

Procurement and Contract Design in the Construction Industry ... not one size fits all

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the Construction Industry**

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TABLE OF CONTENTS

ABSTRACT	4
1. INTRODUCTION	4
1.1 The overall perspective	4
1.2 Purpose of the present study	5
2. THE WELFARE MAXIMISATION PROBLEM	6
3. ALTERNATIVE WAYS TO TENDER CONSTRUCTION AND MAINTENANCE	8
3.1 Complete un-bundling; buying input	9
3.2 A first step towards bundling; Design-Build	10
3.3 Bundling and the performance contract	10
3.4 Bundling and Public Private Partnership	12
4. TRADE-OFFS IN TENDER AND CONTRACT DESIGN	13
4.1 Tendering – a reverse auction	13
4.2 Payment mechanisms and incentives	15
5. COMPARISON OF CONTRACTING ALTERNATIVES	17
5.1 DBB/UPC vs. DB	17
5.2 UPC versus bundling	18
6. SUMMARY	21
BIBLIOGRAPHY	23

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ABSTRACT

This paper considers the choice between different approaches to contract for the construction and maintenance of infrastructure projects. The need to control for user costs over the life cycle of an asset is demonstrated to be a core aspect of contract design. The more likely it is that a certain problem in the current infrastructure could be sorted out in several different ways, the more strongly should the tendering agency consider innovative design alternatives such as performance contracts of Public Private Partnerships. It is also demonstrated that contracts which cover both construction and subsequent maintenance must be accompanied by bonuses and penalties for remunerating or punishing the entrepreneur for delivering (or not) appropriate infrastructure quality.

1. INTRODUCTION

1.1 The overall perspective

An ITF study under preparation will investigate when different strategies for road maintenance, operation and development are needed in order to guarantee an optimal service level over the life-cycle of the road infrastructure. Focus is on better evaluation of road maintenance, on rehabilitation and road user costs, including consequences for future levels of service. It will also explore the current practices for road maintenance evaluation and identify cost-effective solutions to optimise service levels of the infrastructure. The purpose is to draw conclusions and make policy recommendations on the future data needs, required improvements in evaluation methodologies and performance measures.

The present paper comprises one out of four background studies to meet this overall target and is concerned with contracting issues. It is given the following objectives:

- To determine the contribution of innovative road delivery approaches such as PPPs to generate value for money.
- To assess the effectiveness of implementing bonuses and penalties tied to performance-based indicators to improve the road life-cycle cost.
- To evaluate the role of incentives in promoting efficiency.

1.2 Purpose of the present study

The perspective of the ITF study is that of infrastructure life cycle costs. Infrastructure is costly to build while subsequent spending on maintenance of the assets is comparatively small on an annual basis. In view of their often long service-life, the (present) value of spending on maintenance may still be substantial. Furthermore, there is a link between the two cost components in that more spent during the construction phase to create an asset with higher quality may save on subsequent maintenance costs, and vice versa. Importantly, the quality of the road also affects users, since an investment that has been built to a high standard will have greater chances to deliver high-quality services. An optimal level of spending on infrastructure construction and maintenance must therefore account for all three cost components in order to deliver appropriate services to society.

Infrastructure investment shares these qualities with costly projects in several other sectors of the economy. Once built, however, a road, railway, airport or port has low opportunity costs, i.e. it has no value for a use other than it is built for. In combination with other market failure problems, this means that the provision of infrastructure services is typically a responsibility of the public rather than the private sector. But although the public sector is ultimately responsible for service delivery, many countries don't use in-house resources to build new and maintain existing infrastructure any more. Rather, these services are provided by the private sector after a process of competitive procurement.

There are several ways to design the contract(s) when a public sector agency tenders construction and maintenance. One choice has to be made between bundling and un-bundling of construction and maintenance activities, contract durability is another choice parameter, using fixed price, unit price or other constructs for making payments a third. The purpose of the present paper is to identify the way in which the public sector should design the procurement process and the subsequent contract in order to minimise social costs under the whole life cycle of the assets. It is demonstrated that the design alternatives may function better or worse – i.e. deliver infrastructure at lower or higher cost – depending on the particular features of the different projects which are to be implemented. There is therefore no simple recipe to give, but rather a recommendation to adapt the process to the particular features of each project. This is the same observation which Paul Klemperer (2002) makes about auctions in general, namely that “its horses for courses, not one size fit all”.

This review is made against a background of the growing literature on contracting under asymmetric information and contracts with higher and lower transaction costs. While some references are given, the paper does not review this literature. A further point of departure for the discussion is the position of the public sector principal in this relationship. It is thus the principal who makes all choices with respect to the design of the procurement process which are subsequently presented to the market, codified as a quote for bids. A restriction when making this choice is, of course, the perceived impact of design on the number of participants in the upcoming bidding contest. Other than this, the principal is the leader in a process which results in roads, railways etc. which do or do not deliver services at the lowest level of costs to society.

As a point of departure for the discussion, section 2 details the trade-offs involved when roads and other infrastructures are to be designed, built and taken care of. Section 3 specifies alternative contracting approaches. Section 4 points to some theoretical insights with relevance for understanding efficiency properties of the respective tendering

alternatives. Section 5 makes pairwise comparisons of the contracting alternatives while section 6 concludes.

2. THE WELFARE MAXIMISATION PROBLEM

Irrespective of if a road is built and maintained using in-house resources or if it is tendered, the ultimate purpose of the activities is to ascertain that resources are used in order to maximise social welfare. A point of departure for the problem in focus here is that a decision already has been taken to improve the existing network by way of building a new road, a bridge etc. The challenge is then to put in place rules and procedures which minimise the sum of costs for construction, maintenance and for users over the life cycle of the asset.

The investment problem is the starting point for this optimisation. The purpose thus to establish the optimal standard or quality (q) of a project in order to minimise its life cycle costs. Quality here refers to the capacity of the infrastructure that is to be built (number of lanes etc.), surface smoothness, safety aspects and possibly also the environmental impact from building and using the asset.

Costs to society comprise four components. The first refers to (generalised) costs for the users, $c_u(q)$, including time, vehicle operating costs etc. of using the road. The second component represents costs for third parties, $c_3(q)$. This captures the possibility that traffic is noisy or generates external hazards for residents along the road or for society at large. The third is the cost for providing capacity, $C(q)$ and the fourth costs for subsequent maintenance $c(q)$. Costs are discounted present values.

Construction costs increase in quality since a better road – i.e. straighter, wider and more durable – is more expensive to build than road with lower quality; this motivates the shape of $C(q)$ in Figure 1. But a road which is better since its sub-structure is more robust may reduce future maintenance spending, pointing to the trade-offs in place between construction and maintenance.¹ If only these monetary costs for construction and maintenance are accounted for, the optimal quality would be in the figure.

But the better the quality of a road, i.e. the smoother and more convenient a trip, the lower are the costs for users. Moreover, it is feasible to build and maintain the road in ways that reduce third party costs. Noise can be mitigated by using less noisy pavements or by building noise barriers. Emissions in the form of particles from studded tires can be curbed by using pavements that are harder and emit fewer particles. Costly extra spending on quality therefore reduces also third-party costs.

Social efficiency, illustrated as q^* in Figure 1, calls for balancing construction costs against the implications of quality choice not only for subsequent maintenance, but also

¹ There are examples where a higher quality road may *increase* maintenance costs; a wide road is for instance more costly to maintain than a narrow. This can, however, without loss of generality be subsumed in the aggregate cost minimisation problem.

with respect to its impact for users and third parties. The socially efficient quality is therefore higher than it would be if the facility was built with the objective of minimising financial costs only, i.e. $q^* > \hat{q}$. This provides an overall lesson for the rest of the paper in that irrespective of which contract design that is chosen, it must account for subsequent maintenance and user aspects. If not, there is a risk that the project is not compatible with social welfare maximisation.

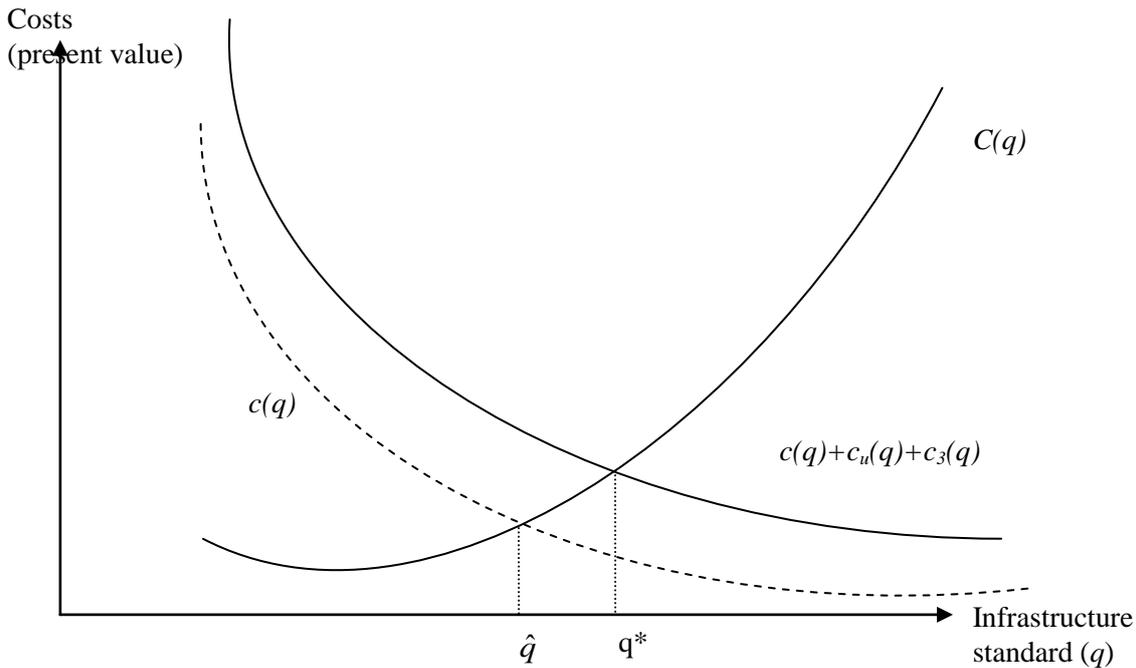


Figure 1: **Balancing construction and maintenance costs against costs for users and third parties.**

In this context it is also reason to establish that the use of Cost Benefit Analysis (CBA) for prioritisation of infrastructure investments has a long history.² This technique is directly applicable also for the choice of quality, which is in focus in the present paper. Research on the appropriate parameter values to apply has been and is intense. This includes vehicle operating costs when using roads of different qualities, the value of time savings, reduced accident risks when a road is improved etc. Recent advances in parameter value estimation include costs from noise disturbances to people living along a new road as well as environmental costs resulting from the use of the assets. There is, thus, much information available for establishing the trade-offs necessary for identifying the cost minimising quality of new infrastructure, i.e. q^* .

² The World Bank manual is available at worldbank.org/transport/roads/tools.htm and the corresponding manual from the European Commission at ec.europa.eu/transport/sustainable/2008_external_costs_en.htm

3. ALTERNATIVE WAYS TO TENDER CONSTRUCTION AND MAINTENANCE

As already indicated, infrastructure services have traditionally been provided by in-house resources. This is a command-and-control strategy implemented by detailed instructions to the agency's staff. The foundation of this strategy is a set of manuals with comprehensive technical specifications indicating the technical requirements for roads, bridges, tunnels etc. Manuals and construction norms represent the accumulated experiences from construction and maintenance over a sequence of years. The manuals may be said to represent the tangible manifestation of the (perceived) choice of optimal quality discussed in section 2.

In order to enhance productive efficiency, the common practice for implementation has shifted towards competitive procurement. This section will specify four different approaches for designing the procurement process and the subsequent contract(s) between a public sector representative and one or more commercial provider(s) of construction and maintenance services. In order to clarify the essential qualities, each approach is formulated in its most stripped-down version. There are indeed examples of contracts which combine these features in other ways.

The description is supported by the time line drawn in figure 2, illustrating the generic features of an infrastructure asset's life cycle. At date $\tau=0$, the first ideas about a problem which may require an investment are formulated. Based on a crude description of the situation at hand, the preparation of a detailed project design is initiated at $\tau=1$. At $\tau=2$, construction commences based on the design created during the previous period. When the project is opened for traffic at date $\tau=3$, maintenance begins. The road surface has to be renewed every 10 to 20 years and may require one or more major rehabilitations before the end of the project's life, T .

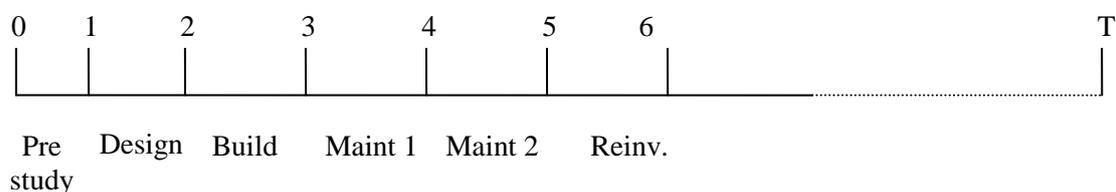


Figure 2: **Time line for the life cycle of a road.**

The presentation uses the degree of bundling of activities to distinguish four different types of contracts. Section 3.1 introduces the completely unbundled approach while section 3.2 describes a partial bundling strategy. Section 3.3 and 3.4 then discusses two slightly different ways to bundle construction and maintenance, namely a performance contract and a Public Private Partnership. In the wake of a comprehensive review of

contracting practices in different countries, the present categorisation is fully based on Swedish experiences.

3.1 Complete un-bundling; buying input

Contracts based on the Design-Bid-Build (DBB)³ logic is here used to represent what seems to be the most common approach to contracting in infrastructure, for example accounting for over 90 percent of all investment contracts in Sweden between 2000 and 2009 (Mandell & Nilsson 2012). A core feature of this framework is the separate procurement of each task: Based on a problem description and a preliminary idea about how the problem should be resolved, a contract to prepare the detailed design of a project is tendered at time $\tau=1$. There are examples of the principal performing this task in-house, but that does not change the logic of the process.

Based on the results of the design study, a quote for bids for the construction of the project is sent out and a contract is awarded at $\tau=2$. Once the project is completed, the new piece of infrastructure is part of the existing network and also part of a maintenance contract. These contracts are re-tendered with 5-7 year intervals. In addition, reinvestment in new pavements and subsequently more comprehensive re-construction works are tendered with longer time intervals but typically independently from the maintenance contracts.

One feature of a DBB contract is thus that it is one out of several components of a completely unbundled process. A second quality of this approach is that the quote for bids for the construction contract tendered at $\tau=2$ comprises a description and quantification of the activities to be undertaken by the contractor. This includes hours of work to carry out meticulously defined tasks, volumes of clay, gravel, rock and asphalt to be moved from here to there and a host of other (observable and measurable) input activities \bar{x}_i , $i=1, \dots, n$; the bar over activity x here represents that the quantity is set in the quote. These estimates are the result of the design contract tendered at $\tau=1$. This design is, in turn, based on the same manuals as when construction and maintenance were in-house activities. At the construction site the contractor performs this sequence of input activities which result in a project with the qualities specified by the contracting agency.

A third feature of the unbundled approach is the use of a Unit Price Contract (UPC; see Bajari et al 2007 for an introduction to the meaning of this payment principle) for the completion of the activities specified in the quote for bids. The tendering process ends with each interested entrepreneur submitting a bid B comprising the unit price, p_i , for each input required to have the road built. The aggregate bid from the winning bidder is therefore $B = \sum p_i \bar{x}_i$. This contracting approach will subsequently be referred to as

DBB/UPC in order to emphasise the close correspondence between the engineering and remuneration aspects.

Disbursements are made according to actual volumes up to \bar{x}_i , typically within an interval of for instance +/-25 percent to account for quantity uncertainty. Any quantity deviations outside this pre-set interval will have to be negotiated, and so will also any changes of,

³ The DBB acronym seems to be common in the engineering community. It refers to that Design is performed first, then comes a Bid for the construction contract where after the project is Built.

or additions to the original contract. Payment is therefore based on the physical measurement of all input activities during the implementation of the contract. After that all activities have been completed, the new piece of infrastructure is (hopefully) ready for use.

The logic of the construction contract also carries over to the contract with a consultant preparing the project design at time $\tau=1$, as well as to the contracts for maintenance and of reinvestment activities. The precise activities to undertake both design, maintenance and reinvestment activities are thus described and quantified by the contracting public agency in the respective quotes for bids.

3.2 A first step towards bundling; Design-Build

The quote for bids for a Design-Build (DB) construction contract is sent out at $\tau=1$ rather than at $\tau=2$. The quote describes a road with certain overall qualities that should be made available at time $\tau=3$. Rather than detailing the project inputs, this contract provides information about the qualities of a road with a certain width, alignment and other descriptive characteristics which is supposed to be built. A DB contract therefore leaves the *how* issue of input specification to the contractor who is supposed to deliver an output. Input activities and quantities – i.e. x_i – will therefore never be part of the quote for bids. The quote for bids for a DB contract still has to account for that the standard of the road-to-be handles the trade-offs between current and future costs, including the travellers' as well as bystanders' valuations.

All participants in a contest for a DB contract must prepare their own detailed project planning before submitting a bid. Moreover, DB is based on a fixed price rather than the Unit Price Contract. In this way, the DB sharpens incentives for cost savings by according more flexibility to the builder during the project's implementation phase.

The principal must still retain the responsibility for the trade-offs which have to be made in order to implement the high quality q^* rather than some more simple standard. The agent may therefore still be circumscribed when it comes to the choice of some design parameters. After that a project built under a DB agreement is opened for use, subsequent tendering of maintenance and reinvestment activities proceeds in the same way as under the complete unbundling approach.

3.3 Bundling and the performance contract

A further step to enhance the entrepreneur's control over, and responsibility for the way in which a project is designed and built is to bundle construction and maintenance and possibly also renewals into one contract. A performance contract⁴ combines design, construction, maintenance and renewal activities, replacing the sequence of procurement contracts in figure 2 with one single document. Initially, it is assumed that the contract extends into eternity.

⁴ In a World Bank paper, Stankevich et al (2005) refer to performance contracts as first and foremost renewal contracts that also include several years of maintenance. In Sweden, performance contracts are labelled "functional contracts".

In the same way as for DB, a performance contract is signed with a fixed price reimbursement of construction costs. After that an inspection has verified that the road has been built according to specifications, the bill for this task is paid. Maintenance costs, which may be indexed in order to make the principal carry the risk for unexpected price changes, are subsequently charged on a monthly or annual basis during the length of the contract. The different bids for contracts are compared by summarising appropriately discounted costs for the different parts of the assignment, picking the lowest bid as the winner.

The bundling of construction and maintenance induces the contractor to internalize the trade-offs between $C(q)$ and $c(q)$. In this, the builder can still use the industry's standard manuals and methods, but this is at the discretion of the entrepreneur. But in order to make the entrepreneur account also for user and third party costs, i.e. to implement q^* rather than \hat{q} , the quote for bids and the subsequent contract will have to establish mechanisms to handle a number of dimensions which are used as proxies for quality. This includes the following aspects.

Availability: Payments from principal to agent for maintenance must be conditioned on lanes or sections being available for use during the duration of the contract. This makes it necessary to have a system in place which penalises the agent for reduced availability. The possibility to use the road is affected both by accidents, by maintenance activities and possibly also by other disturbances. Availability clauses can be designed in order to incentivise the entrepreneur to undertake (planned) maintenance during off-peak periods of the day or of the year.

Surface quality: The quality of travelling deteriorates when a road gets increasingly uneven. Rough rides have consequences for the time of a journey, for vehicle operating costs, for riding comfort and possibly also for safety. In Sweden, surface quality with respect to rutting and longitudinal smoothness (IRI) is measured on a regular basis. The contract should therefore include a bonus/malus system which relates actual road standard to target parameters. In this way, the agent is given incentives to fix problems at shorter intervals than if only the out-of-pocket maintenance costs are considered.

Safety: In addition to road surface quality, contractor activities may affect road safety. Examples include frequency and intensity of snow clearance, maintenance of street lights, road markings and side-rails as well as clearing of side areas in order to reduce the risk of wildlife accidents. These aspects may be complex to steer by using economic incentives but can be dealt with by minimum standard clauses in the contract. In addition, there are examples of contracts where the observed number of accidents on a new road is benchmarked against risks on other similar roads in order to punish poor and remunerate good outcomes.

Environmental concerns: To the extent that the principal has information on how environmental externalities may be mitigated by changes in design or by adjusting maintenance activities, this should be included in the contract. Again, it could be done either by way of direct instructions or with bonus/penalty constructions linked to the annual compensation.

The value of time savings, reduced accident risks etc. which have been derived in order to undertake CBA can be used as a basis for designing incentive clauses. In this way incentives may be aligned to user valuations so that the overall result of the contract is as close to the optimal standard q^* as possible.

The discussion has so far been based on the assumption of a perpetual maintenance contract, which induces the contractor to internalise any and all implications of the choice of construction quality for future maintenance and user costs. There are obvious problems with never-ending contracts. One is that the initial tendering contest may generate high bids to insulate the winning contractor against an uncertain future. Moreover, any (un-anticipated) maintenance cost savings will benefit the contractor. For these and other reasons it is therefore to consider contracts of shorter duration.

The prime focus for the choice of contract duration lies in the necessity to induce the contractor to internalise the consequences of the initial choice of construction standard for subsequent maintenance and user costs. In particular, it is vital to avoid a situation in which the contractor optimises construction so that performance criteria are satisfied during the contract period, while the quality of the asset plummets shortly after it is handed over to the principal. But trade-offs in engineering design with respect to life length are imprecise. It is therefore difficult to design the construction of an asset at $\tau=1$ to pinpoint precisely when the rate of deterioration accelerates. This may mean that the contract could cover a period of one or possibly two (expected) renewals in order to avoid strategic shirking with regard to long-term quality in order to save on investment costs.

3.4 Bundling and Public Private Partnership

Public Private Partnerships (PPP) are often thought of as a mechanism for cheap infrastructure financing. It is, however, not obvious that it is less costly for a commercial firm to raise equity and loans in order to build infrastructure than it is for a government to use current and/or future tax revenue to pay for projects on going concern. Irrespective of whether this is so or not, the financial dimension of PPP is not part of the present analysis.

PPP is rather defined as a combination of bundling and external funding: a PPP is a performance contract where the contractor uses a combination of equity and external loans to have the project built, and where construction costs are repaid during the lifetime of the contract. The (potential) benefit of using a PPP contract to build infrastructure therefore materialises if it can be established that this is a way to save on costs to society compared to using some of the other contract designs.

There are different ways for the contractor to recoup the initial costs. The focus here is on situations where costs are recovered by the government making availability payments to the contractor. Based on the winning bid for a PPP contract, the winner is thus compensated for annual maintenance costs plus a down payment, for instance an annuity, of the initial investment cost. Compensation is affected by performance by way of carrot-and-stick clauses according to the same design outlined in the previous section. This logic also carries over to models with demand risk.

Figure 3 pinpoints the difference between a PPP and a performance contract for a particular numerical example.⁵ The performance contract remunerates the entrepreneur for investment costs, here each year of the construction period. After that maintenance and rehabilitation costs are compensated during the rest of the contract period; this is the graph with diamonds. The upper graph with squares, starting in year 4, illustrates disbursements under the PPP alternative, assuming an annuity to pay back the investment costs plus the annual maintenance cost and the spending on recurrent reinvestment.

4. TRADE-OFFS IN TENDER AND CONTRACT DESIGN

In order to understand the qualities of the four different alternatives reviewed above it is reason to re-capitulate some core theoretical results related to procurement and contract design. Section 4.1 therefore establishes some lessons from auction theory which are relevant for the design of the procurement process while section 4.2 establishes incentive aspects of different mechanisms to remunerate a contractor for services rendered.

4.1 Tendering – a reverse auction

A public procurement process is implemented by submitting bids in closed envelopes which are opened at one and the same occasion. The buyer then picks the best bid, often the bid with the lowest price. In contrast, a traditional auction means that it is the *highest* bidder that gets the opportunity to *buy* the commodity up for sale. In spite of this difference between buying and selling items or services, the theoretical analysis of the two is identical. This resemblance provides the theoretical platform for analyses of how different designs affect the outcome of a tender and for the normative recommendations concerning how to design the auction and the tender in order to maximise the probability that the objectives of the buyer of a service are met.

⁵ The figure is constructed assuming that the project lasts for a period of 40 years; thereafter it has no scrap value. It costs 330 to build the project, 110 for each of three years of construction. The annual maintenance cost is 1 percent of the total investment, increasing by 1.5 percent per year. Every 12th year a reinvestment, which costs 6 percent of the investment cost, is undertaken. After this new pavement has been laid, maintenance costs drop to the original level of 1 percent of the investment cost again. The discount rate is 4 percent.

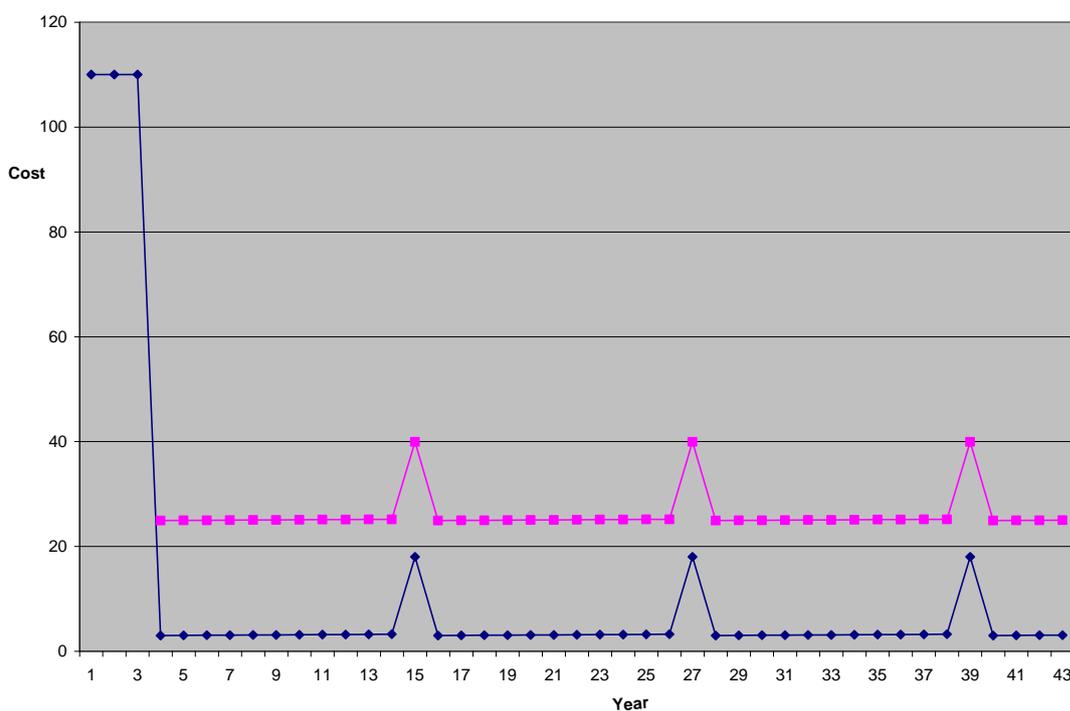


Figure 3: **Life cycle costs (lower graph) and annual maintenance cost plus investment cost annuity (upper graph) for an infrastructure investment**

An important pillar in this analysis is *the revenue equivalence theorem* (cf. Klemperer 2003 or Milgrom 2004 for two different introductions to the theorem and to auction theory at large). The theorem establishes that under certain circumstances it does not matter if bidding is open (open outcry or English auction) or closed (as in the procurement process). The expected revenue in the auction or the expected cost in the procurement is the same.

Several conditions have to be met for this result to be valid. One important prerequisite which we know is not commonly met is that bidders are *risk neutral*. When bidders rather are risk averse, the analysis may therefore have to be adjusted. Another important prerequisite is that the bidders' costs for delivering a service are private. The meaning of a *private cost* is that each bidder knows their own costs for delivering the service and that it does not matter what it costs their competitors to produce the services. The meaning of this concept becomes clearer by relating to the opposite situation in which *costs are common* to all. The costs for delivering construction projects may for instance be uncertain due to that the geotechnical situation at the construction site is uncertain. This uncertainty is the same for all, i.e. it is a common cost. A bidder's costs for hiring labour or using plant may be completely unrelated to the corresponding costs for its competitors, i.e. it is a private cost. Depending on the significance of common costs in a project, a contract may have to be designed in different ways.

Not only price but also quality may be important when a winner is to be selected and a contract designed. Many quality dimensions may be straightforward and easy to measure. Time of delivery or completion of a project is one example. To the extent that quality variables of this nature are important for the buyer of the services and if they are

verifiable the identification of the winning bidder should take this into account. There is a substantial literature which develops techniques for combining price and quality parameters when the winner of a contest is to be identified, but this is not dealt with further here.

There are, however, also situations where important quality aspects of a project are *non-verifiable*. Even if everyone agrees about the need for quality, and even if all in principle would agree that a delivery is of sub-standard quality, it may still be impossible to prove in court that it is not up to standard. Examples include aesthetic dimensions of architecture or of TV shows. Even more problematic is a situation when quality not even is observable. It is, for example, difficult to judge *ex post* whether a car repair or a dentist treatment really was necessary.

An important example of non-verifiability in construction contracts is related to that investment projects have a long expected service life and that quality problems may not appear until long after that a road etc. has been opened for traffic. Irrespective of how serviceable the road may look at opening it may turn out to require much more maintenance than what is reasonable to expect.

In order to understand the consequences of verifiability problems it is important to point to an important difference between the public and the private sectors in this respect. One way for the market to reduce the risk for this type of quality quarrels is the *reputation* mechanism: A firm which may get away with a delivery of poor quality once or twice may build up a bad reputation. Private buyers of services can then avoid hiring this firm.

The public sector is, however, not permitted to base the identification of winner on what could be perceived of as a rumour. An essential aspect of most if not all legislation relating to procurement practices is the necessity to describe *ex ante* which criteria that are used for selecting a winner and to verify *ex post* that these criteria indeed were decisive for the selection made. This is a crucial technique for reducing the risk for corruption and nepotism. As a result, the public sector must use other means than reputation in order to ascertain the delivery of appropriate but non-verifiable quality.

4.2 Payment mechanisms and incentives

There are two models with diametrically opposite qualities for paying an agent for a job. Contracts based on a fixed price means that the agent will get a pre-set amount – typically the winning bid in the tender – once the assignment has been completed. If the winning bid underestimated costs, the deficit has to be footed by the entrepreneur. But the fixed price construction also means that every effort to reduce costs compared to the plans made up when the winning bid was submitted will enhance the financial result of the builder.

One downside of the fixed price contract appears if the agent is risk averse. Risk aversion gives a bidder reason to add a premium to the bid in order to compensate for the extra risk which has to be taken. Transferring a certain risk from a less risk averse (public sector) buyer of services to a more risk averse entrepreneur will therefore, *cet. par.*, increase costs. A second aspect of the fixed price construction is that the buyer – the tendering agency – may be less informed than the supplier. If a builder is better informed about the conditions at the construction site, it is possible to charge a price which not only covers costs but also provides scope for an above-normal profit. This risk

(for the principal) or chance (for the agent) is higher the lower is the competitive pressure in the bidding process.

A third aspect of the fixed price contract concerns the adversarial relation between the parties. This becomes particularly onerous if the contract has to be amended after having been signed. In the construction industry, changes, amendments and deductions are the order of the day, and the result is that the tenderer has to initiate re-negotiations with a (temporary) monopolist for price changes. Proof is difficult to get buy, but the saying in the industry is that these change orders is the single feature which provides the largest financial surplus in many contracts.

Cost plus contracts have the opposite qualities. The entrepreneur has no reason to put in more effort than necessary in this assignment where all activities and costs which are required to build a road are paid for. Any unexpected costs have to be footed by the tenderer, meaning that the entrepreneur will not have to take on any risk. In order to ascertain that the entrepreneur does not shirk, and to avoid that the entrepreneur does not do work which is not required to fulfil the contract, the parties have to be very close during the implementation of an assignment. This also means that changes of the original work description are simpler to implement than with a fixed price contract. Bajari & Tadelis (2001) and Tadelis (200x) argue that cost plus contracts are particularly beneficial in situations where it in beforehand is obvious that it is difficult to foresee contingencies of the contract.

There are several remuneration practices which fall in-between these two extremes. An incentive contract takes the winning bid in the tendering process as a point of departure. Cost savings and increases relative to the bid are split between the parties according to a pre-set number such as 50/50, 30/70, etc. This balances the opposing incentives of the two extreme mechanisms. Since the entrepreneur is entitled to a share of a cost saving, at least some extra effort to save on costs may be worthwhile. At the same time, extra costs due to unforeseen contingencies are split according to the same formula. While the incentive contract has no consequences for uncertainties per se, it works to reduce the worst possible outcomes of a project.

A number of bonus/malus clauses can be tied to a contract and be complementary to the basic payment. It is for instance feasible to pay a premium for a project which can be opened before time, or to charge a fee for late openings if this dimension of a contract is of particular importance. In road construction, there are also examples of lane rental agreements. If so, the original quote for bids includes a penalty for each day or each hour traffic on an existing road is negatively affected by the construction of an additional lane, an interchange etc. This motivates bidders to design the construction process in a way which minimizes the disturbance on traffic.

In the construction industry, the unit price contract is commonplace and provides an additional example of a contract with qualities which lie inbetween the fixed price and cost plus contracts. As previously described, the quote for bids includes a detailed enumeration of tasks as well as an estimate of the quantity of each. While risk is with the seller in a fixed price contract, and with the buyer in a cost plus contract, a unit price contract separates price and quantity risk. Since the buyer has specified quantities, deviations from the pre-set quantity is the responsibility of the buyer, while the agent bears the risk for that the unit prices submitted during the bidding process are sufficient to cover costs.

A unit price contract is thus a technique to make the buyer responsible for defining the meaning of a good solution. As a result, the buyer is responsible for the development of new techniques, or must at least be aware of new approaches to handle a certain situation in order to use this approach. Moreover, the current legal framework forbids the public sector principal to allow a contractor to change implementation strategy compared to the strategy established in the quote for bids. This is so even if an alternative approach would be obviously better. If it becomes obvious that substantial changes are required of the plans compared to a first tender, a re-tender is necessary since all potential entrepreneurs are entitled to get the opportunity to bid on what then is another project. These different qualities of a UPC make it a clumsy means for dealing with changing circumstances, including adaptation to new information about the situation at the construction site.

5. COMPARISON OF CONTRACTING ALTERNATIVES

The purpose in this section is to identify some general aspects to account for in the choice of contracting framework. The first observations concern the choice between DBB/UPC and DB contracts. Section 5.1 makes this comparison where maintenance and rehabilitation is not dealt with since it is handled in the same way for both. Section 5.2 then adds performance contracts and PPP to the comparison; section 5.3 concludes.

5.1 DBB/UPC vs. DB

DBB/UPC is the traditional way for contracting. It is reasonable to believe that this fact signals some basic rationale, i.e. that the market over the years has developed this type of contract for good reason. One candidate motive is related to the problems with verifying the quality of a road or railway which is about to be opened for traffic. If the tendering agency is anxious to have the asset built in a way which it believes reduces the risk for premature rehabilitation, DBB/UPC provides a safeguard; the project is implemented in precisely the way specified in the quote for bids. Under this interpretation, a DBB/UPC contract is the construction industry's answer to the wish that life cycle costs of the asset are minimized.

But there may be situations where there are drawbacks with using DBB/UPC and where it may be better to use the fixed price DB contract instead. Mandell & Nilsson (2012) compare costs for design and construction for the two alternatives in order to identify circumstances under which one should be preferred over the other. Both types of contracts result in a road which is supposed to open for traffic once construction is finalized. From the non-verifiability argument in favor of DBB/UPC it is obvious that the presence of substantial problems with verifying the quality of the new piece of road is a strong argument against DB. Since DB contracts seem to be rare in practice, one reason may be this problem with verifying quality.

Disregarding this possibility for a moment, the basic motive for DB comes to surface by establishing a problem with DBB/UPC contracts, namely that the tendering agency (or its design consultant) is fully informed about all relevant aspects of the construction problem

at hand. The quote for bids thus includes detailed specification of all inputs to be used, \bar{x}_i above. To specify the cost minimizing design, the agency must have full control over the situation at the construction site, it must be informed about which alternative approaches that may be used to have the project built. In addition, it must have full control over the entrepreneurs' prices for all items used for construction, including staff, equipment, plant etc. If not, it is difficult to identify the cost minimizing design choice.

The more complex the construction task is, the more unrealistic is the full information assumption. This means that the benefit of DB contracting – *ceterus paribus* – increases in complexity. With several bidders contemplating over different ways to undertake the assignment to build a road from Here to There, the chance is higher that their respective ingenuity results in a solution which is better – i.e. less costly for the tendering agency – than under the centrally planned solution derived under the DBB/UPC contract.

In all projects, common risks are a curse. Road construction provides a larger challenge in this than residential or office construction for the simple reason that infrastructure covers a much larger and often a much more diverse area than a building. Establishing ground conditions is therefore always a challenge. The more elaborate geotechnical surveys that the principal pays for and makes available before bids are submitted, the better is the chance for bidders to avoid winners curse problems. With access to good information bidders have to include a smaller margin for uncertainty in their bids.

This aspect is common to both DBB/UPC and DB contracts, but in the former type of contract the uncertainty is a concern for the tendering agency while the latter, fixed price contract includes all uncertainties in the quote for bids. A means to reduce risk in the DB contract is to identify geotechnical trouble spots in beforehand and to single them out from the overall assignment. Risk with respect to deviations from the forecast could then stay with the principal.

Another way to handle this risk is illustrated by a contract which the Swedish Road Administration signed with a builder in 2005. The contract was for SEK 555 million for a new 7 km highway. One part of the project was a 1.1 km tunnel. With the quality of the rock being uncertain, the quote specifically asked for separate bids for the tunnel and the rest of the project. It also indicated that the builder could retain 40 percent of any cost savings made and had to accept 30 percent of cost overruns, relative to the bid for the tunnel part of the project, i.e. it made use of an incentive contract. Of the winning bid, SEK 51 million was for the tunnelling which consequently had a different risk profile than the bulk of the contract.

An additional downside of the DB contract is that *all* bidders have to take on the work necessary to specify a design at sufficient detail in order to be able to submit a fixed price bid. From a social perspective this includes a degree of duplication of costs, and therefore puts DB at a disadvantage. The existing legislative tendering framework however points to a way to handle this problem. This can be done by way of a two-step procurement strategy where only a few bidders are shortlisted to prepare the final bid. In this way, the extent of cost duplication is reduced.

5.2 UPC versus bundling

The question in this section is if and when a public sector agency should tender a performance contract rather than the completely un-bundled strategy with DBB/UPC at

the core of the sequence of contracts. Hart (2003) provides the basic logic involved in this choice: The unbundled alternative should be chosen if the quality of the construction project can be specified while the quality of the service cannot, and vice versa. Since a performance contract is designed to be an instrument for controlling (otherwise) non-verifiable quality, and since appropriate means to control for the quality specifications is in place, the performance contract provides a viable alternative to the unbundled alternative(s) based on DBB/UPC.

But this is not sufficient, since the objective function is here linked to the possibility to minimise life-cycle costs for the road: If it is feasible to control (user) quality both via a DBB/UPC and a performance contract, which provides the cheapest solution? To provide an answer it is reason to take the discussion back to the main argument in favour of DB contracting, namely the possibility to stimulate the thinking around construction. The motive for performance contracting – which includes DB as a first step of the process – is thus stronger the more complex the situation at the construction site is; the more probable it is to engineer smart solutions to challenging problems by way of asking several firms consider their respective solutions to the problem, the stronger is the argument in favour of bundling. A bundled contract which gives the entrepreneur leeway to solve the construction in cheap ways, and where it is feasible to control quality may then deliver the road at lower costs than the completely unbundled set of contracts.

The final comparison is between DBB/UPC and a PPP contract, or rather between PPP and the performance contract where the additional feature is the private financing of construction costs. An obvious drawback of having the contractor raise project financing is that commercial firms in most countries are charged a higher interest rate than a public sector representative for borrowing the same amount of money.⁶ To the extent that the private borrower has a contract with the public sector which guarantees an income stream to service the debt, the difference in interest rate is not necessarily large. The difference in interest costs is still a valid argument against PPP since it means that any cost savings from a PPP project must be sufficient in order to balance the higher costs for financing.

But there are two arguments in favour of PPP which may balance this cost increase. First, a commercial entity which combines equity with borrowing to pay for the initial investment will be forced by lenders to accept detailed project reviews in order to assess the project qualities ex ante, and – after that a project has been opened for traffic – to monitor the maintenance phase in order to reduce the downside risk of the loan. This includes due diligence analyses of any technical aspects of the project proposal that may affect its financial viability. The review could, for instance, scrutinize the inter-temporal trade-offs between investment and maintenance costs in the investment proposal. This scrutiny not only benefits the lender but also increases the chances for a project as a whole to be successful. External reviewing on a commercial basis is typically much more scrupulous than when project finance is raised as part of the state budget. Any interest rate differential is therefore at least partially a payment for risk monitoring and reduction which reduces the risk that the project goes bankrupt.

⁶ In countries where the government has to pay a large interest due to insolvency concerns of lenders, there may be situations where a private enterprise is charged less. For this to be feasible there must be safeguards to guarantee a SPV full control over future revenues from the asset in addition to the other motives given above.

A second argument is that private financing may operate as a lever to enhance the agent's commitment to the contract in a world of opportunism and incomplete contracts. To see this, assume that the agent is corporatized in the shape of a special purpose vehicle (SPV) to insulate the ultimate owners against extreme risk exposure. Under a performance contract all construction costs are paid for right after that the project has been opened for traffic while a PPP contract is compensated by way of down payments during the contract period.

Nilsson (2011) demonstrates that a PPP contract where the agent sits with a claim on the principal which gradually shrinks when debt is re-paid will reduce the risk for than the SPV abandons the project due to unexpected cost increases. To see this, assume that an unanticipated quality problem appears in year $\tau < T$, making it necessary to increase maintenance costs from c to \hat{c} . Under both performance contract and PPP, the SPV has built the project according to its own specification with the purpose to optimise costs over the life of the contract. The SPV is therefore liable for covering the cost increase.

Under a performance contract, the SPV was reimbursed for initial investment costs when the project was opened for traffic. Subsequent annual payments will be c to pay for maintenance costs $\hat{c} > c$. If the difference between \hat{c} and c is large, or with little or no own capital left, the SPV risks going bankrupt. The principal's choice is then between increasing payments to \hat{c} or taking over the facility and re-letting it, but probably still having to pay a higher maintenance cost than stipulated by the original contract.

Under a PPP contract, the annual payment to the SPV is not only c but also debt service to lenders plus the investor's rate of return on the capital provided for the construction. If the SPV seeks to re-negotiate the contract after a cost increase, the bankruptcy threat is less credible since the SPV would then lose its risk capital. The conclusion is therefore that there is more scope for bargaining between the public sector principal and the SPV owners under PPP than under a performance contract as a result of exogenous cost increases. The principal's risk to have to pay the full cost increase is thereby reduced.⁷ It can also be demonstrated that the significance of this difference in bargaining power is even more important as a means to reduce the risk that the winning bidder deliberately shirks on quality of the construction part of the contract when the original bid is submitted.

⁷ The Arlanda railway link is a Swedish PPP contract signed in 1993 with services opening in late 1999. Shortly after, the September 11 attack had severe consequences for international air traffic and for patronage at the airport and on the train, and put the operator of the airport commuter service under severe financial strain. The financing solution established in the 1993 contract, however, meant that the SPV could not expect the government to make up for the losses. In case of bankruptcy, the owners would have lost their risk capital while the banks would have retained their claims on the company. Losses were therefore covered by owners and after a couple of years results were again in the black. See further Nilsson et al. (2008).

6. SUMMARY

The switch from using in-house resources to build and maintain assets towards competitive tendering has opened a range of contracting alternatives for the tendering agency. One particular technique, here referred to as Design-Bid-Build in combination with a Unit Price Contract, is in frequent use. The suggested hypothesis is that this preference can be understood by realising that it provides an opportunity to control for (otherwise) non-verifiable quality: A detailed quantification of precisely *how* a builder shall be working, rather than a description of what the purpose of the project is, provides little latitude for the builder to shirk on the quality which the tendering agency believes to be appropriate. In this way, the infrastructure is built with an emphasis on what is believed to minimise life cycle costs for society at large. This inter alia includes the benefits to the future users of the facility.

In contrast, a fixed price Design Build contract is signed on the properties of the road etc. which is to be built, but leaves the *how* issue to the builder. A problem with this way of contracting lies in the difficulty to verify that the quality of an asset is acceptable once construction is finalised. An apparently nice road could thus deteriorate in quality and result in high life cycle costs, both due to the need for frequent repairs and because of high user costs.

Ignoring this result for a minute, the analysis has highlighted a benefit of the DB contract. This is based on that DB provides an opening for having more than one builder consider the cost minimising way to implement complex projects, i.e. road investments which possibly could be built in more than one way. Smart solutions to carry out the work may save on costs relative to the DBB/UPC approach. This quality bears over also to a performance contract which has the additional benefit that it provides a means for verifying quality. This is so since the entrepreneur is made responsible for the new road over a period of time after that the construction has been completed. The PPP adds further to this quality in so far as it provides a lever for further reducing the risk that the builder shirks on quality. In addition, it has been established that the performance contract as well as Public Private Partnerships provide means to control for quality which are not available if a DB contract is used.

The main conclusion of the discussion is that there is no such thing as one type of contract which should be used under any and all circumstances. A situation where the standard DBB/UPC contract seems to be clearly better than the alternatives is when there is little scope for implementing a project in more than one way. The reason is that the alternative mechanisms more than anything should be used as a means for bidders to consider alternative implementation techniques. If there is little to lose in this respect, i.e. if it is reason to believe that there is basically one way to implement a project, the standard DBB/UPC approach is a good alternative also for the future.

But even if it is reason to believe that a project could be implemented in more than one way, it may still be reasonable to stick to the standard approach. The reason is that the other mechanisms come with other challenges, and in particular the need to control for quality in order to reduce the risk for costs being saved at the expense of quality. This

means that the preparation of new projects which are to be tendered should be initialised by characterising the situation at the construction site as well as other idiosyncrasies of each individual investment. With this as a basis, the tendering agency must weigh the pros and cons of the contracting options in order to establish which alternative that ex ante can be expected to deliver the project at lowest possible costs.

Bajari & Tadelis (2001) adds to the range of alternative contracting designs by considering projects where it is particularly difficult to identify contingencies ex ante. This refers to complex projects where there is a probability that the outcome of a project may be affected by events which could not even be foreseen in beforehand. They conclude that this provides a case for using a cost plus contract, meaning that the project should be implemented in close cooperation between the public sector principal and the commercial agent. This further underlines the conclusion that there is not one type of contract which fits all situations, but that it is necessary to adapt a contract to each specific assignment.

The paper has thus elaborated on the role of incentives in promoting efficiency by emphasising the need for an eclectic position in procurement design. Infrastructure construction in organisations which don't use in-house resources any more is therefore increasingly an economic rather than an engineering assignment. In the further development of innovative tendering it is obvious that bonuses and penalties tied to performance-based indicators is a minimum requirement for ascertaining that quality is not compromised. It is also clear that there are further examples of innovative incentive mechanisms which should be tested in the field. But at the same time as this is said, it is perhaps better to call for a comprehensive review of current ways to implement construction contracts in the roads sector as well as in other modes of transport. The ingenuity of market actors is probably much greater than the imagination of economic analysts.

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