safety criteria, etc. In N33 the maintenance organisation was not involved in design and construction. However, simulation games with cases were performed before the maintenance phase.

The main discussion during the maintenance phase related to questions about what is in or out of the contract and questions about requirements of the RWS. The focus was not strictly on the actual contract but on how things could be done in the best way and the expectations on each party. "*If you were to read the contract and follow it word by word, you would have big problems,"* said the contractor's operations manager.

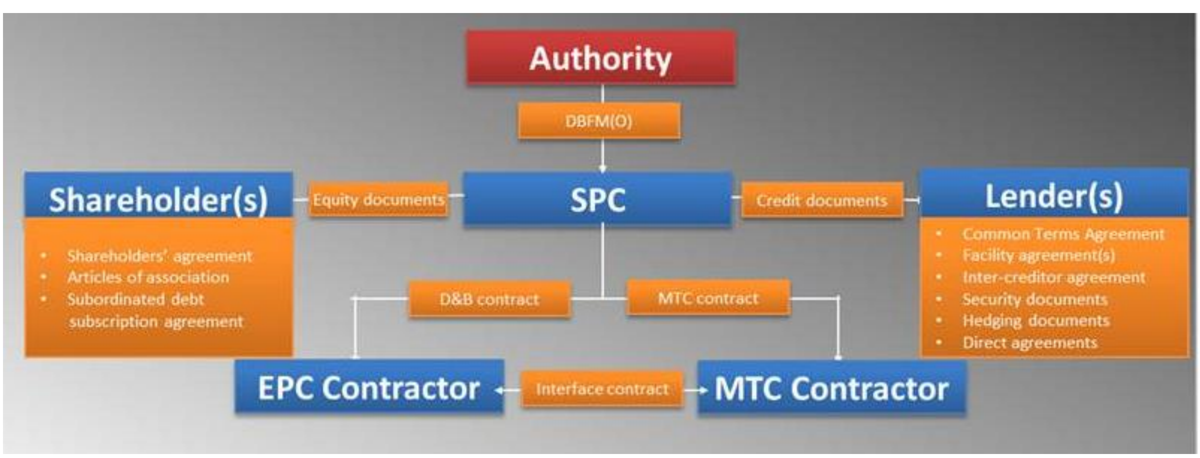
The lender was already involved during the tender. The lender's technical advisor monitors work quality and progress (in terms of fulfilment of work requirements), assesses risks, etc., and creates a due diligence report. The advisor also monitors the progress and quality every month during construction but is less involved in the maintenance phase. One or two times a year a more formal visit takes place to discuss strategies etc. Furthermore, the lender checks that BAM does not receive a lot of penalties so that they are able to pay back the loan.

The financing for N31 was partly provided by the shareholders of Wâldwei.com. The vast majority, however, was provided by a combination of banks: NIB Capital Bank NV, Friesland Bank NV and Bank Nederlandse Gemeenten NV. A one-off fee, paid when the N31 was upgraded, and part of the availability fees are used to repay the loans that Wâldwei.com has entered into.

As commercial banks, BTMU, KfW-Ipex and Rabobank are involved in the N33 project. During the tender, KPMG played an important role as financial advisor and will assist BAM in the coming months towards financial close. Other BAM advisors are De Brauw Blackstone as legal advisor and BDO as model auditor. As bank advisors, Nauta Dutilh (legal), Mott MacDonald (technical) and AON Global Risk Consulting (insurance) were involved.

Figure 2 presents an overview of the project organisation for the DBFM 1 and DBFM 2 projects.

Figure 2. Project organisation in DBFM 1 and DBFM 2



Note: D&B = design and build; DBFM(O) = design-build-finance-maintain (operate); SPC = special-purpose company; EPC = engineering, procurement and construction; MTC = maintenance.

The engineering, procurement and construction (EPC) team and the maintenance (MTC) team include both BAM shareholders and subcontractors. There is also an interphase contractor working to coordinate the two teams. The interphase contractor checks and tests the facility during construction; during the maintenance phase they help the team to make claims to the EPC contractor if there are defects.

Collaboration depth

The DBFM-type contracts reorganised the market completely, according to the contractor. For instance, the whole internal organisation of the contractor was restructured in 2005 due to DBFM. Before that year the contractor did not have a maintenance organisation, but now the contractor describes the company as a multidisciplinary contract company. Several years ago the maintenance team was not that involved in the design, and this became a problem in the maintenance phase. The contractor learned that maintenance needed to be more involved, learning from different contracts, and today maintenance is involved from the start.

The contractor organisation consists of an engineering, procurement and construction (EPC) entity, a special-purpose company (SPC) responsible for financial management and contract management, and a maintenance (MTC) entity responsible for the maintenance part of the project. More or less the same companies are involved in construction and maintenance in these projects, and they are involved beginning in the tender phase. Because the EPC and MTC have different business models, there have been conflicts; it is the operations manager's job to resolve them because in the end, it is the final result of the project that brings in the money. The operational manager states that "*before we tried to squeeze as much as we could out of the client. Now we have to squeeze internally since the client has a more or less fixed budget.*"

The role of the MTC company is to maintain the road during construction as well as to set requirements for the EPC road as regards maintenance after construction. In accordance with the official working processes, the MTC reviewed the design documents in the tender and added requirements to make sure this was the best solution for the maintenance phase. The MTC also reviewed the design during the construction. A large MTC team was involved in the engineering to check the designs, and also during actual construction to check for any deviations.

The maintenance engineers have a long-term perspective – something that does not seem to have been fully applied in the N31 project since, at the time, the maintenance department did not really exist yet. In the N33 there have been several disagreements between the EPC and the MTC because the EPC is focused on meeting the schedule while the MTC is focused on the right quality for the maintenance phase. This creates tension in the project and it is the operations manager's role to make sure the two parties discuss these questions in the right way. There are requirements in the interphase contract to provide solutions when the two parties do not agree. Both parties make life-cycle plans and these have to be coordinated. The N33 project also has a steering committee to solve potential problems; the EPC and MTC are not part of it. The usual next step when escalating a conflict is the top managers of the company, but this step has never been needed.

In theory, the EPC and MTC should be equal, but during construction of N33, the EPC had 200-300 staff whereas the MTC had only around ten. This was due to traditional thinking and the fact that BAM is originally a building company. The operational director and manager supported the MTC during this time to make sure they were heard.

Collaboration duration

For the N31 project, the procurement started before the route determination was completed, making it the first project of its kind in the Netherlands, enabled by a special law in order to support the construction industry through a financial crisis (Lenferink et al., 2012). Time was gained but the parallel process put constraints on the design options for the contractor and did not result in any important technical innovations. This was confirmed by both the contractor and RWS during the interviews.

A parallelisation approach after the (Draft) Route Decision such as applied in N31 can result in a potential conflict between the Route Decision and the terms of reference (ToR) of an integrated contract. The level of detail of the (Draft) Route Decision could limit the creative freedom of the contractors involved in the procurement and, subsequently, in the construction. A further specification of the (Draft) Route Decision to improve the legal position of the stakeholders, together with the formal-juridical character of the route determination/EIA procedure, can limit the possibilities and room for creativity of the contractors. There has to be commitment among the government actors beforehand. Especially in this case, with multiple actors responsible for funding and a project with an experimental character, agreement about the scope, preconditions and the ToR, the main conditions for the procurement procedure, proves to be essential.

Due to the long maintenance responsibilities (20 years), the collaboration duration is very long in these contracts. Because it is difficult to specify all contingences *ex ante* in these long contracts, there is a need for flexibility and re-negotiations during the contract duration. N31 has now been ongoing for 15 years, and the consequences of the choices made at the beginning of the project are starting to show. Also, no standard was set for the quality at the end of the contract. This has led to discussions and negotiations between the contractor and RWS.

Collaboration intensity

The contractor describes how difficult it is to change the mindset within the organisation and estimates that it takes ten years to do so. They try to stimulate good attitude and behaviour with start-up meetings, DBFM courses and morning meetings held during construction. (The maintenance organisation is not present at all of these meetings; they attend only the design meetings.) An additional challenge is the fact that many Polish people work in the project, adding another dimension to the cultural aspect. For N31 there was from the beginning a strong focus on changing the attitudes of the people to fit the project. For N33 it has been a struggle to find the right people and the right competence all along.

Every project is evaluated, and lessons learned are spread through forums that take place in different countries. Infrastructure asset management forums are held to discuss experiences from projects, to develop better future quality. The knowledge mainly resides with the people, not in databases.

In the contracts, there is much room for interpretation and not all requirements can be met; RWS is aware of this, according to the contractor, but it varies considerably between the projects and the people involved. RWS describes the importance of taking a step back but still being involved. The maintenance (asset management) team at RWS want to tell the contractor what to do, and to adjust requires a shift in mindset.

Skills to maintain long-term relationships are needed and the focus needs to be on what is best for the road project (from both sides), not for the individual. According to the RWS portfolio manager, *"Instead of standing opposite to each other, the parties need to stand next to each other facing the road."* The soft skills are therefore the most important in this type of project.

RWS describes the shift from construction to maintenance as a critical phase. There are people coming and going within both the client and contractor teams. This implies that relationships change as both sides as seek to re-interpret the contract. It is important to pay special attention to this and to the value of continuity in contracts and the people. In a long-term contract, it is all about the people and whether they can work together or not.

Project outcomes for N31 and N33

Efficiency

Most identified efficiency-related aspects of the N31 and N33 projects are also related to collaboration (as discussed below), but there is one central issue related to the scope of collaboration in these DBFM contracts. The wider collaboration scope affects efficiency because the lender is pushing the contractor to work fast and with the right quality. This means a second controller looking over the shoulder of the contractor. The financing also has an impact on the maintenance phase since disruption in availability affects the payment. Accordingly, the "F" in the DBFM contracts (i.e. financing) has a positive influence on the time schedule, quality and robustness of the road.

The prolonged duration of collaboration through early involvement of the contractor has improved efficiency. The construction of N31 was completed in December 2008, whereas the construction had initially been scheduled to be completed at the end of 2009. This means that, in total, the decision to procure the contractor early (and in parallel to the route-decision process) resulted in a gain of 11 months in the planning and procurement phases compared to the traditional sequential approach.

The procurement process also benefited from the parallelisation approach, in that the results of the project study could be implemented easily and early. This facilitated the development of the terms of reference (ToR) for the procurement procedure and allowed for a better fit between the ToR and the outcomes of the project study.

Involving the contractor early and including the maintenance also had a positive influence on the efficiency-related aspects of N33, because the contractor was able to fill in knowledge gaps in the (Draft) Route Decision. For instance, the length of the process and the risks could be better assessed by using the knowledge of the contractors involved in the procurement procedure, which resulted in improved project control. The early involvement of the contractor was also helpful in the negotiations with stakeholders. The contractors helped solve implementation-related issues, e.g. by providing detailed information on the types of available sound barriers.

DBFM has worked well for N31 and N33 according to RWS. Financial considerations aside, the long duration of the collaboration is a good thing since the contractor has an incentive to "do things right" due to the availability fee. RWS needed less effort with contract management of the DBFM than the performance contract, according to the portfolio manager. Also, the contractor believes DBFM contracts are "a nice way of working" since they cover the project's entire life cycle – which has resulted in a shift from the client to the contractor and given the contractor a "sense of pride" in the project. As the contractor's operational director put it, "*In the old days we did what the client told us to do; now we think for ourselves*."

However, long contracts also affect the collective memory of the organisation. Decisions and discussions made 15 years ago are hard to remember and most people will not be there during the whole contract; therefore, it is important to get the documentation right.

In the N31 contract, which is now in its maintenance period, there is currently a quality problem. The road has areas of subsidence/settling because the contractor chose a relatively inexpensive road-stabilisation method that apparently did not effectively seal the road from the underlying groundwater over time, resulting in an uneven road. The road has now settled 18 cm in some parts, whereas the agreed maximum settlement in the contract is 10 cm. A complete reconstruction would cost millions; instead, the contractor has proposed evening out the road with asphalt. This top layer would exceed the end date of the contract. However, every choice made in the five to six last years of a contract will affect the end result. RWS does

not want to take over a road that has to be totally reconstructed (a scenario RWS did not anticipate at the beginning of the DBFM period).

The parties are working together to resolve this issue reasonably. If it is decided to reconstruct the road, RWS believe it is reasonable to pay a certain amount for the extra years provided. Making the contractor pay for the whole reconstruction would result in a national contractor going bankrupt. For N33 there is an expected lifetime after the end of the contract has been set – that is, how long the road will last after the end. Every 20-25 years the stabilisation of a road has to be redone, and the requirements are based on that. It will be a challenge to resolve the question of whether the contractor will be required to replace the stabilisations before the end of the contract. (For N33 the requirement of the stabilisation was in the contract to avoid the same issues as for N31.)

From an efficiency perspective, RWS has learnt a lot from the early DBFM contracts. Knowledge and experiences from N31 have been transferred to subsequent contracts, and procurement strategies for this type of contract have been further developed over time. As such, RWS has utilised exploitative learning to make continuous improvements across projects.

Innovation

As with efficiency, most identified innovation-related issues can be connected to the collaboration duration. However, the wider scope of collaboration in DBFM contracts also affects innovation to some extent, because the lender also affects the contents of the tender – especially in the N33 DBFM project, which was procured in a competitive dialogue. Most of these innovations are not ground-breaking, partly because the lender has to approve all proposals and these institutions are generally risk-averse in terms of securing their investments. They only invest if the business case is solid, which is often not the case for risky innovations. Hence, innovations are usually only included if there is a real financial advantage (i.e. a good business case). According to RWS's portfolio manager, this provides reassurance for the client: "*If the contractor brings an innovation, then you know it has been checked by the lender and has a low financial risk.*"

The respondents from RWS claim that contractors are less likely to try new things when they have a long-term commitment (unless client and contractor have agreed to test the new technology and share the risk). Contractors innovate only if there is a financial advantage, e.g. lower maintenance cost. From the contractors' perspective, innovations for the construction have to be included in the tender. However, bids are won on optimisation of workflows and processes according to the contractor.

Involving the contractor early and including the maintenance did not result in substantial technical innovations in N31 or N33. Because the (Draft) Route Decision had already been made before the procurement of the contractor in N33, the contractor could not influence the development of alternatives or the scope of the project. However, for N33 a new way of handling the traffic on the adjacent lane was used by the contractor. The contract required a solution for keeping the traffic open but did not specify the solution. Furthermore, the NEN 15288 standard was required for N33. This standard requires the contractor to show how the risk management and safety issues are organised as well as to evaluate incidents. This standard has been incorporated into contracts for the past several years.

For N33 a wider asphalt machine was used, making it possible to lay both lanes at the same time and avoid the edge between the lanes, making the road more durable. For the contractor, the life-cycle needs of asphalt are of paramount importance, and the contractor has its own lab for this. During the maintenance phase, it is in the contractor's interest to try to shift the first major maintenance need as far as possible into the future, and thereby have fewer major maintenance events during a contract. For this reason, the

quality of asphalt has improved in recent years – to the extent that the use of “improved asphalt” is no longer seen as a quality improvement per se.

A maintenance management system is used for availability requirements as well as a tailor-made software for long-term contracts. The contractor is developing standard maintenance processes using the knowledge gained from its projects. The maintenance management system includes all the objects for the road and generates work orders based on maintenance intervals. The system also includes accidents that occur and the maintenance staff constantly tweak the system for optimisation.

In general, sustainability has not thus far played a prominent role in the tender process. In a new project called A12, sustainability criteria were included, such as the use of low-energy asphalt (i.e. asphalt produced using a low-energy method) in production and LED lights to save energy. Normally, the contractor develops a tender that includes a design (albeit not a detailed one), but the contractor’s scope for creativity/innovation is limited since the plan for the road has already been set by RWS. According to the contractor, the contract is even more inflexible when it involves a reinvestment and not a new road. Issues of quality and time in the tender are controlled by the contractor’s lender.

General conclusions

The contractor BAM was involved in the N31 and the N33 projects and therefore discussed both projects during the interviews. The N31 was the first DBFM project in the Netherlands. It was procured in the context of a governmental programme to speed up construction works in times of financial crisis. This was also the reason why the contractor was involved relatively early, in combination with parallel planning and permitting processes. This enabled a significantly early delivery within budget but did not lead to substantial innovations. The fact that the lender is heavily involved speeded up the process as well.

To enhance more proactive innovation efforts, contractors must learn to apply a life-cycle approach. The main focus of both projects was road availability, and sustainability was not really an issue. The contractor and client implemented some lessons learned from the N31 project in the N33 project. Despite that, a fully integrated contract requires a substantial change in the mindset of both parties (contractor and client), which requires a significant amount of time. Organisations need to adapt to the fact that they are responsible for a long period and therefore have to integrate knowledge on design and construction in order to improve maintenance. Despite this slow process, both the contractor and client see several advantages in the use of DBFM contracts for these kinds of projects.

Case DBFM 3: The Coen Tunnel

Summary

Construction period: 2008-2013

Maintenance period: 2008/2013-2037

Contract sum: ~ EUR 700 million

Delivery system: Design-build-finance-maintain (DBFM) contract

Reward system: Fixed price with payment for investment and yearly payments for maintenance

Contractor selection: Competitive dialogue including three stages and evaluation based on price and qualitative criteria such as capacity, availability and safety

Collaboration model: Limited collaboration model in a rather formal structure, plus system-based contract management

Table 12. Procurement strategies in case DBFM 3

	Focus on competition (market)	Focus on both competition and cooperation (trilateral hybrid)	Focus on cooperation (bilateral hybrid)
Delivery system	Design by contractor (DB/DB(F)M)	Early involvement in joint design, contractor responsible (DB/DB(F)M)	Joint design with shared responsibilities. ECI based on consultant contract
	Design by client (DBB)	Early involvement in joint design, client responsible (DBB)	
Reward system	Fixed price (lump sum)	Cost reimbursement with incentives and target cost	Cost reimbursement with bonuses
	Fixed unit price		
Contractor selection (invitation + evaluation)	Open invitation	Pre-qualification/ competitive dialogue	Direct negotiation
	Strong focus on lowest price	Lowest price and soft criteria	Strong focus on soft criteria
Collaboration model	No or limited collaboration model. No or limited integrative activities and technologies	Basic collaboration model. A few integrative activities and technologies	Extensive collaboration model. Many integrative activities and technologies

Note: The chosen alternatives have been highlighted.

Project overview

The Coen Tunnel, in the northern part of the Dutch Randstad, has long been one of the major bottlenecks in the Dutch infrastructure. Since the beginning of the 1980s, there have been plans to increase the capacity of the tunnel. In 2000, extra money was made available for improving the national infrastructure,

enabling the Coen Tunnel's capacity to be expanded. The second Coen Tunnel project was one of the first DBFM projects in the Netherlands. RWS, the executive agency of the Ministry of Infrastructure and the Environment, has since 2004 applied design-build (DB) contracts for construction projects, performance contracts for maintenance, and DBFM contracts for large projects, with the idea that giving more room for the contractors in the early stages of the projects will lead to better value for the taxpayers' money (Lenferink et al., 2012).

The Coen Tunnel project is both large (estimated value EUR 300 million NPV) and complex. The contract involves the construction of a second tunnel alongside the existing, 40-year old tunnel, including 36 viaducts and bridges that are being renovated or newly built. In addition, the contract includes the maintenance of both the new and the existing tunnel until 2037. This service-led infrastructure project consists of widening approximately 14 km of highways at the north and south entrances to the existing Coen Tunnel, and expanding the tunnel's capacity from two lanes to three in each direction plus two further reversible lanes, enabling five lanes of traffic in one direction during peak hours. Further, the existing transport infrastructure had to be maintained during the widening activities, and traffic hindrances minimised.

Procurement strategies

Delivery system and contract type

The DBFM contract for the Coen Tunnel project was signed in 2008, and the maintenance of the existing tunnel was also then transferred to the contractor, a consortium of companies called Coentunnel Company. The consortium was responsible for financing the project during construction, and is now responsible for maintaining the complete route until 2037.

This service-led DBFM contract was used in this project for political reasons. It was a way to get the market financially involved as well as to solve several problems. Combining design, construction and maintenance in one project was also seen as a way to incorporate maintenance aspects into the design, thereby creating a better business case and lowering maintenance costs. Furthermore, the long-term commitment creates a positive effect on the governmental budget since the budget allocations are made continuously over 30 years instead of in one large initial investment. The supply market was assumed to have good solutions to use in this type of project, which fitted the need for more innovation.

Finally, a large reorganisation (including downsizing) was ongoing at RWS at the time of procurement, decreasing the number of employees as well as the level of client involvement in the projects. The standardised DBFM contracts allowed contractors to monitor their own work progress and quality, thereby generating less work for RWS. Basically, RWS wanted to perform at the same level but with fewer people.

Reward system

The reward system resembles a fixed price, although the actual payments are divided into smaller chunks and paid regularly. The total budget is EUR 700 million, of which EUR 600 million is externally funded by banks and insurance companies, and EUR 100 million is internally funded by the contractor. During the construction, the contractor received EUR 2.6 million per quarter from RWS and an additional EUR 100 million when construction was completed. During the current maintenance phase, RWS is paying EUR 10 million per quarter to the contractor based on road availability. Reductions of EUR 20 000 per fine are made according to reduced availability and unsafe situations. Additionally, a failure on the road has to be

fixed within 24 hours, after which a EUR 5 000 fine is taken out. The contractor counts the bill each month (using their performance measurement system) and then sends the bill to RWS.

Contractor selection

The Coen Tunnel was the first infrastructure project in the Netherlands to be procured using the competitive dialogue (CD) procedure. After an initial meeting between the procuring authority and market parties in June 2005, five consortia met the prequalification criteria and were subsequently invited to participate in the dialogue, which was executed in four main stages: Scheme of Action; Consultation; Dialogue; and Tender Submission. The first stage involved evaluating the competitors' proposed solutions, during which the number of competitors was reduced to three. The second stage involved consultation, during which realisation strategy, inventory of risks, etc. were discussed with the competitors. The third stage involved a dialogue, which resulted in a list of optional requirements to be met plus a division of risks to be borne by the contractor and client, respectively. During the fourth stage, bids were first submitted and subsequently evaluated by the client. The participants' prices for each risk were announced at a notary in The Hague, along with the agency's prices. As such, the risk allocation for each participant became fixed: when the participant put a higher price on bearing a risk than the agency did, the agency would bear it. When the participant could bear it for less than the agency could, the participant would bear the risk. Each participant thus got its individual risk allocation, with an individual price attached to it.

In May 2007, the final bids were submitted and assessed using EMVI (*economisch meest voordelige inschrijving*, or "most economically advantageous tender") criteria relating to prices and quality issues. Environmental issues were however not really on the table during the tender phase. The two losing bidders were notified in June, and a design fee paid to them. Contract version 1.0 was then drawn up and discussed with the remaining participant on 20 July 2007. Contract closure took place on 22 April 2008, with financial closure planned for 22 May and postponed until 10 June 2008 due to difficulties with the financial closure. The construction stage, however, started on 1 June 2008.

Collaboration model

RWS's use of DBFM contracts is based on the idea that RWS should be less directly engaged in the project and give more freedom to the contractor. Hence, implementing an extensive collaboration model that requires significant client involvement was not part of the plan. RWS was not located on site during the construction, although the respondents indicated that they actually would have wanted to be co-located with the contractor during the construction. The reason for this choice is that 15 years ago a severe construction fraud was discovered: contractors made price agreements that clients were not aware of. The government conducted a parliamentary inquiry, CEOs were punished, and there was a sense that the construction industry needed to be "cleaned" and change its way of working. Therefore, RWS decided not to be co-located to avoid any kind of association with bribes, etc. This approach of only using formal meetings to discuss project solutions was not an effective way of working, however, and ultimately some technical staff of RWS were involved on site for informal meetings after time passed and the situation became less tense. RWS still does not have an office on site during the maintenance period. However, every two weeks, informal meetings are held on site, and every six weeks a formal contract meeting is held where e.g. administration and cost issues are discussed.

In order to monitor the progress of the project, the contractor uses an open performance-based quality management system, translated as "System-based Contract Management" (*systeemgebaseerd contractbeheer*, or SCB). This means that availability information can be accessed through a database. The availability report sent to RWS every quarter is the basis for the contractor's payment. In this way, the

contractor has to prove that the requirements are met. This works well according to the client project manager: *"Bills sent by the contractor never come as a surprise. […] In the beginning, the contractor has a lot of explaining to do, in relation to deviations from the expectations, but that gets less and less."* Twice a year the lender's technical advisor visits the site to check on progress in such areas as planning and risk management.

Four dimensions of collaboration

Collaboration scope

Formally, the scope of collaboration is rather wide, as the Coentunnel Company consists of seven partners: Arcadis, Dura Vermeer, Besix, TBI Construction, CFE, Vinci concessions and Dredging International. In addition to its agreement with RWS, the Coentunnel Company has financing contracts with Fortis Bank (The Netherlands), Bayerische Landesbank, the Royal Bank of Scotland (RBS), Bank of Dutch Municipalities (BNG), KfW IPEX Bank and the European Investment Bank (EIB). The design, construction and maintenance during the realisation phase have been outsourced to a subcontractor, Coentunnel Construction, an engineering, procurement and construction (EPC) unit. Maintenance of the traffic and tunnel engineering facilities (VTTI) has been outsourced to subcontractor Croon Elektrotechiek B.V. These contracts state, inter alia, that Coentunnel Company bears the financial risk. In other words, the Coentunnel Company, which itself is paid on the basis of performance, must be able to service its obligations towards the lenders at any time. The three maintenance partners are not equal in financial shares but in financial responsibility. In addition, Coentunnel Company has received a guarantee/security from the EIB. The technical advisor is Atkins, a British consulting firm based in Birmingham.

A contract director is in charge of the maintenance stage, and a technical manager handles the civil and electrical engineering aspects. Each technical manager has a team of technical engineers for civil, tunnel and emergency activities. These engineers have teams for planning and corrective maintenance as well as a team for performing the maintenance activities. The contractor responsible for the civil works is the main contractor while a subcontractor is in charge of the electrical installations. Since the contractor respondents also were involved in the construction stage, they could explain how the organisation worked throughout tendering, design, construction and the ongoing maintenance phase. This improved the understanding of the project and the actions to be taken after the contract was signed.

The project criteria, such as capacity and safety, had to be split between civil works and the electrical works during the construction. This caused an internal dispute regarding responsibility issues that lasted two years and caused monetary loss. Thereafter the parties joined forces and collaborated with each other and with RWS.

Although the collaboration was rather good between the actors in the design and construction stage, the maintenance actors have not really been taking part in the collaboration, which has affected the maintainability negatively. As a consequence, the construction directors decided what to build without thinking about the 24 years of maintenance. According to the contractor respondents, this type of project always starts with "the old way of thinking", because changing a mindset takes time. Attempts were made to emphasise maintenance during the construction stage, but it was difficult to gain sufficient attention. RWS also took notice of this internal conflict. RWS hopes that in the future it is the maintenance team that will manage the contract since they can make trade-offs between construction and maintenance and also build maintenance-friendly installations and constructions.

Furthermore, some of the design decisions need to be approved by stakeholders other than the client. This is only possible if the client remains involved in the stakeholder management and there is a clear design of stakeholder engagement. This means that stakeholder management can never be fully transferred to the contractor.

Collaboration depth

From the client side, the Integrated Project Management (IPM) structure was applied, resulting in a project director, a project controller, a project manager, a stakeholder manager, a technical manager and a contract manager. This standardised project governance structure was implemented at RWS about a decade ago, also to ensure the integration of different departments within the client organisation.

The initial contractor project organisation vertically (EPC and Electrical and Mechanical works) separated the installations from the rest of the construction. This caused problems for both project control and system engineering. The contractor successfully solved this by fully integrating both teams, including the financial streams. According to the project managers, the project organisations should be "mirrored", so that similar roles and tasks are present on both sides of the project team (client and contractor) in order to facilitate communication. Further, it is important that each role is empowered and can make decisions in his or her specific area of expertise.

Collaboration duration

Both the client and the contractor believe that the length of the DBFM contract (30 years) is sufficient. The contractor thinks this is long enough to get a return of investment (e.g. five years would be too little time to earn back the investment). However, it is too long for renewals since the status of the facility can't be known in advance. The performance contracts for asset management (maintenance) used today for each region are five years long, and RWS would like to make them longer. Shorter contracts result in many interfaces. On the other hand, RWS believe that new tendering every five years results in a better development process. For the civil teams, the longer the contract the better, according to the contractor; but for software and other elements, different life cycles apply. The contractor argues that the easiest approach would be to keep the system as is for 24 years, but "that is not how the world works" since it is connected to other objects in the system and user needs are dynamic.

The long duration of the maintenance contract was a big challenge in the tender phase, at which point the contractor knew exactly what to build whereas the maintenance part had to be estimated more roughly. Around 70-80% of the maintenance estimation is ok and the rest was risk-taking – partly because they did not know which supplier would be used when the tender was prepared, and partly because the contractor had not received any information from RWS on the pre-existing tunnel.

When the contract ends the residual value is expected to be at the same quality level as today. Inspections are planned for two years before the end so that RWS knows what to expect with regard to maintenance needs. RWS does not expect to get a lot of information on the asset performance at the end of the contract. The contractor plans to provide RWS with a copy of some of the collected information – an amount equal to approximately 8% of the yearly data collected by the contractor. It is not clear, however, whether the data delivered will actually be of value for RWS, also because RWS does not know exactly what kind of data they need and what format it should take in order to do their asset management.

Collaboration intensity

DBFM was a new experience for both client and contractor. The main challenge raised by the respondents has been working together and understanding each other during the project. Because the procurement phase was driven primarily by legal and financial discussions, the technical assignment and contract management system were not fully addressed upfront. In an internal evaluation report, project managers indicate that staff should simply try to be nice to one other – especially during the initial phases, which require a substantial amount of "give and take". Both sides should be able to win when changes are required. The strength of collaboration increased somewhat over time, as the actors gained experience with this type of integrated contract.

The main difference for the contractor is that RWS normally controls the quality in the traditional contracts, but for DBFM the contractor must monitor their own work quality. This is difficult since people are used to looking around to see if anyone is there to control them; if not, they might cut corners with quality. As the engineering director of the contractor remarks of project staff, "*They don't have the mindset that it is their own house they are building*." According to the director, only a few people in the project had "the new mindset" in the beginning, and it took three years to change the mindset of the whole project. During this time, decisions were made that might have been more favourable for the construction stage than for the maintenance phase.

Project outcomes

Efficiency

According to the respondents from RWS, DBFM works well in the construction stage. As mentioned earlier, the lenders have a technical advisor (Atkins) that monitors the construction as well as the tender. In this case, both the tender and the construction process were adjusted to a lower degree of risk after the comments from this advisor. The fact that the project is privately funded discourages changes after the tender phase because, according to the contractors' technical manager, "*lenders do not approve any risks.*" That said, the manager also indicates that "*if there had not been any external lenders, we probably would have taken even less risk since it is then only our own money*."

In the Coen Tunnel project (and most of the early DBFM projects) the focus was on design and construction and not enough on maintenance. RWS was expecting more maintenance focus in the tendering phase than what was realised. The same short-sighted focus is found within RWS where the building department is larger than the maintenance department. It is by now evident that maintenance should take the lead for longer projects, but there is a long way to go before this mindset is fully incorporated into DBFM contracts, and the change will take a few decades still. The subcontractor in charge of the electrical installation had not been a true maintenance company prior to its involvement in this contract; its maintenance division was built from scratch during the project. This means that no previous maintenance data was available, only technical information from the suppliers.

Financial problems have now arisen in the maintenance phase regarding accidents/incidents that were not clearly defined in the contract. An approach to dealing with such incidents is now described in all new contracts. For the Coentunnel project, the incident management has financial consequences for RWS since the RWS management initially thought these costs were included in the contract. The incident costs are not higher than if RWS would take care of the incident management themselves. However, RWS believes the contractor is doing more than needed when managing incidents, with the result that newer and better-

quality parts are acquired. Although these parts require less maintenance and last longer, which is beneficial for the contractor's maintenance process, RWS is paying for the upgrade.

Another occasional issue is that instead of maintaining an item, the contractor will claim it has been damaged, buy a new one, and send the bill to RWS. It is difficult for RWS to know if an item is damaged or just worn out since this difference is not clearly described in the contract. RWS is now trying to negotiate a better contract regarding this, but the contractor is less interested in a renegotiation than RWS. Furthermore, the high penalties represent too high a risk for the contractor not to repair or change the items. RWS wants to add this type of refinement to the contract.

Traffic volume has a maximum level stipulated in the contract; above that level, wear-and-tear is not included and results in an extra cost for RWS. The volume level was set with input from the whole region (including the province and municipalities). For any changes to be made, RWS (or the municipality) needs to have a budget for installation and maintenance. This is not in line with the RWS internal policy. For example, changes from 120 km/h to 130 km/h require new signs but also lead to more wear on the asphalt.

Another example of ambiguity in the contract is the matter of ventilation for certain particles in the tunnel. The ventilation for particles is expensive, and the regulations for this have changed since the tender such that the fans are no longer needed. The running of the fans requires energy, which incurs costs in terms of both direct energy cost and the CO_2 potentially emitted at the energy source. There are however two issues to consider. First, if the fans are turned off, who will get the economic benefits? The requirements for the fans in the first place were not clear, and RWS had to pay extra for the contractor to be able to fulfil them. Both parties are interested in turning the fans off, albeit for different reasons: the contractor wants to stop paying the electric bill, and RWS has an environmental sustainability focus. The second issue is how to convince the other stakeholders (the province and municipalities), which set the criteria several years ago, to approve a change in the contract.

From an organisational point of view, this project has not been a success for RWS when compared to the parallel strategy of creating large performance contracts for maintenance. DBFMs create isolated islands in the RWS infrastructure network, with specialised people dedicated to the projects. This has increased the need for more administration. Changes made in the network affect different areas in different ways since they have different contracts. The involvement needed is, therefore, higher in a DBFM contract than in the regional performance contracts. These performance contracts are put in place to create efficiency and span entire regions; in total there are seven such contracts. In each region, there are teams for roads, waterways and tunnels. Adding DBFMs into the equation increases the number of interfaces, adds administration, requires specialised teams, etc. A choice has to be made; either a performance-based contract for each region or large DBFM contracts for regions. The contractor can then make money in one part and lose some in another part, which will result in less tension and quarrels. The solution is not to add DBFMs into the existing maintenance structure, as is done today.

Normally, the maintenance division within RWS would be in charge of the maintenance and take over from the large project organisation when the construction is finished. For DBFM contracts the whole contract has to be transferred to the maintenance organisation, and RWS was not prepared for this. New competencies are needed, along with a different kind of mindset. The maintenance organisation cannot apply the same strategy as for other projects. This means they cannot get as involved on a detailed level in the maintenance as they usually do, which results in a feeling of lost control. They want to get involved but are not allowed because it is the contractor that is responsible. The contract manager has to prevent people from the client organisation from trying to revert to traditional approaches. For example, when the IT department wants to upgrade the system and the cables, they have to understand that it is the function of the cables that is important, not what type of cables that are used. The contract manager tells the IT

department: "*Tell me what you need and I'll ask the contractor how he wants to do it and what it will cost*." New competence is needed for asset managers to be able to handle the DBFMs from the RWS perspective. If a municipality wants a change in the infrastructure, it normally does not have a budget for 20 years of maintenance. Any changes require re-negotiations between the municipality, RWS and the contractor.

Furthermore, regarding taxpayers' cost, the RWS respondents were concerned with the interest on these projects, which is around 25% of the cost. The RWS also loses part of your flexibility since the lenders fix the design early. When these factors are combined with the lack of maintenance quality, the contract is not perceived as effective as assumed in the beginning. In contrast, the current status of the contract with regard to the project organisation and availability is quite good. If the administrational and organisational issues were excluded, RWS would choose DBFM for a new tunnel since the technical specifications are now more standardised. For this contract, they had to experiment a bit too much (i.e. many changes were made), which resulted in an increased cost.

It was stated that the contractor is driven by money and therefore makes sure the road continuously has the highest quality. According to the contractor, DBFM contracts result in a higher quality than traditional contracts since RWS has another budget line and can only afford low quality in a regular situation. When choosing materials and systems it helps that "*normally the [decision-making authority] is with the client but now it's with the contractor; that is the main difference,*" as stated by the maintenance manager of the contractor. The contractor stresses the importance of a well-functioning organisation since the machines used for maintenance are expensive to run and the fines are severe at EUR 20 000 for every 15 minutes the availability is reduced. The contractor tries to avoid fines during the maintenance phase, as these are not included in the budget. Fines in the maintenance phase are due to faults from the construction stage, according to the contractor respondents in charge of the maintenance. Furthermore, both contractor and RWS believe the fines in the maintenance phase provide a good incentive for improving availability.

Despite the difficulties during the tendering process and the learning in the project company, no lessons learned from this project have been transferred to subsequent projects, according to the contractor. "*We don't have lessons learned. We learn again.*" The contractor believes there is a "knowledge drain for the organisation". Instead, every project starts from the beginning, especially the risky DBFM projects. This is because it is a top-down organisation, and if the management level does not have the right mindset it "just will not work" and it "will take another generation" to change the mindset.

Innovation

Innovation in the Coen Tunnel project was mostly seen in the maintenance phase, such as change of installation suppliers. RWS believes that the contractor has a reactive way of innovating and it will take a few more years before the contractor will change things in a proactive way. According to RWS, the contractor makes changes it would not normally make in a normal maintenance contract since expensive maintenance creates changes in the assets.

When discussing innovation and development in the contract, the contractor starts by describing the culture of the consortium: "*When you are fighting internally it's not the best climate for new thinking*." According to the contractor, the construction and maintenance teams did not really talk to each other. The solutions used were good "but could have been better". The contractor admits that they could have thought more about maintainability in the design stage. The easier it is to maintain the facility, the faster the response time on incidents will be. A current maintainability issue is that the electric cabinets cannot be opened when the road is open to traffic, so they have to wait until the road is closed to fix an electrical fault. In this case, availability was not taken enough into consideration.

According to the contractor, innovation is not the basis for this type of contract. The civil engineering did not have any innovations. There were simply no incentives for it. Due to the high penalties for reduced availability, existing and proven solutions were less risky to use. Furthermore, the technical manager indicated that *"the potential financial risk for the project was high, which is why we worked to lower the risk and chose proven technology."* The contract manager for the civil engineering team was involved in the tender phase (where he applied his maintenance knowledge), but found that it was difficult to make people take maintenance issues seriously. In the design stage, according to the contractor, "money rules" and the cheapest and least-risky solution is always used. Innovations for a long-term perspective are not considered; "it's here and now" that is the focus in the design. The contractor will get fined if something is more expensive in the construction stage than in the tender. Price is always what matters most, even if there are other criteria as well. The project manager of the contractor therefore stated that "*when RWS changed the contract form, they thought they would get a different way of building, which would have been possible in an ideal world (laughter)*."

Proven technology is used to reduce risk. For example, the conventional lights chosen have a known lifetime of five years, the lifetime of LED lights was less clear because the contractor did not have experience in using LED. LED might be cheaper during the maintenance phase due to lower electricity consumption, but again, the design was mostly based on the construction perspective. Maintenance aspects should have been considered during the design stage so that choices could be made from a life-cycle perspective. The contractor respondent noted that he once participated in a tender but his precise knowledge of maintenance risks increased the bid price and therefore decreased the chances for the main contractor to win the tender. So now he is not involved anymore, although he could prevent the company from taking serious risks.

During the maintenance phase, a new machine has been developed by the contractor to facilitate maintenance. Because this machine can work in the emergency lane, it can be used during the daytime, parallel to the traffic lane, without having to close any lanes (which would result in a fine). (Another option is to work at night, but there are only 35 nights marked for maintenance per year, including for purposes of renewing the asphalt layers.) The contractor has a long pay-back time on the machine for the development cost, which is possible in this contract. Tasks performed by the machine include grass mowing, changing lights, emptying sewers, and cleaning the strip between the roads. The machine is also rented out to other companies, resulting in extra income for the contractor.

Another development realised during the contract regards the asphalt. Asphalt is normally renewed every 8-10 years, but an innovative chemical spray to make the layer last another eight years is used in the contract. The sub-contractor providing this innovation (who was not involved in the beginning) assumes part of the risk for this method. The spray is cheap and will, therefore, be applied more often than every eighth year to make sure the asphalt meets the requirements.

The electrics part of the contract could have been more innovative, according to the sub-contractor in charge. This could have been possible if the construction and maintenance teams had talked to each other. The sub-contractor is currently trying to expand the lifetime of the installations by analysing the weekly and monthly rate of degeneration to calculate the optimal time for renewal. The lights are changed, for instance, when they are still working but will likely soon fail.

Currently, there is an ongoing discussion regarding whether to switch to LED lights. This investment will benefit RWS after the end of the contract, so should they help pay for the investment? The contractor currently has no incentive to replace the (rather new) lights with LED lights. However, the contractor has no incentive to change due to environmental considerations, which are now a priority for RWS. An option presented by the contractor is to turn off the fans used for particle ventilation (explained in the previous

subsection on “Efficiency”), and instead, use the money saved to invest in LED lights. RWS and the contractor have not yet agreed on this. It is the contractor’s belief that RWS wants the money upfront instead of a LED light investment. In the meantime, the fans continue to contribute to the environmental impact of the project.

For the regular asset-management performance contracts, the sustainability standards are updated every five years when there is a new tender out. This means the requirements can be changed to better fit the conditions every five years. The overall scope for innovation is therefore probably greater in the new performance-based contracts than in the long-term DBFMs. For this DBFM, not everyone realises that the same systems that are new now will be here in 10 and 20 years. However, RWS think that it might be cheaper for the contractor to switch to new systems when the spare parts for the old systems become too expensive or obsolete. In this way the market will regulate itself and, as long as RWS does not interfere with the DBFM maintenance phase too much, no extra cost will be added for an upgrade of the systems. In this way, the respondents from RWS argue that you have to trust the concept of DBFM and be patient.

General conclusions

The Coen Tunnel was one of the first DBFM projects in the Netherlands. This means that the full potential of integrated contracts procured using a competitive dialogue procedure might not have been realised due to the inexperience of both the client and the contractor. Furthermore, the project had a high financial risk, which strongly influenced the risk-averse attitude towards new technology and innovations. The construction stage of this project was efficient for the client since it was delivered on time for a fixed fee. The contractor, however, appears to have lost quite a bit of money, which somehow needs to be re-gained during the maintenance phase. Currently, the project is being maintained for a period of 30 years; since the beginning of the maintenance period, several innovations have been developed that have increased the efficiency of the maintenance. Also, the maintenance and incidents organisation is organised efficiently. Financial incentives based on road availability were important drivers for these developments. Based on the learning experiences, the standard clauses in the contract type and collaboration methods have been adjusted by the client organisation.

Appendix 2. Research questions and outputs of the Working Group on Private Investment in Infrastructure

Introduction: Getting the basics right

What are the economic characteristics of infrastructure? What is infrastructure and what are operations? What are the models of private participation in infrastructure and through which significant private investment actually takes place?	Makovšek, D. (2019), "What is Private Investment in Transport Infrastructure and Why is it Difficult?", Working Group Paper, International Transport Forum, Paris.
Can private investment improve productive efficiency? Improve project selection? Close the infrastructure funding gap? Have other positive effects when it is private?	Makovšek, D. (2019), "The Role of Private Investment in Transport Infrastructure", Working Group Paper, International Transport Forum, Paris.
What have the private investment trends in transport infrastructure been over the last 20 years? How much of that was foreign private investment?	Mistura, F. (2019), "Quantifying Private and Foreign Investment in Transport Infrastructure", Working Group Paper, International Transport Forum, Paris.

Defining the challenge: How uncertainty in contracts matters

How does uncertainty affect risk pricing? Beyond investors, do suppliers in PPPs also have issues with risk pricing? How does its transfer to the private sector affect competition? What does uncertainty mean for the public vs. private cost of financing?	Makovšek, D. and Moszoro, M. (2018), "Risk pricing inefficiency in public–private partnerships", *Transport Reviews*, *38*(3), 298-321.
Is uncertainty also an issue in long-term services/operations contracts?	Beck, A. et al. (2019), "Uncertainty in Long-term Service Contracts: Franchising Rail Transport Operations", Working Group Paper, International Transport Forum, Paris.
What is the competition for large transport infrastructure projects in the EU Market? Is there a difference between traditional procurement and PPPs?	Roumboutsos, A. (2020), "Competition for Infrastructure Projects: Traditional Procurement and PPPs in Europe", Working Group Paper, International Transport Forum, Paris.

Addressing uncertainty for suppliers: the construction phase as example

Adversarial vs. collaborative procurement – is collaborative contracting the future?	Eriksson, P. et al. (2020), "Collaborative Infrastructure Procurement in Sweden and the Netherlands", Working Group Paper, International Transport Forum, Paris.
What lessons in dealing with risk and uncertainty were learnt in Danish mega projects from Storebaelt to Femernbaelt?	Vincentsen, L. and K. S. Andersson (2018), "Risk Allocation in Mega-Projects in Denmark", Working Group Paper, International Transport Forum, Paris.
What can governments do in the short run to reduce inefficient pricing of risk by construction contractors?	Kennedy, J. et al. (2018), "Risk Pricing in Infrastructure Delivery: Making Procurement Less Costly", Working Group Paper, International Transport Forum, Paris.

Addressing uncertainty in long-term contracts in the absence of continuous pressure for efficiency

What is the public sector organisational counterfactual on which private investment should seek to improve?	Holm, K.V. and T.H. Nielsen (2018), "The Danish State Guarantee Model for Infrastructure Investment", Working Group Paper, International Transport Forum, Paris.

Partial fixes to the Private-Public Partnership approach

How would an organisational structure consisting of PPPs come close to a network-wide management approach? What benefits would it yield?	Vassallo, J. (2019), "Public-Private Partnerships in Transport: Unbundling Prices from User Charges", Working Group Paper, International Transport Forum, Paris.
Should the public or the private side bear the cost of long-term uncertainty? How could we design a PPP contract to avoid hold-up due to incomplete contracts?	Engel, E., R. Fischer and A. Galetovic, (2020), "Dealing with the Obsolescence of Transport Infrastructure in Public-Private Partnerships", Working Group Paper, International Transport Forum, Paris.

Long-term strategic approach

How do the PPP and regulated utility model (RAB) compare in terms of efficiency incentives?	Makovšek, D. and D. Veryard (2016), "The Regulatory Asset Base and Project Finance Models", International Transport

	Forum Discussion Papers, No. 2016/01, Paris.
What basic considerations underlie the choice between a PPP and RAB approach?	Hasselgren, B. (2020), "Risk Allocation in Public-Private Partnerships and the Regulatory Asset Base Model", Working Group Paper, International Transport Forum, Paris.
Which are the preconditions a country would need to take to establish a RAB model on a motorway network? Is user-charging a must?	Alchin, S. (2019), "A Corporatised Delivery Model for the Australian Road Network", Working Group Paper, International Transport Forum, Paris.
From the investors' point of view, does a RAB need to be fully reliant on user-charging?	Francis, R. and D. Elliot (2019), "Infrastructure Funding: Does it Matter Where the Money Comes From?", Working Group Paper, International Transport Forum, Paris.
Incentive regulation can also yield perverse incentives. Can the capex bias be managed?	Smith, A. et al. (2019), "Capex Bias and Adverse Incentives in Incentive Regulation: Issues and Solutions", Working Group Paper, International Transport Forum, Paris.
Does it make sense to pursue hybrid solutions between PPP and RAB?	Zhivov, N. (2018), "The Thames Tideway Tunnel: A Hybrid Approach to Infrastructure Delivery", Working Group Paper, International Transport Forum, Paris.
Uncertainty and private investment mobilisation in transport infrastructure	
What lessons can we draw from recent attempts to mobilise private investment in infrastructure in the aftermath of the global financial crisis?	Makovšek, D. (2018), "Mobilising Private Investment in Infrastructure: Investment De-Risking and Uncertainty", Working Group Paper, International Transport Forum, Paris.
Synthesis	**ITF (2018), *Private Investment in Transport Infrastructure: Dealing with Uncertainty in Contracts*, Research Report, International Transport Forum, Paris.**

Collaborative Infrastructure Procurement in Sweden and the Netherlands

This paper examines how different types of procurement strategies enhance collaboration among the project partners. Collaborative contracts are one possible approach to address uncertainty in infrastructure delivery. However, they are generally incompatible with private financing. The analysis draws on experiences in Sweden and the Netherlands. The paper is part of a series of 19 papers and a synthesis report produced by the International Transport Forum's Working Group on Private Investment in Transport Infrastructure.

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