Pertti Lahdenperä

Financial analysis of project delivery systems

Road projects' operational performance data revisited

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Abstract

A Project Delivery System (PDS) refers to the organizational framework of a project that defines the control mechanisms and the relationships between actors and their incentives. It is of major importance to the project owner as it, for instance, contributes to the project's level of efficiency. This publication compares the cost efficiency of Design-Bid-Build (DBB), Construction Management at-fee (CM), Design-Build (DB), Design-Build-Operate (DBO) and Design-Build-Finance-Operate (DBFO) in road management based on an (earlier reported) international data capture focusing on the operational performance of these PDSs.

Operational performance refers to the activity-based cost performance of an organization characteristic to a PDS where the timing of the activities is taken into consideration. On these premises a financial analysis that takes into account financing arrangements and corresponding payment systems was made to determine the systems' present costs to a road authority based on relevant market estimates. Moreover, a step towards understanding their overall efficiency was taken by focusing also on differences in speed of delivery which result in expenses or savings to the user community.

The financial analysis of the costs to the owner revealed that, apart from the evenly matched DBB and CM, the broader the scope of services supplied by one contract in the case of public-financed systems (DBB, CM, DB and DBO), the more cost efficient the PDS. If the early commissioning advantage is included in the analysis, especially CM, but also DB improves its competitiveness in relation to the other PDSs. The variation in the financial estimates has no influence on the ranking of public-financed PDSs in practice. DBFO's competitive position is not absolutely clear, but it seems to be in the middle category with DB. Consideration of the early commissioning advantage, however, makes CM (that enables fastest commissioning) nearly equal or in some cases even better than DBFO, which, on the other hand, increases its superiority over DBB.

It must be remembered though that the scheme is, in general, sensitive to project properties and constraints, and fluctuations in the financial and construction markets. The PDSs of the analysis were applied to a relatively large road project in well-known conditions where all PDSs could be considered be applicable.

Preface

There is a continuous strive for better performing organizations and production systems in our society. Part of that effort was a research project called *The performance and development potential of project delivery methods for infrastructure* (*Inka*) carried out by VTT Technical Research Centre of Finland for the industry some years ago.[*] The research concentrated on gathering data on the performance of different road project delivery systems and comparing their performance levels in realized projects. Means of further development were also sought.

As regards actualized performance, both value and cost factors were included in its evaluation. Since the value generation-related criteria used in the comparison were diverse and largely qualitative, it was not considered necessary to strive for detailed cost analysis modelling either. It is, however, the cost factor that has sparked off a heated public debate especially as far as the form of financing – public or private – is concerned. That is why this follow up study seeks to define more accurate cost performances of project delivery systems (PDSs) – and why the private-finance option has been added to a group of alternative PDSs. The performance data gathered in the earlier study enable such an examination. New data were not involved in the analysis.

The source documents of the earlier study phase included, for instance, works by national audit offices and scientific researches. Since these sources only provide a cross section, a large number of parties involved in practical road projects were interviewed. This led to collection of partial information which does not enable statistical evaluation of the validity of the study results and diminishes the transparency of the study. Yet, we are relying on second-hand performance data which may be burdened by other influential factors but PDS. Some uncertainty about the data naturally exists.

Due to the extensive surveys made, literature studied and the congruence of the data from various sources and around the world, I, however, feel confident enough to base my computations on these data and to subject the analysis to open discussion. The previous work presumably provides the most comprehensive conception of the PDSs' operational performance in road management. For that, I am very grateful to my former colleague at VTT, Mrs. Tiina Koppinen, whose contribution was crucial for that study. She conducted the massive literature survey and did the practical fieldwork and travelling required by the surveys and their synthesis and has also been involved in reformulating the initial data for the analysis – whilst also being long-suffering with me continuously querying about survey-related issues that came up during this study phase.

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[*] The study was reported in two publications by Koppinen and Lahdenperä (2004a; 2004b) in the first place. The former focuses on the antecedent survey phase while the latter introduces the final results. A partial summary of the present situation is also given in an article by Koppinen and Lahdenperä (2007).

Besides PDS performance data, financial issues and estimates were also to be defined. Since financial estimates may be more time-dependent, it is important to note that the computations for the study were made at the end of 2006 based largely on the prevailing market situation. The same time-dependence applies also to the reasoning and drawn conclusions on the whole. Thus, some of the financial figures may be slightly different today, but the saving grace is that the change reminds the reader of the continuous fluctuation and the need to update figures for future decision making. Since the actual completion of the analyses, publication has been deferred due to requested expert commentary and reviews. They were deemed necessary to ensure quality work.

Therefore, I wish to express my gratitude to the many finance, construction and road management experts – both known and unknown – who contributed through numerous conversations and views along the way. Their wisdom is also reflected in this document.

These include the many experts interviewed during the earlier stages of the research and partners in earlier projects on the topic in which yours truly has been involved. Of the more recent, inspiring and fruitful discussions I want to emphasize those with Messrs Markku Teppo and Matti Vehviläinen (both from the Finnish Road Administration), Nicholas Anderson (Swedish Export Credit Corporation) and Kimmo Lehto (Municipality Finance; Inspira). The contributors also included Dr. Eva Liljeblom and Dr. Anders Löflund, both professors in finance at Hanken (the Swedish School of Economics and Business Administration, Helsinki). Mr. Jorma Tiainen, for one, helped in the fine-tuning of the language of this publication – thanks, once again.

Tampere, August 2008

Pertti Lahdenperä

Contents

Abbreviations

bp	basis point (one hundredth of a percentage point)
CAPM	Capital Asset Pricing Model
CM	Construction Management
DB	Design-Build
DBB	Design-Bid-Build
DBFO	Design-Build-Finance-Operate
DBO	Design-Build-Operate
PC	Present Cost
PDS	Project Delivery System
PFI	Private Finance Initiative
PSC	Public Sector Comparator
SPV	Special Purpose Vehicle
WACC	Weighted Average Cost of Capital

1. Introduction

1.1 The project efficiency dilemma

Road management is the responsibility of the public sector. Road projects involve manifold activities, some of which owners have traditionally performed in-house, while at least construction has been outsourced. Over time broader service packages have been introduced which include, besides construction, also technical design and often maintenance for a certain period – sometimes even financing – under a single contract. As a result, the owner has many options to organize road management.

Among the numerous issues to consider when selecting a proper option or Project Delivery System (PDS), the (whole life) project cost is always an important one. Due to varied projects and project conditions, the collection and comparison of cost data is not, however, easy. Hardly any two projects are alike or implemented under similar conditions which makes it difficult to draw conclusions on the relative cost efficiency of different PDSs. However, there is an urgent need for such knowledge.

1.2 Objectives and scope of the study

This study aims to clarify the cost efficiency dilemma concerning different Project Delivery Systems (PDSs) in a road management context by defining their indicative, relative cost performances to support the road owner's strategy development. Especially since a single-value, exclusive solution hardly exists, the aim is described in more detail by the following knowledge-contributing subobjectives:

- To understand financing and payment practices intrinsic to different PDSs.
- To model and construct a computation system for PDS cost comparisons.
- To define the most likely relative cost performance of each PDS.
- To study the sensitivity of different PDSs to key financial parameters.
- To ponder whether PDSs' costs can indicate their economic efficiency.

Here, PDSs are applied to a relatively large project, minimum size €30–60 million, in well-known conditions and involving no factors of uncertainty due to third parties. All PDSs can be considered to be applicable to such a project. Arrangement of private finance for smaller projects may be too costly while long-term contracts and required design freedom do not allow much uncertainty in scope definition. Although the study also aims to meet the generalizability goal by relying on performance data collected from various countries, Finland has been selected as the primary application environment as to financial estimates and accounting constraints.

1.3 Study's role in the research entity

The study is a follow-up to an earlier research by Koppinen and Lahdenperä (2004a; 2004b) where approximations of PDSs' cost performances were calculated (based on the same *operational performances*) through direct discounting – the private-financed option and financing issues in general were excluded. The cost to the user community was also ignored. In addition to correcting these deficiencies, the report also focuses on the significance of various financial parameters by means of a sensitivity analysis.

The foundation formed through the earlier research and the role of this effort can be examined by considering the difference between *operational performance* and *financial performance:*

- *Operational performance* is indicated by costs of different key project activities at the time the costs occur and/or as work progresses. This means that the performance data consists of timed and steady cost cash flows of key road management activities and there is a known fixed current cost, and start and end dates, for each activity of all studied PDSs. For the definition of specific values, data is collected from numerous projects in various countries.

- *Financial performance* depends also on the financial arrangement and corresponding payment system (in addition to the cost and timing of activities) and, once the time values of money have been determined, results are calculated for PDSs as explicit index numbers (relative present costs). Since the regulations and financial markets of countries are different, Finland has been selected as the application environment as to financial estimates and accounting constraints.

Thus, *financial performance* is not evaluated separately but rather as an additional feature by reprocessing the different *operational performance* data. The *operational performance* data is taken from the earlier study as such without reconsidering its origin and validity. The factors causing differences between PDSs' efficiency are not looked at again, either. However, a short introduction to the data and to the way it was arrived at is given before delving deep into financial issues.

The reliance on the earlier study phases also explains the exclusion of some customary aspects from this publication, namely cost performance based on other studies. That information was already analyzed and taken into account in defining the *operational performance* data used in them. Also, no comprehensive illustrations of PDSs' overall *financial performance* were available to support proper discussion. Therefore, sections on present knowledge and comparison of the results to other studies are not included in this text. The review of PDSs was also kept to a minimum here for the same reason.

2. PDSs and present cost data

2.1 Project delivery systems compared

2.1.1 Responses to alternating challenges

The PDS determines the division of labour and contractual and operational relations between the major players of a project. It is an organizational means of creating preconditions for the successful implementation of a road project. The appropriate PDS may be a means of avoiding problems and a key to attaining project-specific goals.

Such goals are, for instance, quick completion of a project or low acquisition price. Proper assignment of risk between the parties, the owner’s desire to influence the details of the design, and the available in-house management resources may also be key factors in PDS selection. The type and size of the project in question also have an impact on the selection of the most appropriate procurement method. Various decision-making and advisory systems have also been developed to aid the owner in the selection of an appropriate PDS for an individual project (e.g. Alhazmi and McCaffer, 2000; Mahdi and Alreshaid, 2005; Oyentunji and Anderson, 2006).

PDSs vary a lot. If the focus is on the organizational alternatives of the investment phase, the variations are typically classified into traditional design-bid-build, management-type and design-construct-type methods on the roughest level of examination (e.g. Dorsey, 1997; Sanvido and Konchar, 1998; Peltonen and Kiiras, 1998). With these methods the owner takes care of maintenance separately.

If maintenance is included in the same contract with construction, more variations exist (cf. e.g. Miller, 2000; Levy, 1996). The fact that the ownership of a major road facility remains with society and that the owner also carries the utilization risk limit the alternatives that need to be studied. Thus, from the viewpoint of cost efficiency and/or financial analysis, the key issue as to the alternatives is whether the financing of the investment is included in the contract. This results in the public and private-financed main variations.

2.1.2 Main types selected for the study

The number of PDSs, including all variations, is substantial, but only a limited number can be included in the study. The above classification into five main types of PDSs is a good starting point. For the sake of comparison, all work is assumed to be out-sourced (i.e. commissioned to industry) in all PDSs (instead of being partially performed in-house by the owner). Daily maintenance is excluded from the study. Therefore, the PDSs included in the research are:

- Construction Management (CM), where, in addition to a designer, a manager is hired by the owner to manage the overall project and implementation is realized through numerous partial construction contracts held by the owner (the study examines CM-at-fee excluding CM-at-risk, where partial contracts are held by the management contractor). Periodic maintenance is commissioned separately.

- Design-Bid-Build (DBB), where the owner has contracts separately with a designer and a contractor. Design is completed prior to procuring construction and a contractor is typically selected based on the bid price (since quality is already defined). Periodic maintenance is commissioned separately.

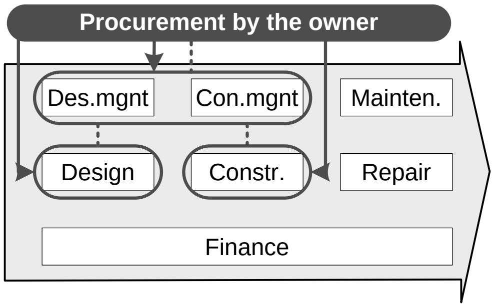
- Design-Build (DB), where a (design-build) contractor under a contract with the owner is responsible for the project's design and implementation as a whole. The quality/features of a design proposal may be a selection criterion in addition to price. Periodic maintenance is commissioned separately.

- Design-Build-Operate (DBO), where the responsibility is assigned through a single contract to design, build and maintain the asset for the contract period. The means of competition are varied. The owner arranges the financing and pays for the investment in due time (as in CM, DBB and DB).

- Design-Build-Finance-Operate (DBFO), where the responsibility is assigned through a single contract to design, build and maintain the asset for the contract period. The service provider arranges the financing and the owner repays the investment as part of the service fee starting after commissioning.

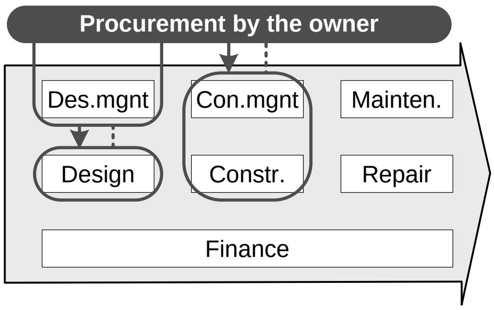
The above list of five adheres to the presented classification (Section 2.1.1). CM, DBB and DB represent the three main alternative ways to organize the work in the investment phase when maintenance is commissioned separately as necessary. DBO and DBFO, again, transfer the liability for maintenance to the same single-point-of-responsibility service provider that also assumes responsibility for construction while the former is a public- and the latter a private-financed option. In both cases design is also always in the same package with construction since no one is willing to accept life-cycle liability for someone else's design: efficiency incentives would be weakened in any case.

Figure 1 presents the PDSs and their variations in slightly greater detail. Should more information on the PDSs and their rationality be needed, it is available from the sources referred to above or the previous publications of the same research entity.



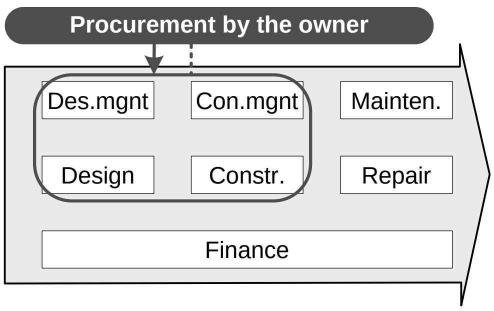
CONSTRUCTION MANAGEMENT (CM)

- Different parties are responsible for design and construction, but the CM organisation participates in management of both. The actual work is generally outsourced and contracts are signed in the name of the client (CM-at-fee; see figure) or the CM body (at-risk).
- The payment basis for management is usually fixed or time-based while for construction works it is fixed (CM-at-fee) or completely target price-based (CM-at-risk).



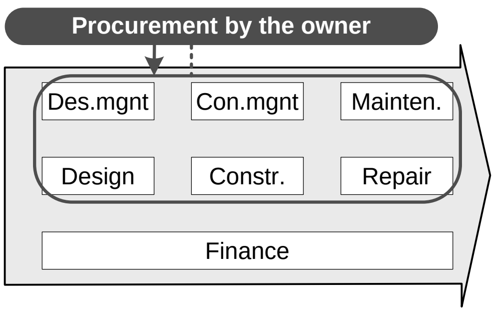
DESIGN-BID-BUILD (DBB)

- Different parties are responsible for design and construction; design has already progressed far when the contractor is selected. The general contractor normally subcontracts much of the work (comprehensive contract; see figure) or coordinates parallel contracts entered into by the client (divided contracts).
- The payment basis is fixed especially in the case of competitive bids; alterations carry a separate cost.



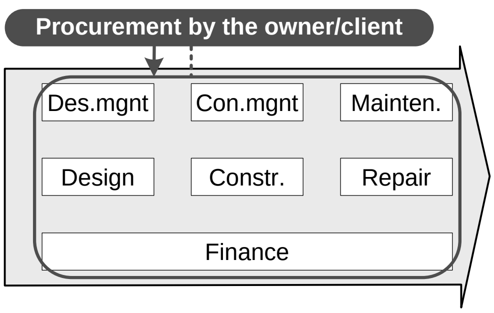
DESIGN-BUILD (DB)

- A single service provider is responsible for design and construction as a whole, possibly on performance-basis. Design delays or errors do not reduce the contractor's responsibility for impeccable completion of the project.
- The payment basis is fixed or target price-based (up to price ceiling / guaranteed maximum price) and compensation is paid as the project progresses or on its completion (construction-phase financing not shown).



DESIGN-BUILD-OPERATE (DBO)

- The service provider assumes responsibility under a single contract for at least design, construction and maintenance of the facility. The contract may also cover other services to the client or directly to the users.
- The payment basis for the investment is fixed or target price-based, and the client usually pays compensation as construction progresses. A maintenance fee tied to service quality is paid during operation.



DESIGN-BUILD-FINANCE-OPERATE (DBFO)

- The service provider is responsible under a single contract for at least design, construction, financing and maintenance of the facility. The contract may also cover other services to the client or directly to the users.
- The payment basis generally includes incentives based on service quality. The client pays off the investment as part of the use-period service fee which also covers maintenance and other possible services.

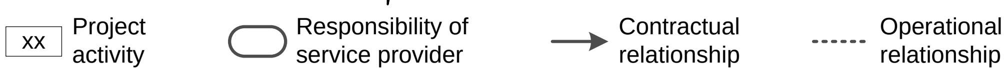


Figure 1. Overview of the five main types of PDSs.

2.2 The knowledge on PDSs’ cost efficiency

The cost criterion is a major determinant in any discussion related to PDSs or business in general. It often includes expected costs and cost (un)certainty (cf. decision-making systems of Section 2.1.1), the latter describing the likely (actualized) deviation from the expected (average) value. Expected cost performance is of primary interest here.

While there may be a lot of fragments of information around, more comprehensive knowledge is sparse. Research on actual cost performance, again, usually compares only two PDSs (e.g. AECOM, 2006; Ernzen et al., 2004) or variations and/or performance of a certain PDS (e.g. Molenaar et al., 1999; Construction Industry Council, 2000; Salmela et al., 2003; NAO, 1998; Hall et al., 2000) which does not allow formulating a general view on the efficiency of a number of different PDSs, especially since studies focus on PDSs applied in projects of different type, size, etc. and under different circumstances.

Especially studies covering the life cycle of an asset, just compare life cycle contracts with conventional ones without differentiating between the many existing alternatives. Moreover, these studies tend to draw conclusions on the basis of comparing actualized project data with pre-project expectations which, despite the credibility of the actual research work, is also problematic due to the usual bias in estimates (MacDonald, 2002; Committee of Public Accounts, 2003).

The starting assumption is the same as in the evaluation of the appropriateness of DBFO, which is often based on the so-called Public Sector Comparator (PSC) (e.g. HM Treasury, 2004). The PSC tool is used to compare a conventionally financed project delivering the same outputs as the DBFO deal under examination to DBFO. There has been considerable debate about the reliability, accuracy and relevance of the PSC, especially since purposeful manipulation has been found to have taken place (Committee of Public Accounts, 2003; Russell and Nelms, 2006).

Most studies also focus on a certain country where the potential of a certain PDS may not be utilized in full which might skew the result and work against the goal of the generalizability of results. Moreover, many studies on PDSs concern vertical construction (Bennet et al., 1996; Sanvido and Konchar, 1998; Ling, 2005; Thomas et al., 2002) and the results, although indicative, cannot be assumed to be directly applicable to road construction, since it often differs from vertical construction in many ways.

Thus, it would be helpful to have more evidence on the performance and true costs of various PDSs in road management in order to get a picture of their overall cost efficiency. An international viewpoint is also a must because only few countries have extensive experience from all types of PDSs which calls for a broad-based data capture.

3. Research data

3.1 Tracing the performance data

To define PDSs' *operational performances*, this research entity charted the performance of different PDSs in actualized road projects in England, Australia, New Zealand, the United States, and Finland. This was necessary since a recent procurement portfolio of a single country does not usually cover all the PDSs, or their use has been limited. For instance, only one DBFO project (but no DBO projects) had been implemented in Finland while the UK has given up the use of DBB. Also, culture and regulations may limit the capacity of a PDS which may not become apparent if performance is explored only based on a certain (foreign) market without extensive comparison of results from numerous markets.

A total of 66 persons, as specified in Table 1, were interviewed in May 2003 to February 2004 which generated a large volume of performance information (Koppinen and Lahdenperä, 2004a). Half of the interviewees were client representatives while the rest were primarily hands-on project participants (designers or constructors). This was necessary to allow determining the internal cost structures of the integrated PDSs, i.e. the relative costs and timing of different activities within a PDS. Objectivity was, naturally, ensured by the conformity with the owners' data on the overall cost level.

In order to improve the generalizability of results, the interviewees were asked to give 'average' actualized values of cost and schedule items based on numerous projects or to give evaluations based on one or a few cases, where the effects of potentially unique circumstances were eliminated. Fourteen projects were examined in more detail (in addition to cases described in literature). The interviewees' statements covered achieved percentage savings or additions (separately in owner and industry activities) and schedule effects in different project phases (procurement, design, construction and maintenance) in different PDSs compared to DBB. DBO and DBFO projects were included in the same data sample for defining their common *operational performance*.

Table 1. Research interviews.

Country	Client	Contractor	Designer	Consultant
Finland	11	4	1	1
UK	5	2	0	1
Australia	12	4	1	4
New Zealand	1	1	1	2
USA	4	1	2	8
In total (66)	33	12	5	16

Different financing solutions were excluded from the study phase in order to eliminate the likely bias from diverging tax codes, financial arrangements, etc. in different countries. Surveyed performance data should not be sensitive to such issues. The charting resulted in information on relative cost and schedule performance of similar activities in different PDSs, i.e. the percentage differences compared to those of DBB. Obvious modes of parallel estimates were used in further calculations although it has to be noted that the answers that were based on systematic analysis of larger project portfolios were weighted accordingly.

For the determination of PDS-specific *operational performances*, reference project data were analyzed resulting in comparative costs (monetary values) and timing of all related project activities in a certain PDS (the balance between design, construction, etc.). It formed the basis for calculating the costs of the other PDSs based on the relative (percentage) differences on the activity level. It is important to note that both the interviewees' evaluations and the cost structure of the benchmark projects were verified against literature data (of which examples are given in Section 2.2).

Comparative PDSs' *operational performance* was calculated separately for two reference projects while only the costs of the bigger one are presented in this publication; the smaller project is only used for verification and commenting. Both reference projects were extensions and improvements of existing roads (the dominant type of road projects today) with investment value of €35–60 million (considered suitable to be delivered with any of the PDSs studied).

3.2 Applying the performance data

The results from the international data capture combined with the reference project data were taken as a starting point for the financial analysis of this study. The resulting PDS-specific activity costs and timings are presented in Table 2. For the analysis, the costs of activities are divided into uniform monthly costs for the overall duration of the activity (which is naturally only an approximation). A graphic illustration of the *operational performances* of this phase including all the PDSs is provided in Figure 2 based on the data of Table 2.

Since the figures were based on an actual project, inflation was inherent. Therefore, the costs were first converted to the June 2002 price level (the launch of the primary reference project) prior to the analysis based on the average change in civil engineering costs during the design and construction period (i.e. 4.0%; Statistic Finland, 2006). This is explained in more detail later in this publication. (In the case of the second reference project the examination was identical except for the timing of the launch of the project.)

The programming phase that precedes procurement is similar for all PDSs and excluded from the comparison as a sunk cost item. Maintenance costs (direct and administrative), again, are based on an industry average to cover actual repair works that were not yet topical in the reference projects. The figures given in the table represent current costs of the first month only after completion. The time value of money was naturally taken into account (i.e. the difference in the completion times of construction between the PDSs).

While there appear to be many minor variations in activity costs between the PDSs, the major determinant at the total level seems to be the variation in construction costs. A major contributor here is the increase over original contract costs (or target price), which in the case of DBB and CM was found to be 10% in practice (based on the survey). The corresponding figure for DB is 4% and nil for DB[F]O.

3.3 Validity of performance data

Utilization of earlier collected data makes it necessary to ponder, already at this stage, whether the *operational performance* data is reliable. No systematically collected cost data existed for use in some interviews. Another challenge faced were the individuals interviewed. If an interviewee was biased against any one of the PDSs, that may have skewed the analysis. The Governments' budget-based annual authorization practice may also have slightly affected the interviewees' estimates on DBB although comparable figures on all PDSs were asked for. However, the low variation between the interviewees' estimates can be considered to support the reliability of the data in general.

While there were slight differences in the perceived cost performance of the PDSs between different countries, the differences were relatively small, and the information from different countries was found to form a coherent set of data backing up the overall assessment. This despite the fact that the subject countries are at different stages of development: the UK and Australia have more experience from integrated PDSs over a longer period while the USA and Finland are still somewhat more conventional.

Moreover, at the time of the research no DB[F]O project had yet finished, although many of the roads have been in use for years. Therefore, the whole-life costs could not be measured *ex post* nor were they reported anywhere. As to CM, performance information was available only from a few interviewees and only for Finland, leaving some unanswered questions concerning the validity and generalization of that information. Although CM may appear more cost efficient than DBB, the fact that CM has been often criticised and largely abandoned in other countries in road construction may offer a partial answer. In any case, the presented performance evaluation of CM should not be considered an absolute truth.

Table 2. Actualized activity timing and costs in different PDSs.

	Project Delivery System Activity	Start [month]	Finish [month]	Realized current cost [€] (i
	Construction Management			
*)	Procurement	0.0	2.5	30 000
**)	Design	2.5	18.5	3 409 821
**)	Construction	6.5	47.5	57 285 000
*)	Client administration	2.5	47.5	1 092 507
**)	Maintenance	47.5	48.5	40 329
*)	Client administration	47.5	48.5	1 613
**)	External advice	2.5	47.5	6 069 482
	Investment total (nominal)			*67 886 810*
	Design-Bid-Build			
*)	Procurement	0.0	2.5	30 000
**)	Design	2.5	18.5	3 589 286
*)	Client administration	2.5	18.5	143 571
*)	Procurement	18.5	21.0	30 000
**)	Construction	21.0	62.0	63 650 000
*)	Client administration	21.0	62.0	2 546 000
**)	Maintenance	62.0	63.0	42 286
*)	Client administration	62.0	63.0	1 691
**)	External advice	21.0	62.0	1 764 889
	Investment total (nominal)			*71 753 746*
	Design-Build			
*)	Procurement	0.0	10.5	54 000
**)	Tender award	10.5	10.5	90 000
**)	Design	6.5	41.3	3 015 000
**)	Construction	10.5	51.5	57 285 000
*)	Client administration	10.5	51.5	246 000
**)	Maintenance	51.5	52.5	40 860
*)	Client administration	51.5	52.5	1 634
**)	External advice	10.5	51.5	418 000
	Investment total (nominal)			*61 108 000*
	Design-Build-[Finance-]Operate			
*)	Procurement	0.0	18.0	216 000
**)	Tender award	18.0	18.0	180 000
***)	Design	14.0	46.0	3 409 821
***)	Construction	18.0	55.3	48 692 250
*)	Client administration	18.0	55.3	246 000
***)	Maintenance	55.3	56.3	37 230
*)	Client administration	55.3	56.3	745
**)	External advice	0.0	55.3	3 124 701
	Investment total (nominal)			*55 868 772*

*) Internal cost to the owner; paid promptly
**) External cost to the owner; paid promptly
***) External costs to the owner; paid promptly in DBO and as a part of the use time service fee in DBFO
i) *Maintenance* cost and the cost of related *Client administration* cover only the first month of maintenance here (unlike in Table 5).

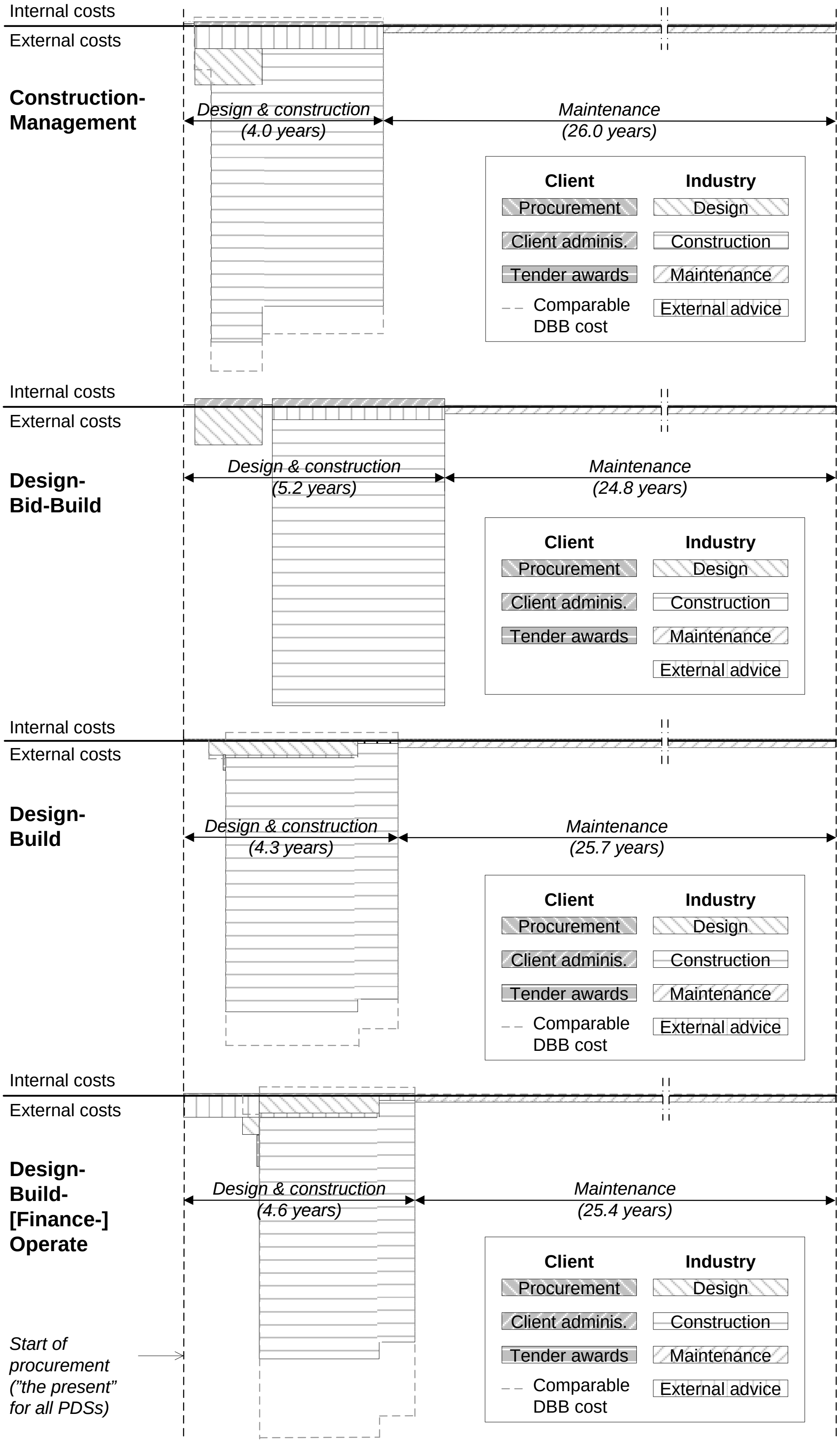


Figure 2. Illustration of timed activity costs with different PDSs (30 year period).

4. Research premises and methodology

4.1 Methodology overview

The analysis follows the discounted cash flow method and results in PDSs' present costs (PCs). Two complementary analyses were made: cost to the owner (analysis 1) and comparative costs to the society (analysis 2).

The analyses are based on the *operational performance* data which means that all actual cash flows (cost to the owner/society) are not available. Activity costs of various PDSs generate different costs to the owner due to the diverging financial arrangements and speed of production. Therefore, this chapter focuses on financial arrangements, formulation of comparative cash flows, and the justification for including the time of commissioning in the analysis. The presentation, including supporting Figure 3, is intended to explain and argue for the principles of the computational model summarized at the end of this section (and presented in more detail in Chapter 6).

4.2 Financial arrangements

DBB, CM, DB, and DBO are public-financed options where the owner (client) is supposed to pay for the work as it progresses. This applies both to the internal (owner's administration) and external costs. In DBFO, again, it is the duty of the service provider to arrange the required financing for the investment, and the owner amortizes the investment only as a part of the subsequent service fee, provided that no imperfections exist in the delivered services. The payment mechanism puts into financial effect the extensive risk transfer from the client to the service provider.

In DBFO, the service provider is usually a company established specifically to carry out the contract (e.g. National Treasury, 2001). Such a company is generally called a Project Company or a Special Purpose Vehicle (SPV). The shareholders of the company usually include several companies, such as a construction company and a maintenance contractor. The SPV's equity ensures adequate risk carrying capacity and entices debt financiers. The constructed asset and the long term contractual incomes from a public body (with a power to levy taxes) serve as collateral for the creditors.

The owner pays a monthly service fee to the service provider from the commissioning date until the end of the contract period. Thus, the SPV has a strong incentive to complete the construction as early as possible since there are usually no restrictions on early commissioning of a road facility. The service fee is supposed to reimburse for the investment by enabling amortization of the debt and return on the equity. The equity remains in the SPV (almost) until the end of the concession while the debt is paid back in the form of (equal) annuities (interest plus principal). Compensation is also needed for the maintenance and repair due to the wear and tear during the long usage period.

Due to different cash flow structures – or durations – of the debt and the equity, the Weighted Average Cost of Capital (WACC) approach (e.g. Finnerty, 1996) is not appropriate here. Another fact is the irrelevancy of the optimization of the financial structure by considering the influence of taxes. Tax relief exists only when the SPV makes a profit, but it does not lower the actual cost of capital and corresponding charges priced into the service fee. The SPV is often a type of flow-through unit when taxes are largely paid by actual service companies and financiers. Thus, tax consequences are in principle the same for different PDSs and are therefore excluded here.

The selected approach is also supported by a common practice where only the minimum amount of equity required by law is invested into the SPV while the remaining capital is debt subordinated to senior debt (although their sum is referred to as "equity" later in the study which is, however, reasonable from the viewpoint of determining their joint required *return on equity*). In Finland that minimum is €2500 (Finnish Companies Act, 2006) – only a marginal amount as taxation is concerned. The point is that this subordinated debt is also paid back before calculation of taxes.

As far as government projects are concerned, the calculation procedure is also consistent with current Finnish tax laws (Law on taxation of business income, 2006; Value Added Tax Law, 2006) including the relevant sections enacted prior to the first Finnish DBFO road project VT4 Helsinki−Lahti in the mid '90s, and with related advance decisions of tax authorities on the second (and the latest) Finnish DBFO project E18 Muurla−Lohja currently under construction.

The law allows straight-line depreciation over the concession period whereby the amortized amount (roughly) becomes tax deductible, and if there is no surplus, there is no difference in taxes either. The law presumes that the SPV's income is dependent on vehicle mileage, which means that the public client carries the related risks thereby minimizing the SPV's risk premium which matches the intended research strategy. In other words, the usage risk and the related risk of increased maintenance is carried by the owner and the service providers are compensated accordingly which makes all PDSs comparable in this regard. Value-added taxation, again, treats all (but financing) costs similarly and is, thus, excluded from the calculations.

4.3 Comparative cash flows

Calculation of PC means discounting future costs into the present by using a *social time preference* as a time value of money. Often this is made by comparing cash flows that have totally different profiles, which causes a problem: There exists no generally accepted level for *social time preference*, and in many cases the value has been selected purposefully in favour of a certain system, which according to Shaoul (2005) has usually been DBFO.

Comparable cash flows can be (and are) created by assuming that the owner will fund the investment in public-financed options with new debt and amortize the debt during the very same period as the service fee is being paid to the SPV in DBFO. Even if the client does not need debt, the *opportunity cost* approach requires similar measures. An opportunity cost is defined as a cost of something we have to forgo or give up in order to obtain the desired (Snell, 2002); here it is the lost return from an alternative investment made during the construction that matures mainly as annuities during the use and maintenance period. In the public-financed model equity is not required from the public client because ownership covenants or guarantees can be used as security.

The aforesaid concerns, however, only external costs to the client. There are always also internal costs, consisting of procurement and administration, whose amount and timing differ between PDSs. The client's organization and its general budget are supposed to absorb the cost and time changes, and these costs are discounted directly without applying the comparable cash flow approach. Costs to the society caused by differences in commissioning time are treated (whenever included) similarly: additional traffic costs are discounted directly.

4.4 Timing of commissioning

As a public body the road authority should apply economic criteria for the best of society which means that other things besides a facility's life-cycle costs (costs to the owner) are also to be considered. Other tangible and intangible benefits and drawbacks to society should be considered in procurement whenever possible (Finnish Road Administration, 2003). While such consideration is ambiguous in general, in a comparison there is no need to study issues that are common to all PDSs. The same concerns the residual value of the road. It is likely that the owner sets such standards for any contract that differences in road and service conditions between the PDSs are only marginal – this, in fact, was already inherent in the study paradigm of the survey of *operational performance*.

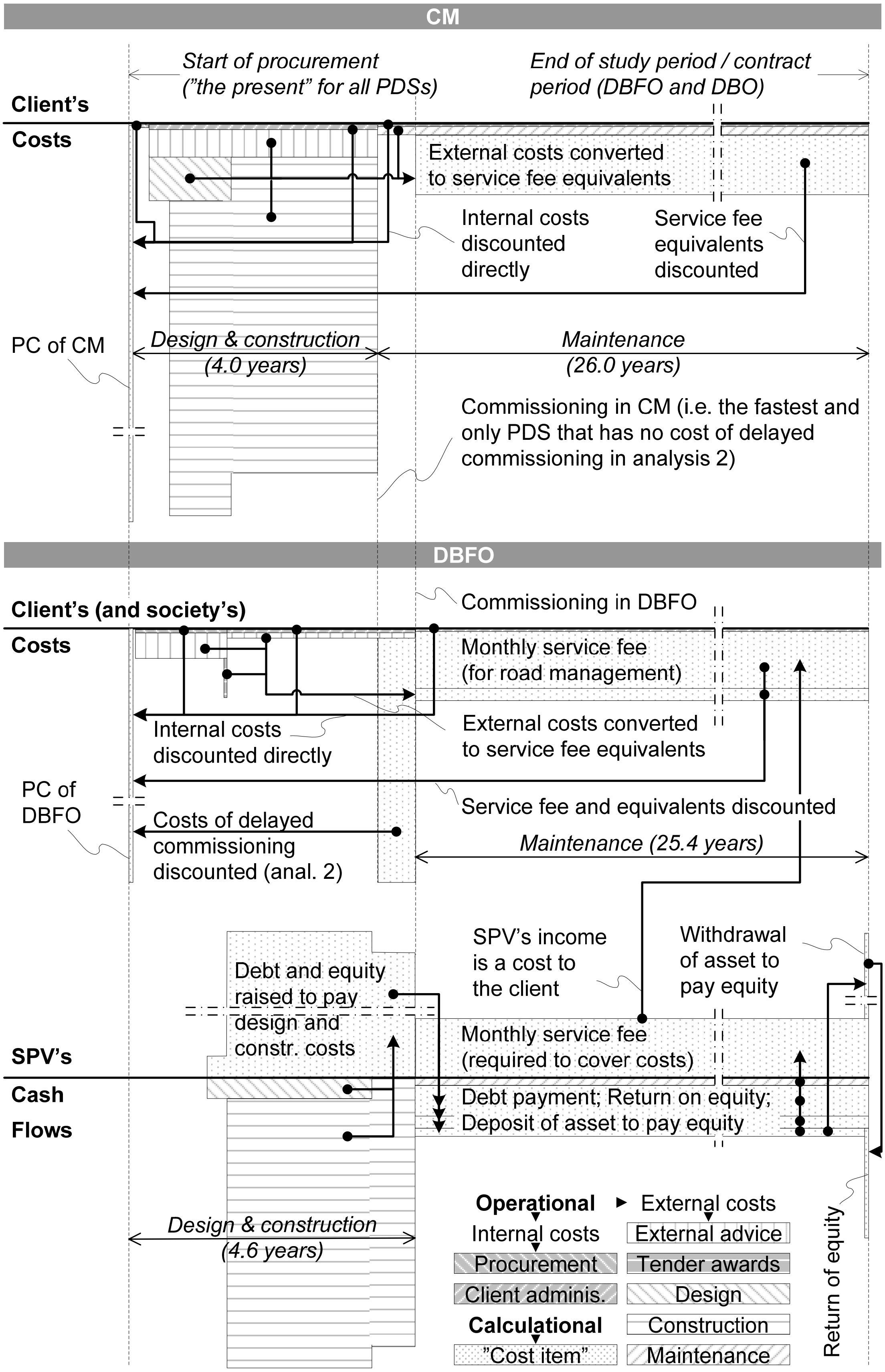


Figure 3. Calculation of financial performance based on operational performance.

Therefore, the only major difference between the PDSs is the variation in the time span between the start of procurement and commissioning of the facility (i.e. completion of construction). Early commissioning produces savings for the user community in traffic costs such as vehicle, driving time and accident costs, and is taken into consideration in the study (in analysis 2) as unitary traffic costs that are identical for all PDSs.

Since the study, at first, looks at the owner's PCs, and savings in traffic costs do not reduce the client's payments, an approach is adopted where delay is considered an additional burden: the fastest PDS is burdened only by its actual cost to the owner while others bear the actual costs and additional traffic costs for the extra duration of the delivery compared to the fastest PDS.

This method is not only justifiable from society's viewpoint but is necessary to remove a methodological distortion: when PC is calculated by discounting future project costs to the present, the later the cost is incurred, the smaller its PC. Thus, when two PDSs have identical cost structures, the one with the slower construction process would be considered more efficient. This cannot be true, however, since a client that decides to invest in a road considers the investment profitable on the basis of road availability. The cost to society should, therefore, be the key criterion when comparing the PDSs.

Due to the inclusion of extra traffic costs into the examination (in analysis 2), it is not reasonable to compare the PDSs based on an identical use period, but rather based on a fixed period from the beginning of procurement. This way, any additional benefits resulting from fast delivery are taken into account as a value added, but only once, since they do not discharge from the responsibility to maintain the road until the end of a comparable use period.

4.5 Methodological summary

As a result of the above, especially considering the manifold characteristics of DBFO, different approaches are applied to different project costs in the calculation model (see Table 1, Figure 3):

- All internal costs of the owner (i.e. from administration) are paid in all PDSs by the owner as they occur. These costs are not converted to the value of the cash flow, whose timing is common to all PDSs (virtual service fee), but are rather discounted directly by using the same *social time preference* used for all other costs. Additional traffic costs due to delayed commissioning are treated in similar fashion: they are discounted directly.

- External costs to the owner in public-financed PDSs, as well as the client's consultancy and tender awards in DBFO, are compensated to service providers promptly. Therefore, these costs are converted to the value of the cash flow whose timing is determined by the DBFO service fee using the *social opportunity cost* rate before discounting them with the generally applied *social time preference*.

- In DBFO external costs of design and construction are financed by the service provider (or SPV) with debt and equity. Thus, the actual cost of capital is used to transform these costs (plus related *financing fees in DBFO*) into a unitary service fee, which includes also maintenance costs. This is then discounted by using the same *social time preference* used for other cost items.

- The actual cost of capital consists of the required *return on equity* and the *senior debt interest to industry* (*risk-free rate* plus *industry margin*). The required *share of equity* is calculated from design and construction costs (plus related financing fee) while the rest is financed by debt. The equity remains in the SPV until the end of the concession and pays an annual yield during the maintenance period. The debt is amortized in the form or annuities during the very same period.

All costs of all PDSs are supposed to increase annually in accordance with the *cost escalation* figure. A step-by step introduction to computations is given in Chapter 6.

5. Definition of comparison estimates

5.1 Financial estimates

The financial estimates used for the analyses are determined here. They represent the most likely scenario in the current market (at the time of writing in December 2006). The estimates are used for the primary case analyses and are summarized in Table 3.

5.1.1 Risk-free rate

The *risk-free rate*, while being a conceptual rate, is often defined on the basis of Government bonds. Corresponding rates have recently been and are anticipated to remain a few decimals below 4.0% in Finland (Bank of Finland, 2006) while in the USA, for instance, they are near 5.0%. At the time of the financial close of the E18 (in autumn 2005), the rate was 3.7% (Finnish Road Administration, 2006), and in order to emphasize the selected Finnish viewpoint, a round 4.0% was selected as the basic rate.

5.1.2 Industry margin

The private sector has to pay a higher rate of interest than the public sector. This margin in relation to the Euribor (Euro Interbank Offered Rate) has been, according to a survey, 0.25–1.5% (Lehtinen, 2005) which has led to the application of 0.5% in practical decision making (Kaleva and Leiwo, 2006). As actual margins have been decreasing, the same rate is selected for the analyses and is used for the entire contract period for simplicity. That margin is also supported by the yield spreads of outstanding bonds of the construction industry which can be even lower (Reuters, 2006).

In practice, neither the margin nor the required return is stable. The construction phase involves more risks than the operation and maintenance period, and debt refinancing (selling to the secondary market) soon after commissioning is likely to lower the cost of finance. The saving is normally divided between the owner and the SPV (NAO, 2006). The construction phase rate may be above a certain rate if the maintenance period rate remains below the same rate by the same amount; still, the length of the maintenance period tends to lower the average rate below this reference rate.

5.1.3 Senior debt interest to industry

Senior debt interest to industry is simply the sum of the *risk-free rate* and the *industry margin* dealt with above. In other words, 4.5% is the basic rate of the analyses.

5.1.4 Cost escalation

Average inflation in the Euro Zone has been just above 2% while in Finland the annual rate has been around 1% and is also anticipated to stay below 2% (Bank of Finland, 2006). The cost of civil engineering works has risen much faster: the pace was 2–3% per year before it accelerated to 5–6% during the last couple of years (Statistic Finland, 2006). A partial reason is the heated market, and the price level is likely to level off in the future. Due to the surfacing works' dependency on oil, for instance, a round 2.0% was selected and the same inflation/escalation rate is assumed to affect equally all services and PDSs.

5.1.5 Social time preference

The most commonly used discount rates in practical net present cost comparisons in different countries have been 6–8% (Shauol, 2005; Grimsey and Lewis, 2005). Shauol (2005), for instance, considers that they favour DBFO excessively. This paper compares pure costs and takes risks and commissioning into account separately, which means that the corresponding components are not relevant as such. Therefore, there is no reason for the *social time preference* rate to differ from the market price for money, i.e. the *risk-free rate* of 4.0% defined above. That ensures fair treatment of all PDSs in the analyses.

5.1.6 Social opportunity cost

An opportunity cost is the cost of pursuing a certain course of action measured in terms of a foregone return offered by the most attractive alternative investment (Esty, 2004). Considering the fact that the alternative should be equal as to risk, a rate close to the private sector's actual cost of capital in DBFO might be justifiable. It would factor in the risks related to the project in question as assessed by creditors and sponsors (cf. Grout, 1997; Klein, 1997). Since the risks between public-financed PDSs are different in any case, and there is a debt option available to the public client as well, this study takes a more practical point of view: it uses 4.0% (the *risk-free rate*) as the basic *social opportunity cost* (and risk issues are dealt with in the discussion section only).

5.1.7 Share of equity

In an investment involving project finance, equity may represent 5 to 30% of the financing while the rest is debt; the *share of equity* depends on expected profitability and operating risks as well as the adequacy of the project's security arrangements (Finnerty, 1996; Merna and Njiru, 2002). Despite the variation, practice has shown that the share is typically 10% of project financing (NAO, 2006; Manley et al., 2006). That share was also used for real-life decision-making by Kaleva and Leiwo (2006) and is consequently applied also in this study.

5.1.8 Return on equity

According to the Capital Asset Pricing Model (CAPM), the expected return on a security or a portfolio equals the rate on a risk-free security plus a risk premium (adjusted by case-specific beta). In business the latter has been estimated to have been, on average, 4.0–4.5% in the last few decades (Fama and French, 2001). On the other hand, a survey resulted in a consensus forecast for a 30-year equity premium of 5.0–5.5% (Welch, 2001). Expectations have, however, decreased 50 to 80 basis points (bps) since then (Graham and Harvey, 2005; PriceWaterhouseCoopers, 2005). Graham and Harvey (2005) reported the most recent expectations of 3.0% over a 10-year horizon while the risk premium applied in Finland seems to have remained generally around 4.0% (PriceWaterhouseCoopers, 2005). This would result in a 4.0% unadjusted risk premium for the study.

As regards beta, i.e. the CAPM risk factor for the risk premium, road DBFO solutions involve hardly any market risk. While the uncertain revenue is usually the main source of market risk, it has here been replaced by the contract-based fixed cash flow; building costs, again, are low-beta or zero-beta activities (Grout, 1997). Therefore, the usual business betas are not applicable and Leviäkangas (1998), for instance, reports a beta just above zero. However, based on formulas provided by Copeland and Weston (1988) and Finnerty (1996), for instance, this low figure increases manifold with a high debt-equity ratio (possibly up to nine-fold in this case). The situation is further confused by the usual practice of refinancing (to lower interest rates after the more risky construction phase), which is, however, not considered separately in the calculations. Therefore, a more approximate approach is adopted and the basic case of this paper is built on a risk premium of 4.0% (with levered beta equal to 1), which added to the 4.0% *risk-free rate* results in a required return of 8.0% on equity (over entire contract period).

5.1.9 Financing fees in DBFO

Consulting fees for lawyers and financial consultants in DBFO are included in the cost of external advice which does not, however, cover the financing fees likely associated with private-financed solutions. In the case of the general debt market, they amount to around 0.5% of the debt raised (which here equals the investment costs). No financing fee is included in public-financed solutions although it might well be reasonable if the client finances the project by debt. In fact, according to some (other) anecdotal information, the selected figure is fairly low for project financing and is likely to represent a type of compromise between the two comparative situations.

Table 3. Summary of estimates used in basic analyses.

Parameters	Basic value for the comparison	
Risk-free rate	4.0%	per annum
Industry margin	0.5%	per annum
Senior debt interest to industry	4.5%	per annum
Cost escalation	2.0%	per annum
Social time preference	4.0%	per annum
Social opportunity cost	4.0%	per annum
Share of equity	10.0%	per annum
Return on equity	8.0%	per annum
Financing fees in DBFO	0.5%	of raised loan(*
Study/concession period	30 yrs	(**
Early commissioning advantage	1.0 M€	per month(***

*) To cover both the debt and equity
**) From the start of procurement
***) Considered in Analysis 2 only

5.2 Other estimates

A financial analysis requires also defining the concession period. That is done here. The likely savings to society due to early commissioning of the road are also discussed. The resulting figures are included in Table 3 together with the financial estimates.

5.2.1 Study/concession period

The total *study period* (*concession period*) is 30 years (from the start of procurement) mainly since that is close to the stated economic life cycle of a road (Tervala et al., 1996). In fact, a concession of exactly 30 years seems to be the most common in UK-based Private Finance Initiative (PFI) projects (PartnershipsUK, 2006).

5.2.2 Early commissioning advantage

The completion of the first DBFO road in Finland, motorway VT4 Helsinki–Lahti, was accelerated by a year compared to traditional project delivery. Based on an *ex post* examination the savings in vehicle and driving time costs were 8.4–9.3 M€ and in accident costs 2.5–10.9 M€ (Murto et al., 2002). This means 1.0–1.7 M€ per month in savings from an investment 1.5 times that of the reference project. Considering the size difference and the inflation thereafter, the monthly cost of delayed commissioning is 1.0 M€. It has to be kept in mind, however, that the early commissioning advantage, especially, is sensitive to the project environment and circumstances as can be judged, for instance, on the basis of the model by Yo and Lo (2005).

6. Calculations for the analysis

6.1 Overview

A spreadsheet software application was compiled for the calculations for the analyses. Consideration of financial items at monthly intervals over the long *study period* (40 years in sensitivity analysis) required about 500 rows for the definition of project cash flows. At the same time, the many project activities and phases of calculation (due to the need to ensure controllability) and the alternative financing options required roughly 100 columns to be employed for each PDS. Considering the many PDSs, two reference projects and the examinations due to the different commissioning dates in the second analysis, etc., at least half a million cells were employed in the application. That is why comprehensive computations could not be included in the publication.

This chapter is, however, supposed to give a detailed introduction to the calculations as required by the transparency and repeatability of scientific work. The text below presents in specific terms the principles of the financial modelling presented in Chapter 3. In other words, explicit functions are recapitulated and particularized, calculations are described narratively and some intermediate results are written out and visualized.

6.2 Basic formulas for calculations

To start with the very basics, interest rate (*i*) describes the periodical change in the value of money. Normally, all rates are announced as annual rates and, thus, the period is a year unless otherwise announced. Considering the fact that interest is compounded to the capital at the end of the period, a future value of a present sum of capital in certain years can be counted as follows:

$$F = P \times (1+i)^n \qquad (1)^*$$

where F = Future value (at the end of *n* periods)
P = Present value (at the time of *0*)
i = Interest rate for all periods
n = Number of periods

Therefore, the present value can also be calculated from future value:

$$P = F \times \frac{1}{(1+i)^n} \qquad (2)^*$$

Equal periodical instalments form another challenge which can be outlined on the basis of Formula (1). For instance, repeated annual transactions from year *0* to *n* (presented in reverse order) result in the following accumulated future value at the time point *n*:

$$F = A(1+i)^0 + A(1+i)^1 + A(1+i)^2 + \ldots + A(1+i)^{n-1} \tag{3}$$

where A = Equal periodic instalments, and
all other parameters as presented in the context of Formula (1)

By subtracting the last transaction (occurring at the point of time *n*) from both sides of the equation the previous can be written as:

$$F - A(1+i)^0 = A(1+i)^1 + A(1+i)^2 + \ldots + A(1+i)^{n-1} \tag{4}$$

On the other hand, one year later the values (of both sides of) Formula (3) would be:

$$F(1+i) = A(1+i)^1 + \ldots + A(1+i)^{n-1} + A(1+i)^n \tag{5}$$

Since the right side of Formula (4) forms a part of Formula (5), the latter can be written into the form:

$$F(1+i) = F - A(1+i)^0 + A(1+i)^n \tag{6}$$

This, again, can be rewritten as follows:

$$F(1+i-1) = A[(1+i)^n-1] \tag{7}$$

This results in a more compact formula for the future value of periodic instalments:

$$F = A \times \left[\frac{(1+i)^n - 1}{i} \right] \tag{8}*$$

Therefore, the periodic instalment can also be calculated from the future value:

$$A = F \times \left[\frac{i}{(1+i)^n - 1} \right] \tag{9}*$$

Now, after examining the relationship between the future and the present value, on the one hand, and annual instalments, on the other, the relationship between the present value and periodic instalments can be determined easily. Using Formulas (1) and (8), both representing the future value based on different initial data, it may be written as:

$$P(1+i)^n = A \times \left[\frac{(1+i)^n - 1}{i} \right] \quad (10)$$

$$\Leftrightarrow \quad P = A \times \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] \quad (11)$$

$$\Leftrightarrow \quad P = A \times \left[\frac{1 - \frac{1}{(1+i)^n}}{i} \right] \quad (12)^*$$

Consequently it is also true that:

$$A = P \times \left[\frac{i}{1 - \frac{1}{(1+i)^n}} \right] \quad (13)^*$$

The above formulas, or more precisely those marked with an asterisk, form the six key compound interest functions. Therefore, they form a logical set to present here although not all of them are used in this study.

One more challenge remains: It was supposed earlier that the payment interval equals the compounding frequency, that is, one year. This is not, however, the case in project procurement, where, for instance, services are paid for on a monthly basis. A fraction of the interest rate (i.e. i/12) and monthly periods cannot be used since this would mean adding interest to the principal once a month and paying compound interest repeatedly. Due to the cascade effect this approach would lead to higher interest than intended. The appropriate rate for periods shorter than a year can be derived from Formula (1) by making both compounding periods produce the same future value:

$$P(1+i)^n = P(1+r)^{n \times m} \quad (14)$$

$$\Leftrightarrow \quad (1+i)^{n/(n \times m)} = (1+r)^{(n \times m)/(n \times m)} \quad (15)$$

$$\Leftrightarrow \quad (1+i)^{1/m} = (1+r)^1 \quad (16)$$

$$\Leftrightarrow \quad r = (1+i)^{1/m} - 1 \quad (17)$$

where P = Present value (year 0)

i = Annual interest rate over the n year period
n = Number of years
r = Periodic interest rate equivalent
m = Number of instalments per year
(i.e. 12 in the case of monthly instalments)

By substituting i with r in the above key formulas including equal periodic instalments, calculations can be made, for instance, on a monthly basis. In the case of conversion between the present and future values of a single item, the annual interest rate can be used supposing the period is presented in years (even if they are not integers). The resulting formulas are collected into Table 4 with multiplier factors' appellations from two different references (Taylor, 1975; Jaffe and Sirmans, 2001).

Table 4. Factors of key interest functions.

Formula (#)	Out-come	Known factor	Multiplier factor	Appellation of multiplier (some examples; possibly depending on the context)[i]
(1)	$F =$	$P \times$	$(1+i)^{k/m}$	Single-payment compound-amount factor [*] Future value of lump sum factor [**]
(2)	$P =$	$F \times$	$\frac{1}{(1+i)^{k/m}}$	Single-payment present-worth factor [*] Present value of lump sum factor [**]
(8)	$F =$	$A \times$	$\frac{(1+r)^k - 1}{r}$	Uniform-series compound-amount factor [*] Future value of an annuity factor [**]
(9)	$A =$	$F \times$	$\frac{r}{(1+r)^k - 1}$	Sinking-fund deposit factor [*] Sinking fund factor [**]
(12)	$P =$	$A \times$	$\frac{1 - \frac{1}{(1+r)^k}}{r}$	Uniform-series present-worth factor [*] Present value of an annuity factor [**]
(13)	$A =$	$P \times$	$\frac{r}{1 - \frac{1}{(1+r)^k}}$	Capital-recovery factor [*] Mortgage constant [**]

where $r = (1+i)^{1/m} - 1$

P = Present value (year 0)
A = Equal periodic instalment (at the end of period)
F = Future value (at the end of n periods)
r = Interest rate for an instalment period
i = Effective annual interest rate
m = Number of instalments per year
k = Number of instalments in total

i) Annotations were presented in connection with formulas where instalment frequency and compounding period both equal one year
*) Taylor (1975)
**) Jaffe and Sirmans (2001)

6.3 Current costs as a starting point

The study is based on using the *operational performance* data given in Table 2 as *realized current costs*. There the costs of the corresponding investment phase activities of different PDSs were defined on the basis of relative approximations given by the interviewees and literature (see Section 3.1), and those relative costs were not modified despite the slight differences in their timing. In general, these figures originate from a real road project and include inflation meaning that there is a potential bias between the cost levels of different phases unless the influence of inflation is taken into account. Consequently, the costs were converted to the cost level of the start of procurement by using the realized inflation rate; the same average rate was used for all activities (see Section 3.2). In practice, due to competitive bidding and the prevailing fixed-price contracting practice, service providers allow for the cost increase in their proposals and, therefore, it makes no sense to use different actualized periodic inflation rates (although theoretically that appears reasonable). As a result, naturally, approximate costs are used.

The costs of activities were first divided into uniform monthly costs for the overall duration of the activity considering the fractions of months here as well as in the rest of the calculations. Conditional multi-step clauses were coded into the software application. The equal distribution represents naturally only an approximation since the accumulation of costs during an activity is hardly linear (thus it was also considered unnecessary to focus on the exact impact of inflation on an activity in the distribution). Then, each monthly cost item was converted to its present value (in terms of the study) by using Formula (2) followed by the summing up of the discounted monthly values per activity. This resulted in the figures presented in Table 5 as *realized constant costs*.

Anticipated current costs of the same table were then arrived at by first dividing activities' *realized constant costs* into uniform monthly costs for the overall duration of the activity. Then, each monthly item was redefined by using Formula (1) and anticipated inflation referred to as *cost escalation*. The time-span was, of course, the time difference between the present and the month in question. The summary figures in Table 5 cover all monthly items of an activity while they are not used in further computations (that are based on each individual monthly cost item) but are only presented for illustration purposes. (From this point forward representative intermediate figures could not be presented due to increasingly more complicated computations.)

The entire effort was justified since the inflation rates during the implementation of reference projects (which were probably factored into the proposals and included in the actualized costs) were different from what is expected in the near future (2.0% is the basic rate in Table 3). The intention was to make sensitivity analyses for different inflation rates which also required the selected approach.

Table 5. Activity timing and computational costs of different PDSs.

	Activity	Start [month]	Finish [month]	Realized constant cost [€]	Anticipated current cost [€]
	Construction Management				
*)	Procurement	0.0	2.5	29 824	29 913
**)	Design	2.5	18.5	3 289 786	3 350 147
**)	Construction	6.5	47.5	52 400 021	54 843 242
*)	Client administration	2.5	47.5	1 006 051	1 049 531
**)	Maintenance	47.5	360.0	10 755 325	15 233 758
*)	Client administration	47.5	360.0	430 213	609 350
**)	External advice	2.5	47.5	5 589 173	5 830 728
	Total (nominal)			*73 500 393*	*80 946 670*
	Design-Bid-Build				
*)	Procurement	0.0	2.5	29 824	29 913
**)	Design	2.5	18.5	3 462 932	3 526 470
*)	Client administration	2.5	18.5	138 517	141 059
*)	Procurement	18.5	21.0	28 083	29 035
**)	Construction	21.0	62.0	55 527 283	59 523 685
*)	Client administration	21.0	62.0	2 221 091	2 380 947
**)	Maintenance	62.0	360.0	10 256 277	14 687 067
*)	Client administration	62.0	360.0	410 251	587 483
**)	External advice	21.0	62.0	1 539 662	1 650 474
	Total (nominal)			*73 613 922*	*82 556 133*
	Design-Build				
*)	Procurement	0.0	10.5	52 995	53 502
**)	Tender award	10.5	10.5	86 822	88 412
**)	Design	6.5	41.3	2 785 629	2 900 356
**)	Construction	10.5	51.5	51 719 425	54 489 405
*)	Client administration	10.5	51.5	222 100	233 995
**)	Maintenance	51.5	360.0	10 617 656	15 084 249
*)	Client administration	51.5	360.0	424 706	603 370
**)	External advice	10.5	51.5	377 389	397 601
	Total (nominal)			*66 286 722*	*73 850 891*
	Design-Build-[Finance-]Operate				
*)	Procurement	0.0	18.0	209 426	212 743
**)	Tender award	18.0	18.0	169 716	174 833
***)	Design	14.0	46.0	3 087 927	3 247 584
***)	Construction	18.0	55.3	43 153 060	45 887 764
*)	Client administration	18.0	55.3	218 015	231 831
***)	Maintenance	55.3	360.0	9 439 029	13 448 096
*)	Client administration	55.3	360.0	188 781	268 962
**)	External advice	0.0	55.3	2 854 028	2 990 714
	Total (nominal)			*59 319 983*	*66 462 527*

*) Internal cost to the owner; paid promptly
**) External cost to the owner; paid promptly
***) External costs to the owner; paid promptly in DBO and as a part of the use time service fee in DBFO

The above concerns the activity costs of the investment phase. Maintenance costs and the related costs of client administration were based on the market average, not on the reference projects from which such figures were not yet available. Use of the market average was also justified since it was an appropriate way of making costs of periodically made repairs part of the cost data. Maintenance phase costs were naturally also converted to the cost level of their actualization (including inflation) in a similar manner as other costs items.

6.4 Definition of comparative costs elements

Anticipated current costs of various project activities were defined for the analyses as described above. This section explains the further computations applied to different cost items in case of different PDSs including costs of delayed commissioning. Figure 3 (on page 23 above) might be of help as a parallel reading with the explanations that follow.

6.4.1 Internal costs to owner

Internal costs to the owner refer to the costs of client administration in different project phases: procurement of different services (either separately or as a package) as well as costs of the later work for ensuring proper service by private service providers. Each monthly item, as defined above, is discounted directly by using Formula (2) and the selected *social time preference* rate. The summing up of the discounted monthly items per activity results in the PCs presented in Table 6.

6.4.2 External costs in public-financed PDSs

In public-financed PDSs, external costs to the owner consist of the costs of purchased design, construction and maintenance services. The client's consultancy (external advice) and tender awards (that exist in DB and DBO as far as public-financed options are concerned) also belong to this category. These items are compensated to service providers and proposors promptly at the time the expenditure is incurred.

For the analyses these costs are converted into a computational cash flow coinciding with the DBFO service fee as justified above in Chapter 3. In practice, each monthly item of service charges and the one-time tender awards were first converted to the cost level of the end of the *concession period* by using Formula (1) and the *social opportunity cost* rate as the interest rate. Then, the resulting total costs per activity were converted into equal instalments over the DBFO service fee period by Formula (9). The *social opportunity cost* remained the used rate while the actual period involved ran from the completion of construction in DBFO until the end of concession, i.e. the DBFO's maintenance period. Finally, the generated equal monthly costs were each discounted separately by using Formula (2) and the generally applied *social time preference*. Summing of the monthly discounted amounts per activity produced the PCs in Table 6.

6.4.3 External costs in private-finance PDSs

In DBFO the external costs of design and construction are financed by the service provider (or SPV) which results in inclusion of additional financing costs into the calculations. In practice, the SPV agrees on the financial arrangement on the basis of its design and construction budget that is here represented by *anticipated current costs* of these activities. Their nominal amount as such serves as the basis from which the additional financing cost item is derived as a percentage share designated as *financing fees in DBFO*. In computation this one-time item emerges in the beginning of design roughly coinciding with its actual existence in a DBFO project.

As discussed earlier, the SPV finances the investment with debt and equity. Since the creditor requires a certain amount to be invested in the SPV's equity before it is allowed to raise debt, and since it is not economically viable to invest more than necessary, it is supposed that the debt-to-equity ratio remains stable (cf. *share of equity*) throughout the investment phase. Thus, the actual cost of capital consists basically of the weighted average of the required return on equity and interest on debt. This is, however, only a rough starting point because different types of principal are paid off at a different pace.

Therefore, after summing up the financing (defined above), design and construction costs per month, each total monthly cost was divided into two parts for computations: the part that corresponds to the *share of equity* that is assumed to be financed with the equity and the remaining part financed with debt. The parts are, again, separately converted to their value at the time of commissioning by Formula (1) whilst different interest rates are applied to different parts: the *return on equity* and the *senior debt to industry* (i.e. *risk-free rate* plus *industry margin*) rates are used.

From this point forward, the treatment of the summed-up debt portion was straightforward: the debt is supposed to be an annuity loan which is why the monthly flow needed for repayment was calculated over the maintenance period by Formula (13) using interest on debt. The resulting item also established the first part of the unitary service fee of the owner. The equity, again, was supposed to stay in the SPV's balance sheet until the end of the contract period which called for different treatment of the asset.

The commissioning-time value of the equity determined above takes into consideration the calculated yield until the end of construction. This yield can now be treated in a similar manner as the debt portion, only the interest is different (i.e. rate of *return on* *equity*). The resulting annuity forms the second part of the unitary service fee. The third part consists of the yield on equity during the long maintenance period: nominally corresponding to one twelfth of the *return on equity* multiplied by the total amount of equity to be added to all monthly instalments of the service fee.

The aim is also to withdraw the invested equity, ignored above, despite the multifaceted project risks so that it can be refunded at the end of the concession. For that reason, an item has to be defined and included in the monthly service fee that accumulates to the sum required for the refund at the end of the concession. In this case, the nominal amount invested in the SPV during design and construction can be considered the end-of-concession future refund in the computations. Formula (9) can be used with the *risk-free rate* supposing the service provider is capable of managing the finances. This is the fourth component of the monthly service fee.

The complicated calculation procedure can be explained by the fact that, as far as investment costs are concerned, all the SPV’s expenses are included in a unitary service fee component. In other words, as long as the facility performs properly, the nominal value of the owner’s monthly payment for the investment remains constant.

The fee for maintenance over the long-term contract period has to be linked to the index also in DB[F]O. The *cost escalation* rate was used to anticipate inflation above and is also used in calculations. In fact, the maintenance costs were already defined for each month separately as described in Section 6.3, and no additional modifications were needed. Maintenance costs constitute the fifth and last component of the service fee.

The summing up of the computed five monthly cost components results in service fees to be invoiced from the owner. Therefore, each monthly item was discounted separately and they were added up to give the PC of design, construction and maintenance − if the entire procedure described is repeated separately for each activity, it results in the PCs of Table 6. Formula (2) is used here while the rate is the *social time preference* rate.

The costs of external advice and tender awards to non-succeeding proposors are paid promptly also in the case of DBFO at the time they are incurred. They are not part of the costs of the DBFO agreement. For that reason, these costs are treated in similar fashion as all external costs in public-financed PDSs.

6.4.4 Costs of delayed commissioning

The relative slowness of a PDS in bringing construction to completion compared to the fastest PDS (CM in this case) results in extra monthly costs for that PDS over the delay period. Inflation was taken into account also in the case of delayed commissioning: the current value of each monthly item was defined separately by using the constant value (from Table 3), Formula (1) and the *cost escalation* rate. Thereafter, the treating of additional traffic cost followed the procedure presented above for the internal costs of the owner: discounting was made by using Formula (2) and the *social time preference* rate. The procedure resulted in the costs presented in Table 7. As shown by the table, the costs of delayed commissioning were taken into account only in analysis 2.

6.5 Activity PCs for different PDSs

The study on many cost items and diverging financial arrangements of different PDSs arrived at PCs based on the detailed computations described earlier in this Chapter. These PCs are presented in Table 6 and Table 7. The former introduces detailed activity and phase-specific costs at the accuracy of the *operational performance* data. The latter, summarizes the costs of some closely related activities in order to provide a more understandable picture. It also presents the comparative cost of delayed commissioning and the summary figures of both parallel analyses. Furthermore, Figure 4 shows the relative cost items in case of different PDSs based on Table 7.

Table 6. Detailed activity PC specification for different PDSs [€] (cf. Table 7).

	Activity	CM	DBB	DB	DBO	DBFO
1)	Procurement (ext.ad./design/total)	29 737	29 737	52 504	206 239	206 239
2)	Tender awards	0	0	85 290	164 844	164 844
2)	Design	3 231 842	3 401 939	2 678 256	2 939 662	3 344 690
1)	Client administration (design)	0	136 077	0	0	0
1)	Procurement (construction)	0	27 180	0	0	0
3)	Construction	50 128 641	51 888 446	49 158 327	40 642 292	46 032 527
1)	Client administration (construction)	965 596	2 075 534	211 101	205 330	205 330
4)	Maintenance	7 810 925	7 354 541	7 683 956	6 808 456	6 808 444
1)	Client administration (maintenance)	312 436	294 181	307 358	136 169	136 169
5)	External advice	5 364 433	1 438 764	358 701	2 727 905	2 727 905

Grouping of cost items for Table 7:
1) *Client administration (incl. procurement)*
2) *Design (incl. tender awards)*
3) *Construction*
4) *Maintenance*
5) *External advice*

Table 7. Summarized PC specification for different PDSs [€] (cf. Table 6).

	Activity	CM	DBB	DB	DBO	DBFO
1)	Client administration (incl. procurement)	1 307 770	2 562 711	570 963	547 738	547 738
2)	Design (incl. tender awards)	3 231 842	3 401 939	2 763 546	3 104 506	3 509 534
3)	Construction	50 128 641	51 888 446	49 158 327	40 642 292	46 032 527
4)	Maintenance	7 810 925	7 354 541	7 683 956	6 808 456	6 808 444
5)	External advice	5 364 433	1 438 764	358 701	2 727 905	2 727 905
Total from analysis 1		**67 843 611**	**66 646 401**	**60 535 493**	**53 830 896**	**59 626 149**
	Delayed commissioning costs	0	13 260 391	3 689 119	7 146 853	7 146 853
Total from analysis 2		**67 843 611**	**79 906 792**	**64 224 612**	**60 977 749**	**66 773 002**

Group contents based on specified items of Table 6:
1) *Procurement (design), Client administration (design), Procurement (construction), Client administration (construction), Client administration (maintenance)*
2) *Design, Tender awards*
3) *Construction*
4) *Maintenance*
5) *External advice*

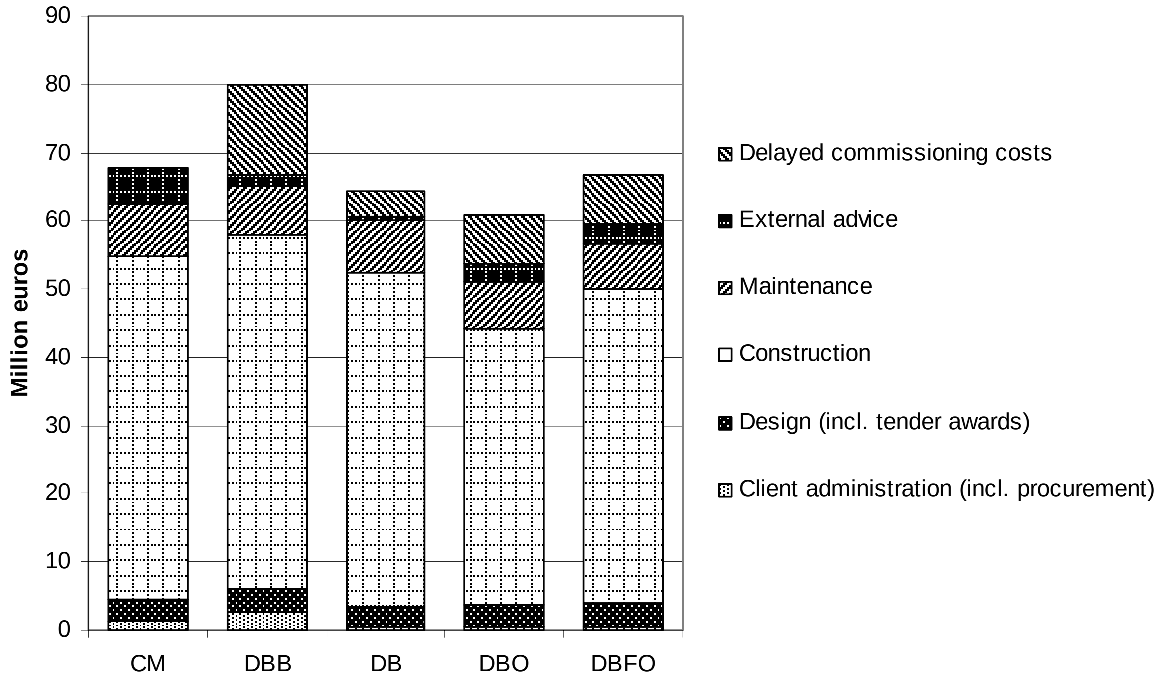


Figure 4. Relative activity and delay PCs in different PDSs.

The review of total costs follows below in Chapter 7, but a few observations about the activity level which causes the overall cost differences may be required first. In the case of design, the cost differences between the PDSs are only marginal. The same can be said about the cost of maintenance. On the other hand, the cost of construction seems to be a major factor – largely because of the differences in cost increases as explained at the end of Section 3.2. Compared to DBB, CM apparently reduces construction costs but only because management costs are separated: it increases the costs of external advice relatively more.

DB can also decrease the costs of construction while it seems to decrease the costs of external advice and even client administration simultaneously. As to the costs of construction, DBO is the most efficient PDS, but the related external advice eats into the savings. In DBFO the costs of design and construction are naturally higher than in DBO due to the more costly financial arrangement.

Albeit the additional costs are treated as part of activity costs in the examination, the overall cost of private finance can be determined on the basis of the difference in total costs between DBO and DBFO: the difference in financial arrangements is the only explanatory factor between these PDSs whose examination is based on the same *operational performance* data as explained above.

Entering into a single integrated contract obviously decreases the owner's administration costs while in the case of PDSs that cover also the long maintenance period this benefit is partly lost by the need for external advice and related costs due to, for instance, a more demanding contractual arrangement. The costs are, however, far less than the corresponding (but contentually different) item in CM which, on the other hand, is the PDS enabling the fastest commissioning of the built asset (that is why no comparative delay costs exist for CM in the above Table 7 and Figure 4).

Here, all monetary values are presented as they came out of the analyses, i.e. without rounding. This was done to maintain the transparency and traceability of the study although the exactness of the source data and the calculation procedures do not support such precision. Therefore, the figures were rounded prior to presenting them as the actual results of the study in Chapter 7 (PCs in Table 8 and Table 9 correspond to the summary rows of Table 7; percentage differences were, however, calculated from the original PCs before the rounding).

While this presentation concentrates only on outputting numerical or monetary values from the analysis, explanatory factors behind the differences in performance of the PDSs as to modus operandi are dealt with in the preceding publications of the same research entity (Koppinen and Lahdenperä, 2004a; 2004b).

7. Relative advantageousness

7.1 Expected performance

The reference project's overall (whole-life) PCs in the case of various PDSs were calculated based on their *operational performances*, financial modelling and the basic estimates described above. Table 8 presents actual costs to the owner and their differences as percentages. Table 9 presents the corresponding figures when the late delivery cost to society is also taken into account in addition to the costs to the owner.

The results of the financial analysis indicate clearly that DBO is the most efficient system in terms of the owner's costs. The private finance of DBFO increases its costs close to those of DB but not to the levels of DBB and CM, which appear to be operationally the two most inefficient PDSs. All in all, disregarding the financing component, the fewer contracts the client enters into to purchase an entire road management package, the more cost efficient the project becomes. Consideration of the *early commissioning advantage* improves the standing of CM with respect to the others the most, but it is likely to match DB and DBO only in cases where the speed of construction is critical. This does not quite happen in a case based on the above set estimates but may be of importance in some projects. The advantage makes DBFO lose ground to CM and DB, but moves it even more clearly ahead of DBB.

The analysis of the other reference project data (not presented in the paper) supports the validity of the results. Differences between the corresponding percentages of these two projects in the basic cases clearly fall within a 2% margin (tantamount to 200 bps relative to the original reference cost) although their cost structures diverge: external advice (from a management consultant) was not actually sought in the other project. In fact, all but one figure describing relative differences are within a 1% margin. On the other hand, the 2% rule remains basically in effect throughout the multifaceted sensitivity analysis and its extreme values: only in a very few cases would the set threshold be exceeded while even there the difference still remains below a 3% margin.

Also, if the inflation priced into the contracts of the primary reference project is supposed to be 2 or 6%, instead of the 4% used in the calculations, the changes in the percentage differences of Table 8 remain within a 2% margin in all cases; in Table 9 they are much smaller. Considering the fact that projects are dissimilar and that there is inaccuracy in the initial data, it is clear that minor differences in the results of the analyses should not be emphasized. Most of the PDSs' cost efficiency differences are, however, much bigger than the presented figures and, therefore, conclusions can be made based on the relatively large differences between the PDSs' cost efficiency.

Table 8. PDSs' actual PCs to the owner (analysis 1; excl. late delivery costs).

	CM	DBB	DB	DBO	DBFO
PC [mill. €]	**67.8**	**66.6**	**60.5**	**53.8**	**59.6**
Differences	*Reference*	–2%	–11%	–21%	–12%
	2%	*Reference*	–9%	–19%	–11%
	12%	10%	*Reference*	–11%	–2%
	26%	24%	12%	*Reference*	11%
	14%	12%	2%	–10%	*Reference*

Table 9. PDSs' comparative PCs to society (analysis 2; incl. late delivery costs).

	CM	DBB	DB	DBO	DBFO
PC [mill. €]	**67.8**	**79.9**	**64.2**	**61.0**	**66.8**
Differences	*Reference*	18%	–5%	–10%	–2%
	–15%	*Reference*	–20%	–24%	–16%
	6%	24%	*Reference*	–5%	4%
	11%	31%	5%	*Reference*	10%
	2%	20%	–4%	–9%	*Reference*

7.2 Sensitivity analysis

Since the financial and other estimates used for the calculations are not exclusive and also likely to change over time and between projects, sensitivity analyses are performed resulting in the graphs of Figure 5 and Figure 6. The basic case of the latter includes the costs of delayed commissioning not included in the former and is likely a more important result than the other one on the basis of the arguments presented in Section 4.4. In other words, Figure 5 builds on Table 8 as to its basic case while the corresponding case for Figure 6 is given in Table 9. Otherwise the figures adhere to the same logic.

The graphs focus on the influence of the variation in the value of nine key cost factors on the relative PCs of different PDSs. According to prevailing practice, only the value of the estimate under study is changed while all the others remain unchanged. The results derived from the basic values are presented in the middle of the graphs while variation occurs horizontally. The *financial performances* of the PDSs are given in relation to the vertical axis. The point of comparison in all examinations is the performance of DBB in the basic case which represents the 100 percent level of performance in terms of PCs with or without the costs of delayed commissioning.

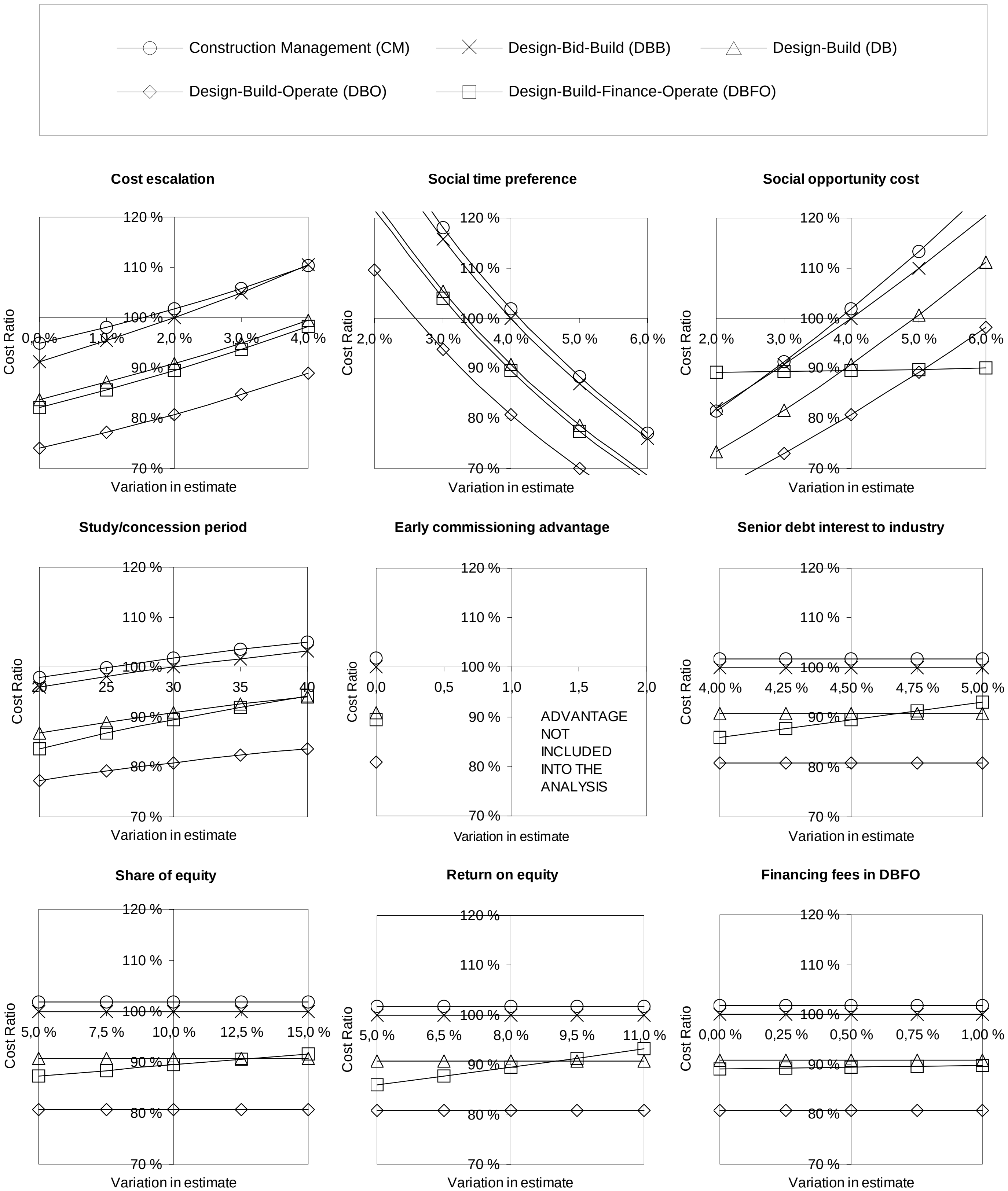


Figure 5. Sensitivity analysis of actual PCs to the owner (analysis 1).

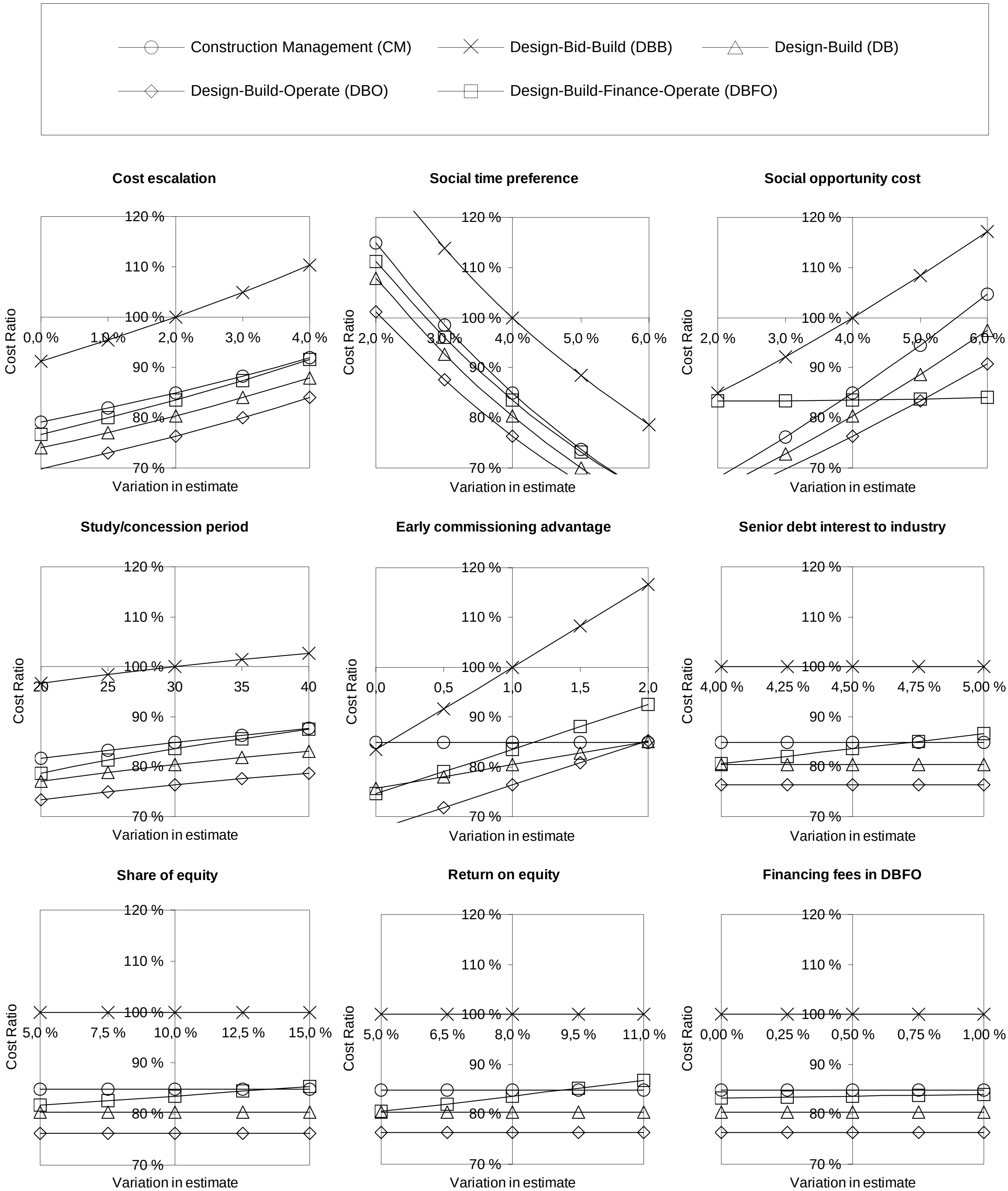


Figure 6. Sensitivity analysis of comparative PCs to society (analysis 2).

The figures show that changes do not usually affect the ranking order of the public-financed PDSs since any alteration affects them much the same. Still, especially the lines representing CM and DBB, are not completely parallel when variations occur in *cost escalation* and *social opportunity cost* due to differences in speed of construction. DBFO is affected differently than the other PDSs by most variations in the estimates. This is obvious due to the different financial arrangement. Increases in *senior debt interest to industry*, *share of equity*, *return on equity*, and *concession period* are detrimental to DBFO's competitiveness. *Social time preference*, again, has no effect, since the cash flows were made comparable. *Social opportunity cost,* which is related to the valuation of risk in public-financed PDSs, seems critical.

It has to be noted, however, that in most cases the change is not as dramatic in practice as it appears from the figures. Many interest rates dealt with as independent factors here are actually derivatives from the market rate and, thus, change in parallel. This weakens the sensitivity of PDSs' relative advantageousness compared to the situation in Figure 5 and Figure 6. Also, the *share of equity*, *return on equity* and *senior debt interest to industry* rate are interrelated, and tend to, at least partially, minimize the sensitivity to any changes. Thus, the figures are, first and foremost, intended for study purposes.

8. Discussion

8.1 Current validity of the results

8.1.1 Operational performance data

As usual, the results are not beyond dispute. *The operational performance* data were based on the preceding study which also discusses their uncertainty concluding that the congruence between the numerous respondents and other studies supports their validity. The used study paradigm involving qualitative features is recognized as imperfect, but it was found to be the only way by which a wide variety of experiences could be included in the study to improve its generalizability. The aim of collecting comprehensive data led, however, also to the collection of partial information which made it impossible to define statistical measures for the reliability of the research results, like the "margin of error". Moreover, the *operational performance* of CM was evaluated on the basis of very limited data since it is seldom used in road construction.

Despite the obvious validity of the data set, from the viewpoint of this analysis, one issue still needs examination: *operational performance* was defined as a common basis for both DBO and DBFO. According to the interviewees, more external advice is required in DBFO while in DBO the owner's administrative burden is slightly heavier. More scope changes also tend to occur in DBO. These differences are easily accepted as a result of motivational and structural differences between the PDSs while, on the basis of the survey, it is likely that those differences largely offset each other on the overall level. Yet, it is likely that a minor difference remains between the two, but it cannot be got at on the basis of the data.

8.1.2 Financial modelling and performance

Financial modelling and estimates are of major interest here. The model was constructed on the basis of a real-life solution with minor adjustments. For instance, the cost of collateral increases the costs of public-financed PDSs to some degree but was excluded from the calculations. Furthermore, the cost of capital of a private-financed option constitutes a profit to the investor and, therefore, returns partially to the public sector through taxation. Moreover, DBFO's cash flows may not be as modelled for simplicity and often also involve several types of financing. Its debt servicing may be accelerated in the early years of maintenance when repairs are not yet needed. On the other hand, the equity is often released during the few last years of the concession, and it does not need to stay in the project until the very end as was also assumed. All these characteristics might make DBFO relatively more advantageous than found in the study.

A survey of diverse documents and anecdotal information on project finance cases suggested, however, that the presented impacts are offset by the slightly higher than estimated financing costs of DBFO due to higher than assumed risk premiums and due diligence audits of major projects (resulting in higher financing fees). The required *return on equity* is often said to be slightly higher than the basic value of the analysis in the study. Yet, it has also been reported that various types of DBFO (PFI) projects have benefited from relatively higher yields compared to alternative investments in the same risk category (Singh et al., 2006). This suggests a developing market (cf. e.g. Quiggin, 2004) which is why the analyses are based on theoretical estimates rather than early experiences from the application of project financing to road construction. Besides, the selected *return on equity* seems to equal the operation period rate of earlier/current projects (cf. Singh et al., 2006) although not that of the riskier construction phase.

Another matter that cannot be disregarded here is the active search for and piloting of special arrangements to decrease the costs of finance in private-financed solutions. An example is the case where the owner provides a major part of the financing and lends the SPV the amount needed to finance the senior debt portion of the overall funding and secures a repayment guarantee from a major financial institution (HM Treasury, 2006). The SPV pays the owner the prevailing market rate, and after payment of the fee required by the guarantor, the owner is left with a surplus that can be considered a net cost saving. Alternatively, the owner may, for instance, guarantee part of the unitary payment or assume the responsibility for a portion of the debt after the infrastructure has been constructed and in satisfactory operation for two years (Kerr, 2006; Bliss, 2007). Such de-risking allows the project to go ahead at substantially lower cost while holding onto the full risk transfer peculiar to DBFO.

In conclusion, the relative *financial performance* of DBFO may be worse or better than presented. It depends on the case and the arrangement. Considering the fact that the most competitive arrangement is usually sought for the PDS in question, lower relative financing costs than those presented may well be reality in some cases in the future.

We have to remember, however, that the calculations are based on an approximation which does not consider the different costs of construction and operation phase financing. Neither does the analysis test the debt servicing cover ratios which are relevant in practice. Correspondingly, the presumption of a pure flow-through SPV may be daring. It may not be the ideal arrangement either. Thus, these issues should be considered in order to improve the accuracy of the results. However, the prevailing calculation practice can at least be supposed to be in line with the accuracy of the *operational performance* data. *Operational performance* is, again, the main explanatory factor behind the differences between the *financial performances* of the public-financed PDSs based on a similar financial solution and, therefore, that issue can be ignored here.

8.1.3 Other considerations

The results describe the situation in a relatively large project with no strict constraints. Such a project is supposed to create economies of scale, entice financiers and offer the leeway needed for design development. Thus, it makes sense to incorporate maintenance and finance into the construction contract. If the above conditions do not apply, less comprehensive PDSs like DB, DBB and CM may well be preferred depending on the project. Therefore, the results cannot be generalized to all kinds of road construction or other types of infrastructure projects.

Projects also involve so many variables that even projects of similar nominal size are hardly alike in all other respects. Projects, their social organization, stakeholder groups, soil conditions, structures, production technologies, innovation potential, contract conditions, etc. differ a lot. Accordingly, the results of this study are aimed more at supporting selection between PDSs as part of the road owner's strategy than individual projects where various factors may deviate from the assumptions of the study, and some other objectives and PDS selection criteria than costs may be more decisive.

Moreover, while Finland has been selected as the application environment of the PDSs as to financial estimates and accounting constraints, country-specific regulations and financial markets can also affect the results elsewhere. However, this may be avoided since the study is grounded in a more or less common understanding of *operational performances* and it treated different PDSs neutrally.

8.2 Anticipated future validity of the result

While a review of historical realization is interesting, the value of financial analysis of this kind is largely based on its ability to serve decision-making on the future use of different PDSs. As to *operational performance*, the interviewees considered DB, and especially DB[F]O, to have substantially more development potential than the less comprehensive DBB and CM (Koppinen and Lahdenperä, 2004b). Other studies have also shown that especially DBFO still lacks the organizational structures and incentives required for optimal performance (NAO, 2001; Rintala, 2004; Eaton et al., 2006).

On the other hand, the earlier study phase also pointed out that a certain tradition of over design prevails in DBB which may offer a possibility for minor performance improvements. Another issue is the tradition of the Governments' budget-based annual authorization which may have affected the interviewees' estimates on DBB (and CM) in some cases although they were to give unbiased figures. Yet, it is obvious that DB and DB[F]O are more likely to improve their competitive position in the future.

Changes in the financial market are likely to contribute to the situation as well. This hardly affects the relative positions of DBB, CM, DB and DBO, but DBFO has a lot at stake. HM Treasury (2006) has recognized a number of ongoing developments in the provision of private finance to support DBFO's competitiveness. They include increasing competition between financiers, more highly geared financial structures, lower cover ratios and lending margins, deferred bid for the selected contractor, and development of a competitive secondary market. Therefore, there is no reason to suppose that DBFO's competitiveness would become weaker than suggested above.

8.3 Contribution of the study

The study determined the owner's/society's PCs in the case of five different PDSs. The analysis was based on a wide variety of project experience gained in different countries and a systematically developed financial model and sensitivity analysis. Corresponding results have not been reported earlier. The data and the results may not be unambiguous, and they do not make further knowledge accumulation unnecessary, but the results can arguably be said to make a contribution to knowledge on the subject matter.

The presented PCs do not, however, necessarily say much about the economic efficiency of the PDSs. Other issues besides monetary ones are important when critically examining the PDSs' ability to produce value for money. The earlier study phase (Koppinen and Lahdenperä, 2007) found a number of other *value generation* differences between PDSs. In general, the more services are included into a contract, the more quality the system generates on average: DB[F]O produces more quality than DB, which, again, generates more value than DBB and CM.

The risk-transfer ability of the different PDSs follows the same logic (cf. e.g. Molin et al., 2004). In CM the client generally carries almost all risks which is also largely true with DBB. In DB the client transfers more risks to the service providers (design delays, constructability, guarantee period performance, etc.) and even more so in DBO and especially in DBFO (concession period performance, whole-life costs, etc.). DBFO's risk-transfer ability is, in fact, the most significant single reason why it is selected (Zhang, 2006).

Considering the facts presented, it is likely that the superiority of public-financed PDSs (in terms of economic efficiency) derives from their cost efficiency in terms of cost to the owner. For the same reason DBFO is likely to improve its competitive position in an economic analysis compared to this cost analysis. The valuation (monetarization) of risk-transfer and quality generation differences constitutes an important theme for further research that will help define the economic efficiencies of the PDSs.

9. Conclusions

This study compared the cost efficiency of DBB, CM-at-fee (with reservations), DB, DBO and DBFO in road management based on an international data capture that revealed the *operational performances* of the PDSs. The financial analysis was executed to define the PDSs' present cost (PC) to the road authority (i.e. the *financial performance*). As a public body, the road authority is, however, obliged to work for the best of the nation and, therefore, another analysis was performed where differences in speed of delivery (completion of construction) and corresponding cost consequences to the society were also taken into consideration. This was also required to remove methodological distortions caused by the discounting practice.

The analyses took a pure cost point of view by supposing no separate financial risk premiums in public-financed PDSs although such risk premiums are included in the price of capital in private-financed PDSs – it is, however, obvious that the actual risk is the same in projects implemented by the public and private sectors. On the level of large project portfolios and average actualized cost performance, the data actually include reasonable risk and the approach is appropriate as it imitates the way the owner ponders the options in practice. Accordingly, the analyses were based on relevant market estimates which provide the public owner capital at a lower cost than private firms. Yet, the pricing of the capital in the private-financed option represents at best an approximation. A detailed estimate would require closer examination of contractual obligations and related risks which was not possible in this work based on a general view of the service provider's duties in DBFO that allows deducting service fees.

The work does not represent the state-of-art in project finance nor study its sophisticated solutions in detail but is based on straightforward and traditional financial structures and rough but well argued market estimates. Simplifications and assumptions have been made as to tax issues and required returns (i.e. stable rates over both the construction and operation phase although the risks differ). Neither does the study focus on the functioning and cost structures of different activities of the road management process as some other works do. Instead, the novelty value of this study lies in the incorporation of the PDS's operational performance differences to the differences caused by the various financial arrangements. Its value-added is also largely based on the fact that it is grounded in broad international experience from road management and sheds light on the sensitivity issues. Single-value, exclusive results hardly exist but knowledge-contributing, indicative conclusions can be drawn in any case.

The financial analysis of the costs to the owner revealed that, apart from the evenly matched DBB and CM, the broader the scope of services supplied by one contract in the case of public-financed systems (DBB, CM, DB and DBO), the more cost efficient the

PDS. As to CM, DB and DBO, this rule applies even if the *early commissioning advantage* is included in the analysis, but the differences between the PDSs become smaller or even marginal, if these benefits become very large. Consideration of the *early commissioning advantage* puts DBB clearly in last place. The variation in the financial estimates has no influence on the ranking of public-financed PDSs in practice.

DBFO's competitive position is not absolutely clear, but it seems to be in the middle category with DB on the basis of the owner's PCs of a 30 year contract. Consideration of the *early commissioning advantage*, however, makes CM (that enables the fastest commissioning) nearly equal or in some cases even better than DBFO, which, on the other hand, increases its superiority over DBB. A shorter than 30 year *concession period* would, however improve the competitiveness of DBFO. It must be remembered though that the scheme is, in general, sensitive to project properties and constraints, and fluctuations in the financial and construction markets. There are also wide variety of possible financial arrangements that have an impact on practical cost efficiency.

The study focuses on comparative costs while only touching on economic efficiency which also covers differences in risk-transfer and value generation. It seems obvious, however, that the relative ranking order of public-financed options remains the same based on economic efficiency criteria since the PDSs' risk-transfer and value generation ability correspond to their cost efficiency. DBFO, again, seems to be a challenger in terms of costs, but its superior risk transfer and good value generation ability balance the situation based on economic efficiency criteria. This is the more likely, the more emphasis is put on the development potential inherent in the PDSs.

All in all, in light of the study, it is obvious that road owners should increasingly select DBO or maybe DBFO procurement for their major projects. The profitable use of the latter may, however, require consideration of a special joint financing arrangement, which decreases the financing costs without actually affecting the risks transferred to the private service providers. Thus, in addition to project properties, the results are also sensitive to the situation in the financial market and the arrangement entered into.

Yet, DB[F]O projects are typically very large to ensure adequate economies of scale, entice financiers and, compensate for the extra effort needed to bid for the work, finalize the contract, etc. In practice, however, more and more projects are launched in the built environment requiring flexibility from the owner's decision making during construction and maintenance. DBO, and especially DBFO, are not applicable in small or very constrained projects. There, the less comprehensive PDSs like DB, DBB and CM may well be more suitable depending on the project. There are also many other criteria for the owner when selecting a PDS than cost that was the focus of this study.

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Abstract

A Project Delivery System (PDS) refers to the organizational framework of a project that defines the control mechanisms and the relationships between actors and their incentives. It is of major importance to the project owner as it, for instance, contributes to the project's level of efficiency. This publication compares the cost efficiency of Design-Bid-Build (DBB), Construction Management at-fee (CM), Design-Build (DB), Design-Build-Operate (DBO) and Design-Build-Finance-Operate (DBFO) in road management based on an (earlier reported) international data capture focusing on the operational performance of these PDSs.

Operational performance refers to the activity-based cost performance of an organization characteristic to a PDS where the timing of the activities is taken into consideration. On these premises a financial analysis that takes into account financing arrangements and corresponding payment systems was made to determine the systems' present costs to a road authority based on relevant market estimates. Moreover, a step towards understanding their overall efficiency was taken by focusing also on differences in speed of delivery which result in expenses or savings to the user community.

The financial analysis of the costs to the owner revealed that, apart from the evenly matched DBB and CM, the broader the scope of services supplied by one contract in the case of public-financed systems (DBB, CM, DB and DBO), the more cost efficient the PDS. If the early commissioning advantage is included in the analysis, especially CM, but also DB improves its competitiveness in relation to the other PDSs. The variation in the financial estimates has no influence on the ranking of public-financed PDSs in practice. DBFO's competitive position is not absolutely clear, but it seems to be in the middle category with DB. Consideration of the early commissioning advantage, however, makes CM (that enables fastest commissioning) nearly equal or in some cases even better than DBFO, which, on the other hand, increases its superiority over DBB.

It must be remembered though that the scheme is, in general, sensitive to project properties and constraints, and fluctuations in the financial and construction markets. The PDSs of the analysis were applied to a relatively large road project in well-known conditions where all PDSs could be considered be applicable.

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