Centre for Transport Studies
STOCKHOLM

DEGREES OF FREEDOM IN ROAD CONSTRUCTION

Johan Nyström – VTI
Hans Lind – KTH
Jan-Eric Nilsson - VTI

CTS Working Paper 2014:20

Abstract

One policy that is believed to increase the rate of innovation and the level of productivity is to move from Design-bid-build contracts (DBB) to Design-Build contracts (DB). A common view is that the latter provides the contractor more degrees of freedom to enable innovation. This hypothesis consists of two steps, first that DB actually has more degrees of freedom and secondly that more degrees of freedom leads to more innovation. This paper focuses on the first step and is based on a review of five road construction projects – two labelled DBB and three DB. It is demonstrated that there is a gap between the textbook definition of the two types of contracts and the actual design of the examples. The degrees of freedom for the contractor are restricted in both DB and DBB contracting and no significant difference in this dimension could be established. Based on this lack of difference in the five projects, the expectation of innovation for the labelled contracts cannot be settled. Some possible rational reasons for the client to restrict the degrees of freedom are also suggested.

Keywords: Innovation, contracting, Design Bid Build (DBB), Design and Build (DB)

JEL Codes: D86, H57, L74

Centre for Transport Studies
SE-100 44 Stockholm
Sweden
www.cts.kth.se

Degrees of freedom in road construction

Johan Nyström
VTI
johan.nystrom@vti.se

Hans Lind
KTH
hans.lind@abe.kth.se

Jan-Eric Nilsson
VTI
jan-eric.nilsson@vti.se

Abstract
One policy that is believed to increase the rate of innovation and the level of productivity is to move from Design-bid-build contracts (DBB) to Design-Build contracts (DB). A common view is that the latter provides the contractor more degrees of freedom to enable innovation. This hypothesis consists of two steps, first that DB actually has more degrees of freedom and secondly that more degrees of freedom leads to more innovation. This paper focuses on the first step and is based on a review of five road construction projects – two labelled DBB and three DB. It is demonstrated that there is a gap between the textbook definition of the two types of contracts and the actual design of the examples. The degrees of freedom for the contractor are restricted in both DB and DBB contracting and no significant difference in this dimension could be established. Based on this lack of difference in the five projects, the expectation of innovation for the labelled contracts cannot be settled. Some possible rational reasons for the client to restrict the degrees of freedom are also suggested.

Keywords*:* Innovation, contracting, Design Bid Build (DBB), Design and Build (DB).

1. Introduction

Costs in the Swedish construction industry have increased without any tangible indications that more is delivered or that quality is improving (see e.g. Statskontoret 2012). Except for concerns over productivity, the government considers the rate of innovation to be low and that measures are needed to be taken. One of the central policy initiatives for handling this challenge taken by The Swedish Transport Administration (subsequently referred to as Trafikverket, the principal or the client) is to tender more contracts under the framework of Design Build (DB) rather than Design Bid Build contracts (DBB) that dominates today. Under the DBB framework, the client designs a project and takes most of the risk. DB is seen to provide the contractor with more degrees of freedom to develop the project, since the contractor is responsible for the detailed project design. As a result, the contractor also assumes more risk.

Theory predicts that DB contracting has a better potential than DBB to promote innovation. The degrees of freedom to design the project enable the contractor to think in new ways of undertaking construction. There are two steps in this argument.

Step 1: “DB gives more degrees of freedom”. This is often seen to be true by definition, but it should be seen as an empirical issue. The main purpose of this article is to investigate if this actually is correct. Hence, are DB and DBB contracts good proxies for degrees of freedom in the design of infrastructure projects? The hypothesis is that DB contracts should provide more degrees freedom than those labelled DBB. As far as we know this issue has not been investigated empirically before.

Step 2: “More degrees of freedom give more innovation”. Even if this is not in focus of the present paper, the claim is not self-evident. As underlined in e.g. Lind and Borg (2010) innovations are risky and when more risk is put on the contractor, the response might be to choose more established and less risky alternatives. At the end of the day, this is also an empirical issue.

This paper is based on a review of five road investment projects, three labelled DBB and two DB. The research question is whether a detailed analysis of these contracts gives support to the hypothesis that DB contracts give more degrees of freedom.

The focus is on the degrees of freedom for the contractor in the tendering and contracting stages of the project. Future work is necessary to establish it any of these contracts actually deliver more innovative approaches than others do.

2. The concept of innovation

Innovation in the construction sector is important for the simple reason that in the long term perspective the rate of innovation will affect the “value for money” that the client can get. A catchword for Trafikverket is “more roads for the money” and in the short term this may be accomplished in an appropriately designed construction contract. In the long term, however, innovation will determine the growth of productivity and the cost savings in actual practice.

Innovations can take many forms (see articles in Bröchner (2012) for an overview). Often it is not necessary to find a new solution but to “import” already existing technologies, methods and ideas from other countries. The innovations could then be referred to as “local”, i.e. innovations in relation to how the objects typically are built.

Innovations also come with a risk, as there might be un-anticipated problems with a new solution. Opening up for new techniques may also generate moral hazard types of challenges as the contractor may introduce techniques that reduce investment cost but leads to higher life-cycle costs (see Borg 2011). This issue will be returned to below.

3. DBB vs DB contracting

The design-bid-build (DBB) framework is the most common way of contracting in Sweden. It makes the principal responsible for the design and the contractor for the construction. If a bridge breaks down due to an under-dimensioned pillar in the design, it is the principal's responsibility while a breakdown due careless implementation such as forgotten rebars, is the responsibility of the contractor. While this principle is clear, the allocation of responsibility may be less so in actual practice.

The usual way of tendering a DBB contract, also referred to as Unit Price Contract, has been used in procurement auctions outside infrastructure (see e.g. Ewerhart and Fieseler, 2003 and Gupta et al 2012). The tendering documents include a detailed Bill of Quantities (BoQ) which not only identifies the activities to undertake for constructing a new project but also quantifies many or most of the activities that are to be implemented in order to deliver the tendered project. To be more specific, a BoQ comprises both adjustable and non-adjustable quantities which may formally be described in the following way:

$$B^{DBB} = \sum_{i=1}^{n} p_i q_i + \sum_{j=1}^{m} p_j \bar{q}_j \quad (1)$$

Here B^{DBB} is the bid submitted by the winning entrepreneur for a DBB contract. q_i, $i = 1,...n$ indicates quantities predicted ex ante and announced in the BoQ. There are also $j = 1,...n$ non-adjustable quantities ($\bar{q}_j$). The entrepreneur's bid is therefore comprises two price vectors, one with a price for each q_i (i.e. p_i) and another for each $\bar{q}_j$, i.e. p_j. The principal makes an ex ante assessment of both quantities. The difference between them is that the winning bidder is paid ex post according to realized quantities for q_i but not for $\bar{q}_j$.

In contrast, a DB contract makes the agent responsible for both design and construction. Rather than prescribing precisely what the agent is supposed to do, the tendering documents formulates in broad terms what the principal wants to buy, such as a road with certain qualities between two places. The quality of the road may be defined in terms of e.g. longitudinal unevenness, rut depth, crossfall, frost heaving, cracks and friction. Each interested agent must then prepare drawings and make an assessment of which activities that are required. Based on this, a bid representing the request for remuneration is submitted and the lowest bid BDB is accepted. The contractor will then be paid this sum at completion of the project or certain subsections of the contract; this is then basically a fixed price contract. This way of tendering construction gives the contractor degrees of freedom to find the most cost efficient ways to fulfill what is demanded.

While a DB contract provides an improved opportunity for the contractor to come up with innovative solutions, this also comes with the contractor having to shoulder a higher risk. The fixed price construction means that the contractor has to take responsibility for all problems in the project, be it due to design, implementation or exogenous shocks. A DB contract is therefore expected to cost more than a DBB, ceteris paribus. This is due both to the contractor taking on more risk and because more work is required for preparing the design. There is, however, nothing to say that the total costs for the client will increase since it is just a shift of responsibility from the principal to the agent when using DB rather than DBB contracting. Mandell et al (2014) provides an in-depth analysis of these tradeoffs.

To summarize, DB in comparison to DBB comes with more degrees of freedom for the contractor to innovate but also entails more work and risk. The final outcome in terms of cost, quality and time is an empirical question. Detailed descriptions of what is to be done in a DBB project has two important consequences. First, the principal gets precisely what is considered necessary to have a new road built. Secondly, in its extreme version it eliminates any possibility to implement a project in any other way than indicated by the tendering documents.

3.1 Empirical comparison of DBB and DB contracting

Despite a general lack of statistical analysis in the construction industry, there are a number of studies comparing DBB and DB. The statistical studies can be divided into two categories.

The first group (Thomas et al, 2002; Ibbs et al 2003; Shrestha 2007; Hyun et al 2008; Bogus et al 2010, Minchin et al 2013) use cost- and time growth as an output variable in the comparison. The results differ between studies and no meta conclusion based on these studies can be drawn. There is however a generic problem with using growth variables. Using cost- and time variables entails the problem of controlling for the initial estimated budget and time. Such plans are very client specific, uncertain and hard to control for. The problem occurs when a slow and expensive project outperforms a fast and inexpensive project, due to an extensive estimated plan in the former. For example, take two identical road construction projects with project goals of meeting budget and finishing on time. Say that the first of the identical projects has a higher budget and longer time frame than the second. If the first project fulfills its targets and the second does not, it cannot be concluded that the first project outperformed the second project. In contrast, it could be that the second project had lower cost and finished earlier that the first even though it did not fulfill its target. A better measurement could be to compare normalized absolute values, such as total cost per km road or project duration per km road.

The second category of papers uses absolute values to compare DBB and DB. Konchar and Sanvido (1998) compare 154 DB with 116 DBB contracts from the house and industrial construction market in the US. Data are based on surveys. It is shown that DB outperforms DBB regarding costs and construction time. Shrestha and Mani (2012) analyse 16 DBB and 6 DB highway contracts based on survey data. Results indicate that project speed per lane were significantly longer for DBB contracting. No significant difference could be seen regarding cost. Hale et al (2009) compare 38 DB with 39 DBB contracts regarding construction of US navy housing. This study uses data from the Navy's financial information system. They conclude that project duration per bed is shorter in DB contracts but do not find any statistically significant difference regarding cost.

The latter three studies indicate that DB outperforms DBB with respect to project duration, i.e. it takes less time to have them built. The two latter papers are, however, not clear on the definition of cost. A DB contract includes design, which is not the case for DBB. Comparing final cost without controlling for this distinction might be one reason for the lack of significant results on cost. Secondly, the studies have poor controls for quality. An observation of lower cost or a faster construction time might be explained by lower quality. Even though quality is difficult to specify and even more difficult to measure, it creates uncertainty if it is not addressed at all. And a third problem is that data from surveys of cost and project duration reported by those that are or have been responsible for the projects always run the risk of being biased.

There is also a forth issue, which is the focus of the present paper. Theory predicts that DB will promote innovation by degrees of freedom in the design. But just labelling a project DB does not guarantee degrees of freedom. If contracts that are labelled in different ways, but if the difference is not implemented in actual practice, systematic results in the form of more innovation in the "DB contracts" are not to be expected. The following sections compare degrees of freedom between five projects.

4. Method and sample

All of the studied projects in this paper are road investments in Sweden. Trafikverket is the client and all contracts are tendered within the framework of the Act on public procurement (largely based on EU Directive concerning public procurement). Our analysis is based on the procurement documents, which all together comprises hundreds of pages for each project. This material also refers to underlying handbooks and reference texts. The focus of the study is to compare the ex ante contracting documents although material for the outcome has been used for some of the projects.

Because of previous experience with problems to get data from Trafikverket, the five contracts are a convenience sample. . The projects are therefore those where information could be provided. This might per se make the organisation provide us with projects that are believed to be "good" in one dimension or another. In order to reduce this risk, the officials at Trafikverket were not informed about the purpose of our study.

5. Five road construction contracts

The Swedish construction industry has two generic documents for establishing the contracting framework. AB supports DBB contracts and ABT that supports DB contracts. These underlying documents are referenced in each contract and controls how to measure things, when to renegotiate prices etc. The documents have been jointly developed by clients and contractors and are updated within approximately 10 year intervals.

5.1 DBB 1: Reconstructing highway

This project is a 9 kilometer road in the south part of Sweden along the old road. It was procured in 2009 and based on AB 04. Four bids were submitted and Svevia won. The ex ante contracting sum were 197 million SEK and the final cost was 228 million SEK, which might include scope changes.

This is a traditional DBB contact. Trafikverket designed the road and the bids were price vectors that together with the predetermined bill of quantities made up the vector sum. The lowest bid won the contract, no soft parameters were included in the evaluation of the bids.

As the project started, Svevia got paid according to the quantities produced times the unit prices.

The payment scheme was referred to as a fixed price, although 80 percent of the contracting sum were made up out of adjustable quantities. A better description of such payment schemes is to see them as cost plus, where the client takes most of the risk (Nyström, 2013).

Bids with an alternative method of construction, "side tenders", were not permitted. However, Trafikverket opened up for bids using construction methods that were equivalent to their own design. Such bids were required to include "*technical documentation from the manufacturer, a test report from a recognized body or other relevant analysis showing that the solution to the equally meets the requirements*". Where to draw the line between a "side tender" and the equivalent solution is not clear, but since no such bids were submitted this was never clarified.

5.2 DBB 2: Bypass Katrineholm

This project is a 20 km highway bypass outside the town of Katrineholm, inter alia comprising three large bridges. The road is to large extent built as a green-field project. It was procured in 2010 with three submitted tenders. The spread of price in the bids were low and the winning bid submitted by Skanska.

The contract was based on AB 04. In addition to standard requirements, it included a statement saying that the client and the contractor should work together in a partnering setting during the design phase. Contrary to standard practice for DBB contracts, no detailed design was included in the tendering documents. The tendering documents were based on performance criteria such as longitudinal unevenness and rut depth etc. Hence, the contractors had to submit a design in their bids and base their price on their own design. However, there was no guarantee that this proposal would be accepted as Trafikverket had the final saying of the design. The idea was that Trafikverket would finalise the design together with the winning contractor, in this way retaining design risk.

The cost for each contractor to develop this tender was allegedly 4-5 million SEK. This is 1,5 percent of the ex ante contracting sum and about double the amount of a regular DBB contract. This illustrates the fact that all DB tenders require a degree of multiplication of tendering costs since each bidder has prepared his own design before submitting the bid.

The payment scheme was based on a target cost, were deviations was split between client and contractor. There was also an option to build an additional 6,3 km of road, which was used.

The tendered price was 312 million SEK and the final cost was 327 million SEK. Some of the cost overrun might have been due to scope changes. The project was finished 2,5 months ahead of schedule. As a whole, the project is considered a success by both parties.

5.3 DB 1: Reconstruction of highway

This project was procured in 2010 and consists of 10 kilometer road with 4 bridges in the south part of Sweden. The contract was based on ABT 06 meaning that the bidders were responsible for the design.

The total price in a bid comprised seven components, two interchanges, three clusters of smaller roads and four bridges. Each part was described using functional terms in tendering documents, such as longitudinal unevenness, rut depth, crossfall, frost heaving, cracks and friction. Based on these descriptions the contractors had to design and price a road that fulfilled the requirements.

Strabag won the contract with a bid of 185 million SEK.

The definition of the road in functional terms provided the bidders with degrees of freedom to design the road. However, the design methods were stipulated in Trafikverket´s underlying handbooks, such as the handbook for surfacing (Vägverket, 2007) or for dimensioning a road (Trafikverket, 2011). Solutions that deviated from this requirement could be accepted but required documentation that verified an equivalent quality. This was expressed in the same way as in DBB 1: "*technical documentation from the manufacturer, a test report from a recognized body or other relevant analysis showing that the solution to the equally meets the requirements*".

Apart from this, there were more aspects of the contract that reduced the degrees of freedom. Lane separating barriers were, for instance, to be of a certain brand, ramps to be formed as a clover, a certain type of grass to be used for seeding the noise barriers etc.

The final cost of the project was approximately 240 million SEK, which might have included scope changes. There were some problems with the evenness of the road after the project was finished, which the contractor had to take care of.

5.4 DB 2: Motorway Extension

This project is an expansion of an existing highway in the south part of Sweden. It includes 8 bridges and 5,5 km of road. The tendering process started in 2010 and the road opened for traffic in December 2012, one month ahead of schedule.

The winning bid came from Strabag at 160 million SEK. The final cost was 192 million SEK, which might have included some scope changes. The tendering document consisted of two projects, one larger and another smaller, where Trafikverket choose not to include the smaller part in the final contract.

In accordance with the DB framework, quality criteria with respect to longitudinal unevenness, rut depth, crossfall, frost heaving, cracks and friction were specified. The contract was regulated by ATB 06.

However, there were aspects in the contract that reduced the degrees of freedom for the contractor to design the project. One was that suggestions deviating from Trafikverket´s handbooks needed support by technical documentation from a third party (the same formulation as before on DBB 1 and DB 1). The client also stipulated that certain types of bridge parapets, lighting and center beams had to be used.

5.5 DB 3: New highway

This was a big green-field investment project in mid-Sweden consisting of 22 kilometers of road and 17 bridges. It was initially split into three different contracts, with an option for the contractors to put in a combinatorial bid for all three (see e.g. Lunander and Lundberg, 2012 for more on combinatorial auctions in Swedish road procurement). NCC won the contracts for all three parts at a price of 439 million SEK. The contract was regulated by ABT 94.

The project also included a partnering bit not directed towards any specific part of the contract but more of a declaration that both parties would work collaborative.

The description of the project in the tendering documents was very detailed. An example is that, contrary to the idea behind DB contracting, Trafikverket defined the thickness and type of asphalt to be used. The tendering documents did not use any functional descriptions of the road. However, the first paragraph of the technical description opened up for alternative solutions, without strict demand of technical documentation from a third party. In principle, this opened up for alternative design.

The final cost of the project was 540 million SEK.

5.6 Summary of the projects

The projects reviewed above are summarized in table 1 and demonstrates that the final cost exceeds the procured price in all projects. It should be emphasized that the total costs also include the client's cost, meaning that the design costs, which are automatically part of the DB contracts' costs, is also included for the two DBB contracts.

Table 1: Summary of studied projects

	Type of road	Length	Open for traffic	Procured price (sek)	Final cost (sek)	Contractor
DBB 1	Highway	9 km	2012	197	227	Svevia
DBB 2	2 + 1	20 km	2012	312	327	Skanska
DB 1	Highway	10 km	2012	185	240	Strabag
DB 2	Highway	5,5 km	2012	160	192	Strabag
DB 3	Highway	22 km	2011	439	540	NCC

Except for DB 3, all contracts comprise more or less far-reaching formal restriction on the degrees of freedom in designing the projects. These restrictions include certain brands of material e.g. barriers and asphalt, detailed design features such as the height of a noise barrier or the shapes of the exit ramps but also in the form of high transactions cost for alternative suggestion of construction. There is a formal requirement that any proposal that deviates from Trafikverket's handbooks was to be supported by technical documentation of quality and independent evidence that the technique fulfils the functional demands.

If the analysed contracts were to be ranked, DBB 2 can be said to have more degrees of freedom than DB 1. Although the client has the ultimate responsibility for the design in DBB 2, the contract is still framed in such a way that innovative ideas from the contractor have a possibility of getting utilized. In DB 1 the contractor is responsible for the design but circumscribed by the underlying handbooks of how to build the road due to the rigid demands for verifying functional equivalence of the proposed technical alternatives.

DB 3 differs from the other contracts in another way. Despite a very detailed a priori technical design, the tendering documents invite alternative designs.

6. Entrepreneurial freedom or not?

Trafikverket wants to promote innovation in their construction projects and one central component of their strategy is to increase the share of DB projects. The stated motive is that DB will lead to more innovation.

The above analysis indicates that there is no clear relation between contract labeling (DBB or DB) and the degrees of freedom for the contractor. If more degrees of freedom are a necessary condition for more innovation, then a lack of relationship between innovation and what is labelled as DB contracts is not surprising.

There are however rational motives for the client not to give too much degrees of freedom to the contractor. Two principal arguments are presented in this section.

6.1 Demand for verification and rate of innovation

The above projects exhibit bounds on the degrees of freedom for the contractor to come up with new solutions. This is done by the client demanding evidence for the quality of an innovative idea, by demanding scientific studies or third parties validating the new methods. This obviously creates cost for the contractor and the more conclusive evidence that the client demands, the less innovation should be expected.

There is however a potential explanation for this. More degrees of freedom and less evidence of quality required by the client, increases the moral hazard problem. This refers to the risk that the contractor introduces techniques reducing the construction costs but increases the client's long term maintenance and reinvestment costs. Hence, there is a trade-off between giving the contractor the opportunity to innovate and the need to keep track of the subsequent operation and maintenance costs.

However, anecdotal evidence indicates that the client's project manager has the possibility to bend the strict formal rules of third party evidence. This gives them the opportunity to accept new proposed solutions from contractors they trust. As lowest price is the most common selection criteria there can be some contractors that the client do not trust, and then they can fall back on the formal rules and demand verification.

This of course raises new problems. The first is that the knowledge and self-confidence of the client's project manager will determine the rate of innovation. Risk-averse project managers will to a larger extent "go by the book" and thereby reduce the rate of innovation. A second problem is that this creates uncertainty for the contractor and there is a risk that the project manager acts in a way that means that the client violates the principle of equal treatment.

Hence, the bounds on degrees of freedom in DB contracting can be explained by the trade-off between innovation and moral hazard. Trafikverket wants to promote innovation but do not want to go all the way since they have the long term responsibility.

One obvious way to address this trade-off is to extend the contractor's responsibility for quality delivered. By way of performance bonds, it would become less necessary to reduce degrees of freedom during construction, since any future cost increases due to poor performance would have to be paid by the contractor. Trafikverket's contracts are trying to go in this direction, but it is not part of the contracts scrutinized here (see Nilsson (2012) for a discussion of this option).

6.2 Procurement contracts, risk allocation and transaction costs

There is also a second potential explanation to why Trafikverket wants to go from DBB to DB contracts, while still shaping the technical solutions. The results above indicate that the client in the DB contract places the design risk with the contractor without giving them a real possibility to deviate from the handbooks. Going from a DBB to a DB contract is then just a way of shifting the design risk of a DBB contract onto the contractor. That is the only thing that differs between the contracts. The design risk of this type of (restricted) DB contract, is small but not non-existent. This entails that the possibility for innovation in a DB contract is not more likely than in the DBB setting.

From the client's perspective, moving away from all risk without any change in expected project outcome looks favourable. The remaining question is how much this shift in risk affects the price. This additional cost for the contractor consists of the direct cost but also of a reduction in competition as fewer companies can be expected to participate in a DB-procurement.

Putting the design risk on the contractor, even if the client has the last word on the detailed design, can also be seen from a transaction cost perspective. This could be a way for the client to get a second opinion from the contractors on their design. If the detailed DB design is problematic, no-one may be willing to submit a bid. This can be contrasted with a DBB contract where the contractor can build according the client´s design even if this is seen to be below standard, since the builder does not have to take the design risk in the latter case

A further benefit for the client is that the risk-shift will reduce the risk for litigation. If the outcome is inferior in a DBB contract, it has to be established if the problem is related to the design (client) or to how the work was carried out (contractor). In a DB project all this risk is in principle born by the contractor so this line does not have to be drawn.

7. Conclusion

The theoretical pros and cons of DB and DBB contracts are well known. DB enables innovation, while DBB has reduces transaction costs and risks for the client. There is however a lack of empirical studies supporting either of these hypotheses. One possible reason for this is the complexity in separating contracting forms from each other.

Our review of five contracts indicates that just taking the contract labels at face value does not capture the degrees of freedom for design, which is was theoretically drives innovation. Hence, Trafikverket´s DB contracts of today do not provide more incentives to innovate than their DBB contracts. In order to separate contracts from each other in this regard it is necessary to look beyond labelling and study the details of the individual contracts.

Although degrees of freedom are lacking in some of the DB contracts, their use can still be rational. As the client carries the long term cost, they have an incentive to secure that the chosen solution does not come with large subsequent costs for operations and maintenance. A second explanation could be that the client would want to get rid of the design risk without giving the contractor any real possibility to deviate from the standard solution of how to build

The paper has also pointed to the necessity of further research on how to promote innovation. Given the bounds in degrees of freedom regarding the current contracts, and an unwillingness to implement an unbounded DB contract direct, here are some suggestions on how to promote innovation in the short run.

1. Identify which quality parameters of an object are decisive for high standard delivery of the services of a new road. Describe these aspects in functional terms and issue tendering documents with this as only criterion for project design, i.e. with no restrictions on the degrees of freedom. If the crucial parameters can be found, and if prequalification is used and there is a rather long guarantee period moral hazard risk can be controlled.

2. Make the process of approving alternative design more transparent by using arbitration

3. Early involvement of the contractor, by using e.g. competitive dialogue

4. Let the client and the contractor share the risks of technologies that both find interesting but too risky for one party to take on by themselves.

Acknowledgements

The authors would like to thank the reference group from BVFF and SBUF for supporting this study.

References

Bogus, S.M., Shane, J.S. and Molenaar, K.R. (2010), 'Contract payment provisions and project performance: an analysis of municipal water and wastewater facilities', *Public Works Management and Policy*, Vol. 15 no. 1, pp. 20-31.

Borg, L. (2011) 'Incentives and choice of construction technique', Licentiate theses, Div. of Building and Real Estate Economics, Dept. of Real Estate and Construction Management, Royal Institute of Technology (KTH), Stockholm.

Bröchner, J. (2012) *Bygginnovationers förutsättningar och effekter* Vinnova, Stockholm.

Ewerhart, C. and Fieseler, K. (2003) 'Procurement auctions and unit-price contracts ', *Rand Journal of Economics,* vol 34, no. 3, pp. 569–581

Gupta, D. Azadivar, J. and Chen, Y- (2012) 'Incentive Functions for Transportation Procurement Auctions' Working paper SCORLAB University of Minnesota

Hale D.R., Shrestha P.P, Gibson G.E., and Migliaccio G.C. (2009) 'Empirical comparison of design/build and design/bid/build project delivery methods', *Journal of Construction Engineering and Management*, Vol. 135, no. 7, pp. 579-587

Hyun, C., Cho, K., Koo, K., Hong, T., and Moon, H. (2008) 'Effect of Delivery Methods on Design Performance in Multifamily Housing Projects', *Journal of Construction Engineering and Management*, Vol. 134, no. 7, pp. 468–482.

Ibbs, W. Kwak, Y. Ng, T. and Odabasi, A. (2003) 'Project delivery systems and project change: Quantitative analysis', *Journal of Construction Engineering and Management*, Vol. 129, no. 4, pp. 382–387

Konchar, M. and Sanvido,V. (1998) 'Comparison of U.S. project delivery systems', *Journal of Construction Engineering and Management*, Vol. 124, no. 6, pp. 435-444

Lind, H. and Borg, L. (2010) 'Service led construction: Is it really the future?', *Construction Management and Economics*, Vol. 28, no. 11, pp. 1145-1153.

Lunander A and Lundberg S (2012) 'Combinatorial Auctions in Public Procurement - Experiences from Sweden', *Journal of Public Procurement,* Vol. 12, no. 1, pp. 81-109

Mandell, S. Nilsson, J-E. and Liss, V (2013) Asymmetric Information and the Choice of Contract Design, Working paper VTI

Minchin, E. Li, X. Issa, R and Vargas, G. (2013). 'Comparison of Cost and Time Performance of Design-Build and Design-Bid-Build Delivery Systems in Florida.' *Journal of Construction Engineering and Management*, Vol. 139, no. 10.

Nilsson, J-E. (2012) 'Procurement and contract design in the construction industry ... not one size fits all' International Transport Forum Discussion Paper 2012-11

Nyström, J. (2013) 'A Way to Empirically Define Contracting Forms in Construction' 7th Nordic Conference on Construction Economics and Organization, Trondheim.

Shrestha, P. (2007) Performance benchmarking of large highway projects. Dissertation, The University of Texas at Austin.

Shrestha, P. and Mani, N. (2012) Impact of Design Cost on Design Bid Build Project Performance. Construction Research Congress, pp. 1570-1579.

Thomas, S-R. Macken, C-L. Chung, T-H. and Kim, I. (2002) 'Measuring the impacts of the delivery system on project performance - Design-build and design-bid-build.' NIST GCR 02-840, NIST, Austin, TX.

Trafikverket (2011) *TRVK Väg - Trafikverkets tekniska krav Vägkonstruktion*. TRV 2011:072- TDOK 2011:264

Vägverket (2007) *Vägverkets regler för reglering av beläggningsarbeten* 2007:103