EJTIR

Issue **9**(2)
June 2009
pp. 143-163
ISSN: 1567-7141
www.ejtir.tbm.tudelft.nl

Experiences from Procurement of Integrated Bridge Maintenance in Sweden

Hans-Åke Mattsson
Royal Institute of Technology (KTH), Dept of Civil and Architectural Engineering, Div of Structural Design and Bridges[1]

Hans Lind
Royal Institute of Technology (KTH), Dept of Real Estate and Construction Management, Div. of Building & Real Estate Economics[2]

Received March 2008; accepted September 2008

The trend in many countries is to outsource maintenance with competitive tendering. The design of the tender is then a crucial issue. A new type of tendering contract, called "Integrated Bridge Maintenance", was introduced in one experimental area in Sweden. In this case bridge maintenance is separated out from the standard road maintenance contract. A pilot project has been running since 2004 for all bridges in Uppsala County with about 400 bridges. The experiences and lessons from this pilot project are presented here, and analysed from a transaction cost perspective. An important feature of the contract was that it contained a combination of *measures* that should be carried out and *properties* of the bridges that the contractor was responsible to maintain. This created a balance between predictability and flexibility for the contractor. The client was satisfied because of increased competence and a low price. The latter can partly be explained by the possibility for the specialised bridge crew to get additional work from other sectors. One problem was that some properties were difficult to measure, which led to some controversies. As information about old bridges always are incomplete a partnering structure need to be built into the contract. Experience has also shown that a conscious policy to maintain long run competition is important. The general conclusion is that the project was seen as successful and as creating more "value for money".

Keywords: bridges; maintenance; partnering; performance contracts

1. Introduction

1.1 General background

How maintenance of infrastructure is organised has changed dramatically over the last 20 years. One important background to this is the general renewal of the public sector, summarized under

[1] SE-100 44, Stockholm, Sweden, T: +4687908033, F: +468216949, E: hans-ake.mattsson@byv.kth.se
[2] SE-100 44, Stockholm, Sweden, T: +4687907365, F: +4687907367, E: hans.lind@infra.kth.se

the concept of "New Public Management". Important aspects of this are the ambition to reach higher efficiency with new more decentralised budget systems and more outsourcing and competitive tendering in order to get "more value for money".

Earlier the road network was maintained as an in-house activity by staff directly employed by the public sector. This is reflected in much of the maintenance literature that sees the problem as how the owner should optimize maintenance in order to reach various goals (Frangopol et al., 2007). When more and more of the activities are outsourced the problem for the authorities involved has shifted to how procurement of maintenance should be organized.

The most radical solution is of course to move towards Public Private Partnerships and Build-Operated-Transfer solution, where both construction and maintenance are outsourced with very long performance contracts. These models are e.g. discussed from a maintenance perspective in Herk et al. (2006), Ng & Wong (2007) and Vickerman (2004).

Most of the infrastructure is however already built and then maintenance has to be outsourced separately from construction. But how should this been done? A number of issues related to this have been discussed in the literature. (Esping and Olsson, 2004) and (Nyström, 2007) focus on the possibilities to use partnering contracts. (Cheng et al., 2008) looks at how outsourced inspection activities should be "packaged" in order to increase efficiency.

1.2 Research problem

The Swedish Road Administration (SRA) has outsourced maintenance of bridges together with road maintenance since the early 1990s (see section 2.1 for a more detailed description). A few years ago they wanted to experiment with a new way of procuring bridge maintenance (called Integrated Bridge Maintenance, or IBM for short) that differed from earlier procurements in the following respects:

1. Bridge Maintenance is outsourced separately from road maintenance.
2. All bridges in a large region are included in the contract.
3. The contract should cover a longer time period.
4. Part of the contract was a "performance" contract that specified the characteristics that the bridge should have, and not what the contractor was supposed to do.

The theories behind these changes are presented in section 2 but major hypotheses behind the experiment is that the new approach can increase efficiency through a combination of increased specialization (1 above), economies of scale (2 and 3 above) and through giving the private contractor a greater degree of freedom concerning exactly what to do and exactly when to do it (3 and 4 above).

The experiment with Integrated Bridge Maintenance is evaluated in this study. The contribution of the study is the following.

- From a practical perspective the study shows how a new type of maintenance contracts can be designed, what problems the implementation of this contract had and the experiences of using this contract.
- From the perspective of the scientific community the study shows how the introduction of a new type of contract can be explained from a transaction cost perspective. It identifies the specific features of the contract and the situation that can explain why this contract was more efficient: why both client and contractor saw the new contract as better than the old one. The detailed presentation of this new contract, and the experience during implementation, also lays the foundation for comparisons with policies and experiences

in other contracts. As will be returned to below, the structure of contracts in this area has been neglected in earlier research.

1.3 Research methodology

Evaluations can be designed in a number of ways, and the method used here is a standard case-study method with an implicit before-after comparison.

From a methodological perspective the ideal method could have been a quasi-experimental study, where similar areas that still used the old contract type are used as a control group. Nyström (2007) discusses this and other methods in the context of evaluating partnering contracts. In the end, however, two factors made us choose the standard case-study approach. First, it was not easy to find a good "control group", partly because the change concerned several different dimensions. Secondly there was a resource constraint and this made a more costly quasi-experimental study problematic.

An important aspect that reduced the problems in the standard case-study approach is that all persons involved on both the client and contractor side had experience from working with the old model, and therefore could compare the new and the old model. As the introduction of Integrated Bridge Maintenance is a rather "technical" innovation without any obvious ideological aspects, there are no reasons to believe that participants were biased in any special direction.

The project was initiated as the same time as the experiment and it was therefore possible to collect data during the whole process from procurement to the actual carrying out of the contract. All possible data sources were used and most important was interviews with both client and contractors during the whole process, various documents including evaluations and inspections from the client and external experts. The data sources are described more in detail when the data is presented. A reference group with participants from the SRA, several of the main contractors in Sweden and the Royal Institute of Technology also followed the project and gave comments during the whole process.

1.4 Structure of article

The article is divided into five sections. In the next section the theoretical framework is presented. In section 3 the concept and theory of Integrated Bridge Maintenance (IBM) is described. Application of IBM in Uppsala County and Örebro County is described in section four. Section 5 contains an analysis based on the transaction cost framework that was presented in section 2. Conclusions and recommendations can be found in the final section.

2. Theoretical perspective

The development of bridge maintenance will in this article be approached from a transaction cost perspective. This perspective can be broken down into three general aspects.

This first is a focus on certain issues, especially questions about industrial organization. The classical question is of course why firms are producing certain things in-house while they buy other things on the market. Coase (1937) formulated this as a question why firms exist at all, why are not everything is bought on the market. Transaction cost theory was further developed by especially Oliver Williamson (Williamson, 1975). One issue that has been raised in the Coase-inspired literature is why contracts are designed in a specific way. The path-breaking study in this area is Joskow (1985), who studied determinants of vertical integration and contract length between mines and electricity producers. Transaction cost theory has been applied in an analysis of the structure of partnering contracts in the Swedish construction sector by Nyström (2007).

Bridge maintenance in Sweden has gone through two stages that fit into this framework. First was the step from in-house production to outsourcing, a step that will not be covered in this article, and then followed an experiment with different types of contracts, and that is what will be analysed here.

The second aspect of transaction cost theory is an interest in details and an awareness of the multiplicity of markets and contracts. Coase put forward the idea in his Nobel lecture (Coase, 1991) that there should be an archive of contracts that economist could analyse. Implicit was a criticism against economist who assumed that most markets are the same and that the specific situation on each market need not be investigated.

In this study both the details of the contract and the implementation was studied in order to understand why a specific contractual solution was chosen and how the involved parties evaluated the outcome of the contract and why. Documenting the details of the contract, and how it worked, is also important as this information can be used by future researchers for comparison with other forms of contracts in other countries.

The third aspect of transaction cost analysis is the hypothesis that differences in organizational structure and contract design, and changes in these, can be understood from an efficiency perspective (see especially "the efficiency principle" in Milgrom and Roberts (1992)). Efficiency covers a number of different aspects, e.g.

- ordinary production cost (related to e.g. economies of scale)
- what incentives does the organizational structure and the contractual design create for the parties involved
- flexibility and the handling of risk and uncertainty.

The hypothesis is that an organizational model, or a specific contract type, are chosen because, weighting these different aspects together, it is the most efficient one. A more efficient contract creates a larger surplus and opens up the possibility for Pareto-sanctioned improvements.

Transaction cost theory also includes more specific hypotheses about important characteristics of a transaction that will affect organizational structure and contractual design. Milgrom & Roberts (1992) mentions the following five characteristics:

- whether there are specific assets involved (asset that only has value in the specific transaction)
- the frequency and duration of the relation
- the complexity and uncertainty of the work to be done
- difficulty of measuring performance
- connectedness to other transactions.

Bridge maintenance is interesting from several of these perspectives. It is obviously a long run work and the number of firms on this market is - as will be shown later - small. The contractors know that how they act today can affect future business opportunities. The specific assets are primarily knowledge about the individual bridges, and one implicit argument for somewhat longer contracts was that it should be rational for the contractor to build up this knowledge. As the quality of the bridge is multidimensional, measuring performance is problematic, as will be shown in the empirical section below.

After describing the details of the procurement process, contractual design and the development during the contract period we will return to a number of these issues in the evaluation section.

3. The concept and theory of integrated bridge maintenance

3.1 The development of bridge maintenance in Sweden

A bridge is normally defined as a manmade structure with the purpose to carry traffic over or around an obstacle made by man or in nature. Since 1998 a bridge is formally defined in Sweden as a structure with the longest span exceeding 2.0 m. The national bridges on the road network in Sweden are owned by the Swedish Road Administration (SRA). The total bridge stock owned by SRA consisted, in the winter of 2007, of 15 500 bridges.

Routine road and bridge maintenance were carried out in-house by SRA until 1992. That year The Swedish Road Administration (SRA) started to go from in-house production to contracting out the maintenance by competitive tendering. The main reason for this reform was the intention to cut public expenditures for operating the road net by exposing this activity to market forces (Österberg, 2003). During the period before 1992 SRA had a bridge maintenance crew in each county (Sweden is divided into 21 counties) that carried out all bridge maintenance and minor repair for the national bridges. Each crew consisted typically of a bridge-engineer and 3-6 workers.

After 1992 SRA divided Sweden into 7 regions (see below) and 133 small districts. SRA procure district-wise a routine maintenance package deal, called "Basic operating and maintenance package", ("Grundpaket Drift" in Swedish, GPD). A county consist typically of 3-6 small districts, which means that there theoretically could be 3-6 different entrepreneurs in the county. Examples of routine road maintenance are clearing off snow, gritting, salting during the winter season, acute repairs of the road surface such as filling potholes, washing away the salt from the bridges after the winter season, etc. The length of a routine maintenance contract is normally 5-6 years. About 1/5 of the districts is then procured yearly. The planned maintenance, such as maintenance of pavements, which is outside the package deals, has been contracted by competitive tendering for a longer period of time.

It is a complex task to manage a large stock of bridges and therefore a bridge management system (BMS) is a must for the effective planning and procurement of new bridges and for the maintenance of the existing bridge stock. SRA has since the mid 1970s used a computerized BMS. The latest update of SRA's BMS is called Bridge and Tunnel Management system (BaTMan), which was introduced in 2004. BaTMan supports the management of a bridge structure during its whole lifecycle, from the design phase to the demolishing stage. BaTMan is an Internet based system, which means that users all the time have updated information online about all bridges in the system (https://batman.vv.se/). This system is comparable to the systems discussed in e.g. Liu & Itoh (2001).

3.2 The concept of integrated bridge maintenance

This introduction of the "Basic operating and maintenance package" meant that there were no longer any specialized groups working with bridges. In this package road maintenance is the big part while bridge maintenance just counts for some 2-3 % of the contract value. Because the volume of routine bridge maintenance is so small, it was observed that it was difficult for the entrepreneur to keep a specialized bridge crew on a continuous basis.

This has led to a worry that maybe the competence in the area of bridge maintenance has been falling. SRA and some contractors therefore suggested that it could be a good idea for SRA to procure bridge maintenance separately in one or two counties for a longer period time, e.g. seven to ten years. The old bridge maintenance crew could be a model for this (Silfwerbrand, 2002).

At the same time there was an increasing interest in moving towards performance contracts and in 2004 the SRA started the experiment with what is called Integrated Bridge Maintenance. The idea was to procure bridge maintenance separately for a larger area than the one covered in the ordinary GPD. An important part of the new model was also that the contract should be more of a performance contract. Instead of stipulating exactly what a contractor should do, the contract should regulate the *characteristics* that the bridges should have. It is then up to the contractor to decide what measures should be taken in order to make sure that the bridges actually had these characteristics.

This experiment is part of a broader set of experiments with contracting forms carried out by SRA, e.g. using new contract forms to stimulate innovation (Stenbeck, 2007) and using partnering contracts (Nyström, 2007).

4. Application of integrated bridge maintenance in Uppsala County and Örebro County

4.1 *Choice of region*

SRA has, as mentioned above, divided Sweden in seven main regions. About 1 850 bridges is located in SRA's Mälardalen Region (VMN), see Figure 1. SRA had decided that the project should be carried out somewhere in this area (Sundquist et al., 2004). The VMN region contains some large and smaller cities but not the largest ones (Stockholm, Göteborg) and it could be considered as a rather typical region both for Sweden and the northern part of Europe.

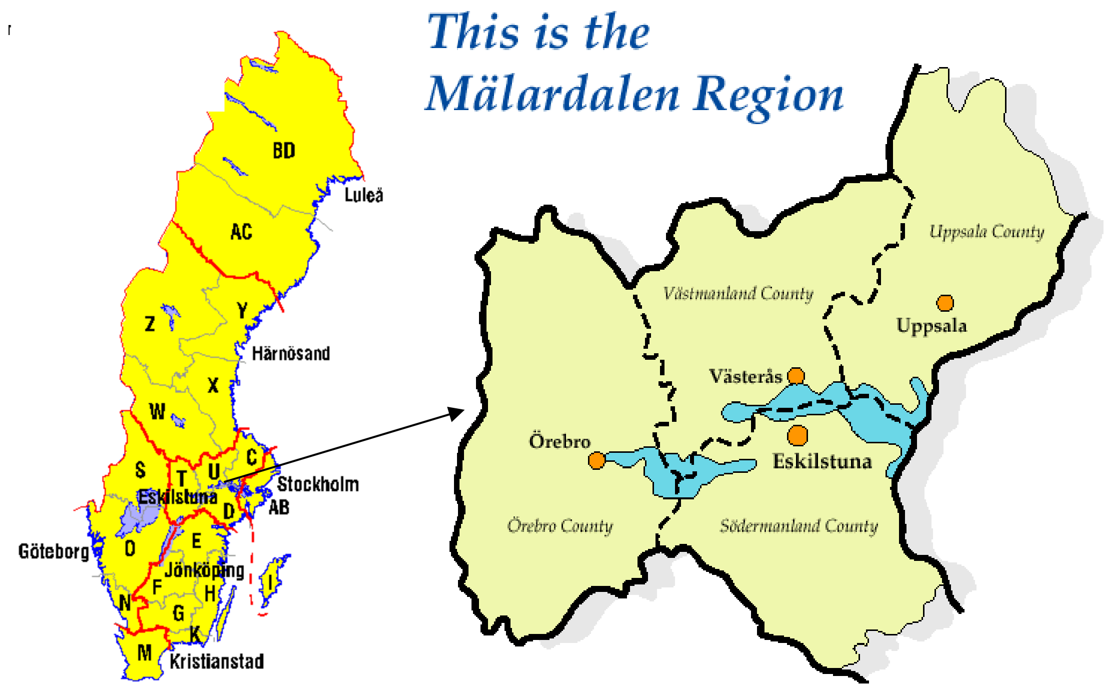

Figure 1. The figure to the left shows SRA's seven Regions in Sweden. The figure to the right shows SRA's Mälardalen Region (VMN). The regional office is in Eskilstuna.
Source VMN.

4.2 *Choice of area*

VMN consists of four counties; Uppsala County, Södermanland County, Västmanland County and Örebro County. Each county is divided into 3-4 smaller districts, which means that there are a total of 15 districts in VMN. During the spring of 2003 a working group analysed a number of possible areas and the time remaining in various GPD-contracts. Since this is the first project of its kind in Sweden the owner (SRA) did not dare to let this pilot project be too large.

The working group found that procuring Integrated Bridge Maintenance for a county was a suitable area for the pilot project. Since a large part of Uppsala County should be tendered for GPD during the spring of 2004 it was decided that the pilot project would be in Uppsala County. Uppsala County is situated some 20 km to 200 km north of Stockholm and contain about 400 bridges. It was also decided that the contract period would be three years and with an option for three more years (Mattsson, 2006). This rather short period also reflected the uncertainties in SRA concerning whether the new model would work well or not.

Uppsala County consists of four districts; Uppsala district, Enköping district, Tierp district and Östhammar district. In order to create a contract for bridge maintenance in Uppsala County it was necessary to buy out the yearly routine bridge maintenance from the GPD-contractors in Enköping district, Tierp district and Östhammar district. This was done by SRA during the winter of 2003.

The tender documents were presented in March 2004. In addition to advertisement in tender journals a small seminar was held at the Swedish Cement and Concrete Research Institute (CBI) in Stockholm. The major reason for this seminar was to present the basic ideas behind the contract for a number of invited consultants and contractors. A meeting was also held in Eskilstuna somewhat later to clarify questions from potential contractors that now had had time to look closer at the tendering documents.

4.3 *Scope of work in the contract for Uppsala County 2004-2007*

The actual contract had the following content. The contractor should perform bridge maintenance for all 400 bridges in Uppsala County. The contract was for three years (2004-09-01 – 2007-08-31) with an option for three more years (2007-09-01 – 2010-08-31). The offer should be in SEK, fixed price. There would be no index-link adjustment for the first year, thereafter yearly adjustments of the prices for a 12 months period.

It was further decided that the bridge maintenance contract should consist of two parts. The first part was more performance oriented and stipulated a number of properties that the bridges in the area should have. These properties lead to a yearly maintenance of the bridges according to the demands in the General Technical Regulations for Bridge Maintenance, ("ATB Brounderhåll" in Swedish) (SRA, 2002). The aim of this bridge maintenance is to prevent or delay the deterioration processes in order to maintain the function and prolong the bridge’s expected service life. A series of technical requirements are defined for properties e.g. absence of de-icing agents and vegetation, cleanliness, intact fixings, open drainage systems and limited crack widths. The properties are summarized in Table 1.

Table 1. Summary of technical requirements for preventive maintenance in Sweden. After Silfwerbrand (2007).

Structural member	**Defect or detail**	**Requirement**
Slope and embankment end	Scour	Not deeper than 0.2 m
	Settlement	Not reduce height > 10 %
	Vegetation	Not higher than 1 m above the ground level
Earth slope and embankment end	Facing	Intact to at least 95 %
Bridge deck of timber		Plank must not be loose. No nails protrude more than 2 mm
Edge beam	Railing fixing	No concrete damage deeper than 0.2 m
Wear layer	Cracks	No cracks with crack width > 3 mm in asphalt wear layers, > 1 mm in bituminous mastics, > 0.5 mm in concrete wear layers
	Wrong level	The top surface of the wear layer shall be above the top surface of expansion joints, edge protections, gulley etc
	Unevenness	Unevenness > 20 mm must not occur 6 m before or after the bridge
	Joint sealant	Has to be connected to surfacing, edge beams etc to at least 95 %
Railing	Deformation	Railing posts must not have deformation > 100 mm
	Fixing	Screw joint shall be intact. Fixing to base plates shall be intact.
	Splicing	Screw joint shall be intact
	Level	In their connection less than 20 mm both vertically and laterally
	Protection ability	Safety netting and splash guard protection > 95 % protection
Expansion joint	Anchorage	Intact to at least 90 %
	Sealing	Free from leakage
Drainage system	(Through) flow	Flow area > 80 %
	Fixing	Intact to > 80 %
Entire bridge	Contamination	Clean to at least 95 % for every structural member
	De-icing agents	Clean to at least 95 % for edge beams, railings, bearings etc
	Vegetation	The near surroundings shall be free from vegetation > 1 m
	Drainage	Bridges above water shall be free from collections of floating objects

Before the contract period started the bridges were inspected together by SRA and the contractor, in order to verify that the bridges had these properties when the contract period started. Otherwise SRA should take action to restore these characteristics.

The second part of the contract specified a number of specific *measures* that the contractor should carry out on the bridges that SRA judged to need improvements in one or more respect. This was the type of contract that SRA traditionally had used. In Table 2 there are some examples of what these measures were. In total there were 25 such specific measures that the contractor should carry out during the first three years.

The contract also stipulated that the contractor was expected to contribute in the research project.

Table 2. Examples of planned measures during the contract period.

Some examples of planned measures in Uppsala County
Replace edge beam
New parapets on stone posts
Strengthening of the superstructure
Increase the concrete cover with 20 mm on roof and wing walls
Apply 30 mm shotcrete inside steel culvert
Replacement of steel culvert
Replace waterproofing, surfacing, parapets etc

4.4 *Submitted tenders and selected contractor*

There were six contractors that requested the tender documents, but only three of them submitted an offer to SRA for the projects first three years. All six companies that requested the documents were interviewed. The firms that did not put in an offer said that they thought that it was difficult to calculate the tender, especially the part concerning fulfilment of properties. They said that it was difficult to estimate the amount of work needed and to assess the risk associated to this work. Since this is a low-margin business a small contractor normally has little room for error on the wrong side in the tender. All of them, however, thought that a multiyear bridge maintenance contract was an interesting idea and that it seems to be a good deal both for the owner and for the contractor. Large companies tended to want large contracts and longer time periods.

In Table 3 the offers made, divided into offers for the measures and the yearly offer for maintaining the properties of the bridges in million SEK (1 million SEK is about 110 000 €) are presented.

Table 3. Potential contractors submitted offer to VMN (in million SEK).

Contractor	**Measures**	**Properties (yearly)**
SRA Production	19.0	1.1
Company X	20.6	2.8
Company Y	25.8	2.4

It should however be noted that the offers actually consisted of a price list for the components that build up the measures, but in order to compare the bids the total cost was calculated given an assumed set of quantities.

The interviewed representatives for SRA were a little disappointed over the fact that only three contractors have submitted their offer. SRA had expected the number of offers to be at least four to five. All of the three contractors that have submitted offer deemed to have met the standards of a contractor set by VMN. SRA Production (SRA-P), which is an independent part of SRA that now is about to be privatised, was the lowest bidder and therefore it was contracted by VMN for this project. SRA-P made the lowest bid for both measures and properties, but in percentage terms their bid for the properties were especially low. VMN judged that this part of the bid could not possibly cover the costs, but that is of course the contractor's problem.

4.5 *The contractor's project organisation*

For this project the contractor SRA-P had chosen to have a person responsible for measures and one person responsible for properties. These two persons supervised both the bridge maintenance crew that consisted of 6-7 workers and subcontractors, see Figure 2.

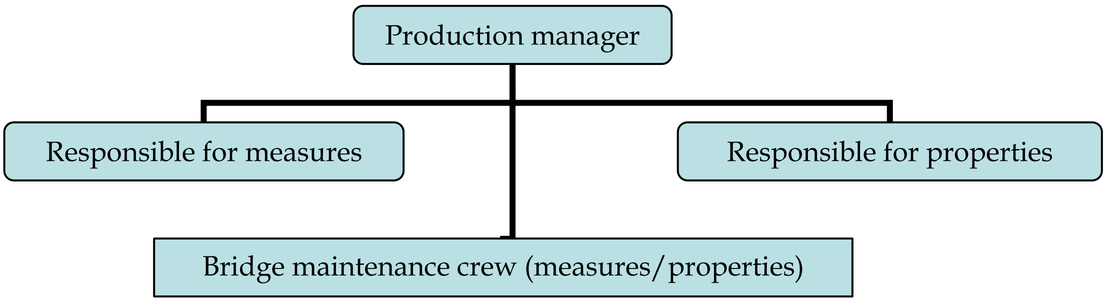

Figure 2. The selected contractor's project organisation.

4.6 Planning of measures and properties 2004-2007

According to the contract SRA-P should repair 25 bridges during a three-year period. During the autumn of 2004 SRA-P chose to divide these repairs in three more or less equal parts regarding number of bridges and costs: nine bridges 2005 with a budget of 6.5 MSEK, eight bridges 2006 with a budget of 6.3 MSEK and eight bridges 2007 with a budget of 6.2 MSEK.

For the work with the properties the contractor chose to divide Uppsala County into seven smaller work areas. Bridges should be inspected visually at least once a year and discovered shortcomings regarding properties should be rectified. The contractor thought that it was helpful for him with these small informal areas when planning the inspections and work to be carried out.

4.7 Performed measures 2005-2007

During 2005 seven of the nine planned measures were carried out according to the plan, three measures were delayed and one measure was moved from 2006 to 2005. The reason for these postponements was the fact that two of the bridges were in a worse condition than described in the tender documents. This was discovered when the contractor started with the work of removing the old edge beams from these two old bridges that were constructed during the 1930s. It was then decided to remove the old superstructures, and not just the edge beams, for these two bridges and build new superstructures on the old foundations. The repair costs for these two bridges were much higher than budgeted. During the late summer of 2005 a steel culvert that was not included in the contract suddenly broke down and it was necessary to replace it quick. Since VMN already had a contractor for bridge maintenance in Uppsala County it was agreed that SRA-P should carry out the replacement of the steel culvert at a cost of more than 2 million SEK.

The parties showed great flexibility when unexpected circumstances or events turned up during the first year of the contract period. As VMN had to keep their budget they needed to postpone some measures when one measure became more expensive than expected.

During 2006 eleven measures were carried out. Of the eight planned measures for 2006 six were carried out according to the plan. Two measures that were delayed from 2005 and three measures that were planned for 2007 were carried out and one measure was deleted. The major reasons for the increased costs for some bridges compared to the offer were that it was decided to carry out more work on the bridge than it was stated in the tender documents. Once more the parties acted in a flexible way given new circumstances.

During 2007 five measures were carried out. Of the eight planned measures for 2007 four were carried out according to the plan. One measure that was delayed from 2005 was carried out and one measure was deleted. The reason for the big differences in costs compared to the offer for one of the bridges was due to the fact that the bridge was in a worse condition than described in the tender documents and that much more measures were carried out.

The planned measures for two bridges were not carried out during the projects first three years. Instead it was decided that these two bridges would be under supervision until further notice. One can say that the bridge that was carried out outside the project, replaced the planned measures for these two bridges. To summarise, all measures were more or less carried out according to the tender documents for the projects first three years, but there were a number of changes in the timing and the details of the measures taken. The signed contract was treated more as a starting point for discussion than as a binding document that should be followed exactly.

4.8 Contracted properties 2004-2007

During May – September 2004 the contractor inspected all bridges and 186 shortcomings in properties were noted and rectified and recorded in SRA's BaTMan. An inspector hired by VMN also inspected all bridges and 283 shortcomings in properties were noted and recorded in BaTMan (Haim, 2005). The difference in detected defects is large, but the inspection results are not sufficiently detailed to conclude if SRA-P detected all SRA's observed defects. Table 4 shows the most common types of defects detected by SRA-P and SRA and Table 5 shows the defects sorted by structural members.

Table 4. The most common types of defects detected by SRA-P and SRA during 2005.

Defect	SRA-P	SRA
Vegetation	92	82
Settlement	43	30
Wear	24	18
Scour	13	68
Weathering	5	12
Cracks	1	41
Other	8	32
TOTAL	186	283

Table 5. The most common types of defects detected by SRA-P and SRA during 2005 sorted by structural member.

Structural member	SRA-P	SRA
Slope and embankment end	99	137
Slope	43	23
Wear layer	24	18
Edge beam	4	15
Earth slope	3	5
Surfacing	1	41
Other	12	44
TOTAL	186	283

Some possible explanations for the difference are that the inspections were made at different dates, the inspectors had different experience and that the inspectors may have different tolerance levels. SRA-P's comments were that SRA had pointed out some small scours in slopes and embankment ends and some small cracks in the surfacing. This is shortcomings according to ATB Brounderhåll 2002, but SRA-P deemed that these shortcomings are insignificant and have very little to do with the function of a bridge. According to SRA-P all major shortcomings were detected and rectified.

A later investigation made by Johansson (2008) also compared the number and type of faults found by the client (VMN) and the contractor in areas with Integrated Bridge Maintenance and faults in areas where bridge maintenance were part of GPD (Nyköping and Västerås). In Figure 3 it can be seen that the client found a larger number of faults in all areas, but that that the difference were smaller in the area with Integrated Bridge Maintenance.

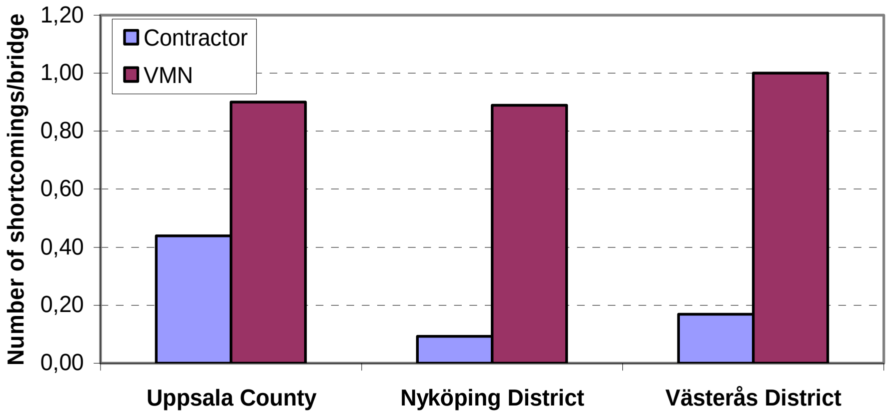

Figure 3. Number of shortcomings in properties found by the client (VMN) and the contractors.

The smaller disagreement in Uppsala County was explained by the fact that Integrated Bridge Maintenance led to more regular inspections by both parties and therefore their views tended to converge.

The largest disagreement in absolute numbers concerned vegetation, and the smallest disagreement concerned settlement in slopes and embankment ends.

4.9 Option for Uppsala County 2007-2010

Both the owner (VMN) and the contractor (SRA-P) choose to utilize the option for three more years 2007-09-01—2010-08-31. VMN was satisfied with that bridge maintenance had been an activity of its own, and also the increased attention on properties compared to the GPD. VMN also stressed the good relationship that had evolved in this project between owner, contractor and VMN's controller. There had been flexibility concerning what measures that should be carried out and adjustments could be made when new information had arisen and both parties had appreciated this.

SRA-P is of the opinion that they now have a firm ground to build upon when carrying out the work. A big advantage is that SRA-P can plan the work and that the guaranteed work volume makes it possible to have long term contracts with qualified and skilled workers.

Furthermore SRA-P has now the same business volume outside as inside the project. SRA-P explains this with that their special knowledge in bridge maintenance is in great demand by other bridge owners, e.g. municipalities. This side-effect of getting the contract is perhaps one explanation for why they were submitting such a low bid, especially for maintaining the properties.

VMN and SRA-P have agreed on a list containing 13 measures to be carried out during the new contract period 2007-09-10 – 2010-08-31. The measures in the list are of the same types and in the same cost range as in the projects first three years, see Table 2 above.

For the properties a new round of inspections was carried out between 1 September and 31 December 2007. The contractor should also rectify the shortcomings that were detected at the end of the first contract period during the autumn of 2007.

During the contracts first three years a working cycle for properties have been developed. It consists of three parts; inspection of bridges during the autumn, analysis of the noted shortcomings from the inspections and plan the rectifying work during the winter and carry out the actual work during spring and summer.

4.10 SRA decided to procure IBM for Örebro County

Since SRA was satisfied with the results from contract in Uppsala County it was decided to continue and procure the same type of Integrated Bridge Maintenance for Örebro County. Örebro County consists of five districts and is situated in the western part of VMN, see Figure 1. In order to create a contract for bridge maintenance in the whole of Örebro County it was necessary to buy out the yearly routine bridge maintenance from the contractors that are in charge of the "Basic operating and maintenance package". This was done by SRA during the spring of 2007.

4.11 Scope of work in the contract for Örebro County 2007-2010

It was decided that the bridge maintenance contract should be similar to the Uppsala contract and consist of two parts; properties and measures. Properties are, as described above, yearly maintenance of the bridges according to the demands in ATB Brounderhåll (General Technical Regulations for Bridge Maintenance (SRA, 2006)). Measures are the specified tasks that should be carried out for a number of structures or structural members that SRA has prioritised.

To summarise the actual contract said that the contractor should perform bridge maintenance for all 700 bridges in Örebro County. The contract was three years (2007-09-01 -- 2010-08-31) with an option for one more years (2010-09-01 -- 2011-08-31). The bridges should be deemed to be in a satisfactory condition if the contractor verified that they met the requirements for properties in SRA's regulations once a year. The contract included repair of 40 bridges during the contract's first three years with an option for 7 more repairs during the possible 4th year. It was also stipulated that there should be increased cooperation between contractor and client according to what is called "FIA step 1", which is a simplified form of partnering. The offer from the client should be in SEK, fixed price, with no index-linked adjustment during the first year, thereafter yearly adjustments. This is the same type of procurement as was used in the Uppsala project, se section 3.3.

4.12 The tender process and selected offer

The tender documents were presented for potential contractors at a small seminar in the second half of March 2007, and the tender documents were available in the middle of April. The offers should be submitted before the first of May 2007.

There were four contractors that requested the tender documents, but only three of them submitted an offer to SRA for the projects four years, see Table 8. The contractors that have submitted tenders for the Örebro package were the same that have submitted an offer for the Uppsala project. All of the three contractors that have submitted offer were deemed to have met the general standards of a contractor set by VMN. SRA Production (SRA-P) was the lowest bidder and therefore they were contracted by VMN for this project.

All four contractors were interviewed and the answers were very similar to the ones presented in section 3.4. There were a generally positive attitude, but smaller contractors worried about how to calculate the cost for keeping the properties at the required level.

From Table 6 one can see that the total of the submitted offers were very close in price. Company Y and Company X had more or less submitted the same price for measures and properties. SRA-P prices were some 7 MSEK lower on measures and some 6 MSEK higher on properties compared to Company Y and Company X. SRA-P had been internally criticized for their low priced properties in the Uppsala project. In the Uppsala project it was SRA-P Operation that was responsible both for properties and measures. This means that the losses on properties could be compensated with profits on measures. The Örebro offer was a cooperation between SRA-P Operation and SRA-P Construction. SRA-P Operation considered the offer on properties in Örebro to be more realistic than the prices on properties in the Uppsala project. It is unclear why SRA production had such a low bid on the measures, and given the large differences in the bids for properties and measures it is rather strange that the final bids were so close.

Table 6. Potential contractors submitted offer to VMN (in million SEK).

Contractor	Measures	Properties	Total
SRA-P	59.6	12.3	71.9
Company Y	67.0	5.5	72.5
Company X	66.5	7.3	73.8

4.13 Planning of measures and properties 2007-2010

VMN and SRA-P have agreed on a detailed list containing measures to be carried out during 2008, 2009 and 2010.

Inspections of properties are to be carried out between 1 Sep and 31 Dec 2007 and the SRA-P should rectify detected shortcomings between 1 Jan and 31 Aug 2008. This is in line with the working cycle for properties that have been developed in the Uppsala project; inspection of bridges during the autumn, analysis of the noted shortcomings from the inspections and plan the rectifying work during the winter, and carrying out of the actual work during spring and summer.

4.14 Comparison between the Uppsala project and the Örebro project

Some key figures for properties and measures have been obtained from the tender documents; see Table 7 and Table 8. In order to compare the tenders Uppsala prices have been adjusted upwards from 2004 to 2007 years prices based on the a special construction index (E84 littera 251 Bridgework concrete). This means that the tender prices for properties increase with a factor 1.09 in the Uppsala project. The tender prices for measures need, in addition to the factor 1.09, to be increased with a factor 3/2 since only 2/3 of the measures were procured inside the project. After these adjustments in Uppsala tender prices from 2004 the scoop of work both in the Uppsala project and Örebro project is similar and the costs could be compared.

Table 7. Key figures for properties.

Project	Bridges	Bridge deck area	Properties (yearly)	SEK/bridge	SEK/m²
Uppsala	400 No.	105 000 m²	1.1 MSEK	2 900	11
Örebro	700 No.	117 000 m²	3.1 MSEK	4 400	26

Table 8. Key figures for measures.

Project	Bridges	Bridge deck area	Measures (yearly)	SEK/bridge	SEK/m²
Uppsala	400 No.	105 000 m²	10.3 MSEK	25 900	98
Örebro	700 No.	117 000 m²	14.9 MSEK	21 300	127

The above calculated key figures can be used to estimate the yearly costs for properties and measures for VMN's whole bridge stock which is about 1 900 bridges with a bridge deck area of 500 000 m², see Table 9. From the table one can see that the cost for properties is some 6-11 MSEK/year and the cost for measures is some 50-52 MSEK/year which results in a yearly cost of about 56-63 MSEK for all bridges in the VMN region. This can be seen as a normal level for bridge maintenance.

The relation between bridge maintenance costs and new bridge construction costs in Sweden during 1988-1992 was 0.7 %, according to Stenbeck (2007). The relation 0.7 % was considered as a low number in an international perspective. If one assume that the cost to construct a new bridge is 15-20 kSEK/m2 then the yearly maintenance cost could be estimated to 500 000 m2 x 15-20 kSEK/m2 x 0.7 % = 53-70 MSEK/year. This cost is in line with the estimates based on key figures obtained from the Uppsala project and the Örebro project.

Table 9. Estimates for VMN's whole bridge stock based on SRA-P's winning tender bids in the Uppsala and Örebro project.

VMN	Properties (Uppsala)	Properties (Örebro)	Measures (Uppsala)	Measures (Örebro)
1 900 bridges	5.6 MSEK	8.4 MSEK	49.2 MSEK	40.5 MSEK
500 000 m²	5.5 MSEK	13.0 MSEK	49.0 MSEK	63.5 MSEK

5. Analysis and evaluation

In this section Integrated Bridge Maintenance will be analysed and evaluated using the transaction cost perspective presented in section 2.

5.1 Design of the tender

The tenders have two interesting qualities that will be discussed here, the first is the size of the region covered by the tender and the second is the combination of procured properties and specific measures.

The size of the area (number of bridges)

Maintenance of bridges needs special skills and there are a number of fixed establishment costs. This leads to *economies of scale* where a larger area leads to a lower cost per unit. As always there are countervailing forces and in this case these include transportation costs and that it is important that the team that maintain the bridges have good knowledge of the bridges in the area. A too large area would lead to inefficiencies because of transportation and information problems, and it can also reduce competition in future procurements as there are fewer experienced firms "nearby".

What is the right balance and the optimal area for the tender is still an open question that will need more research when the system has been in use for a longer period and in more areas. The comments from the contractors do however indicate that they think that the areas chosen are rather close to the optimal size.

From the contractors perspective there was economies of scale in the procurement of specific measures, as these earlier were procured individually.

Performance contracts, properties and measures

The general argument for going in the direction of performance contracts is that it makes it possible for the contractor to choose the techniques used to reach a certain performance goal. At least in a longer perspective it can lead to a higher rate of innovation, as the incentive for the contractor is stronger (Stenbeck, 2007), but this probably takes a longer time than the period evaluated here.

A general problem with performance contracts is to describe the desired performance in measurable terms. In the contracts studied here the strategy has been to describe the *properties* that the bridges should have, properties that is related to the performance of the bridges.

One important feature of a tender is that it should be possible for a contractor to calculate how much it would cost for them to fulfil the contract. If it is easy to calculate the bid, then it would make tendering of interest for a larger group of firms. The easier it is to calculate the bid the more probable it is that the procurement process leads to the tender going to the most efficient firm and at a low cost for the client.

Performance contracts, or the specific version in this case where the contractor guarantees that a number of properties should be fulfilled, create uncertainty, especially when the contract concerns old bridges. Even if there are inspections when the contract period begins in order to make sure that the objects have the "right" properties, predicting how the properties will develop is difficult for old objects. For these objects there is a lack of information both about details in the construction, the quality of the materials used and in how the objects have been taken care of earlier. A contract that specifies that the contractor should guarantee certain properties is not so risky in a situation where the contractor also built the object, as in e.g. a Build-Operate-Transfer procurement. In this specific case, many of the bridges in the area were rather old.

This uncertainty is increased when, as in this case, it was not completely clear for how long time a certain property was allowed to be below the contracted level. According to the intentions in ATB Bridge Maintenenace the bridges should have these properties *all the time*, but everyone was aware of that this could not literally be the case, as it always takes time to prepare and carry out certain maintenance measures. From the contractor's point of view, a longer time allowed below the acceptable limit, the lower would the cost be, as then it would be possible to coordinate several measures and reduce transportation costs.

As can be seen from the interviews in the Uppsala case some small contractors took out the documents but never made a bid for the contract as they judged that the uncertainties about the properties were too big.

How can this uncertainty be reduced? One way is to make the contract a little more flexible by a more partnering like relation between the parties (see below). Another way that was used in these tenders is to *combine* procurement of a number of predetermined measures with procurement of a number of properties. In the first contract (Uppsala) the share of the sum related to the properties was rather low (less than 20 %) and this was a way of reducing the uncertainty for the contractors, as they could be rather sure to make a certain profit on these measures. Given the economies of scale mentioned above, the marginal cost of making sure that the properties are fulfilled would also be lower when you have a crew that is working with specific measures in the area. As there was some flexibility when these measures should be carried out, this also reduced the marginal cost of taking care of situations where certain properties were no longer fulfilled.

The share of the tender related to properties was increased in the second tender (Örebro) and this reflects that both the client and possible contractors at that time should have more knowledge about what typically happen with a certain set of bridges, and how much it costs to make sure that the bridges have the properties specified in the tender.

5.2 *The flexibility of the contract*

The evaluation of the Uppsala project shows clearly a road authority with a predetermined budged must be able to change the contract in an easy way. For some of the measures included in the original tender, it turned out that assumptions about the state of the objects were mistaken. This made it necessary to make much more costly measures than original planned. In order to keep the budget some other measures had to be postponed. In the case studied here, the contractor understood the situation of the client and was willing to make the necessary adjustments without any extra compensation. A part of the explanation for this voluntary cooperation by the contractor could be that contractor used to be part of the same organisation as the client. The contractor was also willing to maintain a good relationship with the client, because the contractor was interested to use the option for three more years.

This is, however, a risky situation from the client's point of view as the contractor suddenly might stop to cooperate and demand that everything contracted on should be carried out and that the client would have to pay more than the original amount if the assumptions in the contract was not correct. One way to reduce this risk is to make the contract explicitly into a partnering contract. Nyström (2007) argues that partnering contracts could be understood as contracts that include elements of reciprocity and in that way makes it easier to renegotiate contracts. Changing circumstances and more detailed information that turns up during the project can change both the value for the client and the cost for the contractor. Low cost for renegotiation related to trust and reciprocity could therefore increase efficiency. In the Uppsala case no explicit partnering clauses or partnering procedures were included, but the parties actually worked in a way that is typical for partnering projects, and that was important for increasing the flexibility of the contract. In the Örebro case a partnering model has been introduced explicitly.

It should be noted that there are possible legal problems with too large renegotiations as other firms may demand that a new tendering round is to be carried out in such a case. So far, this problem has not materialized in reality.

5.3 *Measurability of the properties*

A crucial issue for making it interesting for firms to submit bids is, as mentioned above, to make it possible for the firms to calculate the cost for carrying out the tasks in the tender. One possible cost that the firms must take into account is the costs for conflicts concerning whether the tasks have been fulfilled or not. One aspect of this was mentioned above, and that was unclearness related to for how long periods the bridges were allowed to have a quality that was lower than stated in the contract.

Another possible problem is that there might be disagreement about whether the bridges have the agreed properties at a specific point in time. The number of noted shortcomings in properties in three independent inspections differed considerable, which was shown in section 3. This concerned especially whether there were cracks or not (if they affect the bridge or not), and whether there were a need to remove vegetation or not.

This lack of agreement about what is a shortcoming in properties could create large problems and extra costs for both clients and contractors, and it is important to reduce these differences by describing the controversial properties more in detail in the tendering document. Given the good relations between the parties in the case investigated here, there were no major conflicts related to different views about what was a fault or not, but such good relations cannot be assumed. The consequence of properties that is not described clearly could also be that new actors who are not aware of the vagueness and implicit flexibility either overestimates the cost and do not get the tender, even if they are the most efficient firm, or underestimates the costs and get the tender even if they are not the most efficient firm.

5.4 The problem of long run competition

A recent report from the Swedish Competition Authority showed that the number of bids in publicly procured projects had been falling over the last years (Swedish Competition Authority, 2007). An interesting issue is how the client can act in order to counteract this tendency.

The aspects mentioned above about designing the right area, finding the right mix between measures and properties, and increasing the measurability of the properties are of course important, as well as providing potential contractors with as much information as possible about the bridges. There are also more direct ways to induce firms to put in bids, e.g. paying the contractors submitting bids a fee to cover at least part of the cost for submitting a tender. The fee could be differentiated with respect to how close the bid was to the winning bid. Firms that the clients think are especially interesting could be contacted directly and presented with specific offers if they submit a bid.

If the Integrated Bridge Maintenance concept is introduced in more regions it would also lead to a situation with more firms that have experience of these contracts. Then they might be willing to compete for the contract in a nearby region and in that way the level of competition could increase.

The problem is however not only too little competition. The problem can also be too much competition, and the risk that uninformed contractors put in too low bids and then later create a number of problems, e.g. by being inflexible, in order to earn more money and reduce their losses. The use of pre-qualification clauses and options to prolong the contract if the contractor has performed well is one way to reduce this risk.

5.5 Evaluating the over-all efficiency of the new contract

It was not possible to directly measure the effect on cost and quality of Integrated Bridge Maintenance. The cost for bridge maintenance in other regions was part of the total cost for the maintaining the road system. It would have been very resource demanding to continuously measure the quality of bridge maintenance in other regions. The strategy used in this work was to rely on the views of the parties involved and analyse the arguments that they put forward. As mentioned in the introduction both client and contractor had experience of working with the old system. A lot of effort was in this project put into closely following the implementation and development of the experiment with the new project, participating in a number of meetings between the parties where experiences and problems were discussed. This information clearly pointed in the direction that both parties thought that this new system was better than old, and that they had rational arguments for this.

As mentioned in the section about theoretical perspectives a more efficient contract makes a Pareto-sanctioned change possible: By splitting the gain both parties can improve their situation. From the fact that both parties have stated that the new contract was better, it could be concluded that the change was efficient. The analysis presented above indicates why the new contract was more efficient. A further aspect mentioned by the contractor was that by creating a bridge maintenance team, they could get additional work from e.g. municipalities that also have bridges that needed maintenance. When the contractor has the fixed costs covered by the contract with SRA, and skills build up for that purpose, these additional works were very profitable. This possibility also lowered the price they demanded from SRA, and this in turn contributed to their view that they got a clear increase in "value for money".

Using the parties own evaluation as a base is, of course, not unproblematic. The most obvious risk is self-selection: that those who had invested in promoting the new concept were involved in the implementation, and of course wanted this to succeed. In this specific case this risk does, however, seem low as the initiative to the experiment came from the headquarter of SRA, and because the contractor was chosen by competitive tendering.

More direct measurements of cost and quality given different contractual forms would of course be very interesting and the possibility to do that and get significant results should increase when it has been implemented in more districts.

6. Conclusions, recommendations, and future research

The experiment started by The Swedish Road Administration (SRA) in 2004 with "Integrated Bridge Maintenance" has been judged to be a success. It has created specialised groups of people working with bridge maintenance and the competitive tendering lead to a low price. SRA is convinced that the new form has lead to more "value for money" and has therefore decided to introduce it in other areas also. The contractors also wished to see more of this type of contract from owners in the future. An important feature of the contract was that it contained a combination of *measures* that should be carried out and *properties* of the bridges that the contractor was responsible to maintain. The data and the analyses presented point to the following more specific conclusions and recommendations.

It is important with a careful choice of the area that a contract should cover. The client has to take into account a number of short run and long run aspects including economies of scale, transportation costs, information problems and competition in the long run.

The mix of measures and properties: In a longer perspective it might be possible to contract directly on the things that are of importance for the final customers. At least for the foreseeable future contracting on properties for a large number of old bridges will create a lot of uncertainty for the contractor. Including a number of more easily calculable direct measures is a way of reducing the uncertainty for the contractor. In the short run the most important thing is to choose the right properties and make the properties as measurable as possible. It is also important to clarify how long the properties of a specific bridge are allowed to be below the level described in the contract. This should probably be differentiated between bridges and different types of characteristics.

As the current state of old bridges partly are unknown and that their development is difficult to predict it is important to build in flexibility into the contract. The longer the contract period is, the more likely it is that circumstances might change in such a way that both parties can gain by renegotiating the contract. An explicit partnering structure can reduce the transaction cost for such renegotiations, and would then be an important part of the contract.

Experience has shown that a conscious policy to maintain long run competition is important in order to get a high "value for money" in the long run. Using Integrated Bridge Maintenance in more areas and explicit incentives for new firms to submit tenders are possible measures.

In all of these areas there is a number of interesting remaining research issues, and our view is that the most important is to develop a more measurable and functionally based list of properties.

Optimal contract length is also worth investigating more in detail, as some clients have suggested that the gains from Integrated Bridge Maintenance could be higher if the contract was longer.

References

Coase, R. (1937). The Nature of the Firm. *Economica*, vol. 4, no. 16, pp. 386-405.

Coase, R. (1991). The Institutional Structure of Production. Lecture to the memory of Alfred Nobel. Available at www.nobelprize.org (assessed May 2009).

Cheng, Y.M. and Leu, S.S. (2008). Constrained-based clustering model for determining contract packages of bridge maintenance inspection. *Automation in Construction*, vol. 17, no. 6, 682-690.

Esping, U. and Olsson, U. (2004). Partnering in a railway infrastructure maintenance contract: a case study, part I & part II. *Journal of Quality in Maintenance Engineering*, vol. 10, no. 4, pp 234-253.

Frangopol, D. and Liu, M. (2007). Maintenance and management of civil infrastructure based on condition, safety, optimization, and life-cycle cost. *Structure & Infrastructure Engineering*, vol. 3, no. 1, pp 29-41.

Haim, S. (2005). Funktion, egenskapskrav och åtgärdstider som underlag för effektivisering av brounderhåll. (Function, properties and time demands as basis to increase effectiveness in bridge maintenance). TRITA-BKN Examensarbete 228, Dept. of Civil and Architectural Engineering, Royal Institute of Technology (KTH), Stockholm, MSc thesis.

Herk, S., Herder, P.M., De Jong, W.M and Alma, D.S.M. (2006). Innovative contracting in infrastructure design and maintenance. *International Journal of Critical Infrastructure,* vol. 2, no. 2-3, pp. 187-200.

Johansson, D. (2008). Analys av brounderhåll för Vägverket i region Mälardalen 2004-2007. (Analysis of bridge maintenance in SRA's region Mälardalen 2004-2007). Mälardalens Högskola, Västerås, BSc thesis(2008).

Joskow, P. (1985). Vertical Integration and Long-term Contracts: The Case of Coal-burning Electric Generating Plants. *Journal of Law, Economics and Organization*, vol. 1, no. 1, pp. 33-80.

Liu, C. and Itoh, Y. (2001). Information technology applications for bridge maintenance management. *Logistics Information Management*, vol. 14, no. 5-6, pp. 393-400.

Mattsson, H-Å. (2006). Funktionsentreprenad brounderhåll. En pilotstudie i Uppsala län. (Bridge Maintenance based on Functional Requirements. A Case Study in Uppsala County). TRITA-BKN Bulletin 82, Dept. of Civil and Architectural Engineering, Royal Institute of Technology (KTH), Stockholm, Lic thesis.

Milgrom, P. and Roberts, J. (1992). *Economics, organization and management*. Prentice Hall, New Jersey, USA.

Ng, T. and Wong, Y. (2007). Payment and audit mechanism for non private-funded PPP-based infrastructure maintenance projects. *Construction Management and Economics*, vol. 5, no 9, pp. 915-924.

Nyström, J. (2007). *Partnering: definition, theory and evaluation*. Division of Building and Real Estate Economics, KTH, PhD thesis.

Österberg, R. (2003). *Contracting out Public Services*. TRITA-INFRA 03-046. Division of Urban Studies, Royal Institute of Technology (KTH), Stockholm, PhD thesis.

Silfwerbrand, J. (2002). *Aktivt brounderhåll – en förstudie. (Active bridge maintenance – a pilot study).* TRITA-BKN Rapport 65, Dept. of Structural Engineering, Royal Institute of Technology (KTH), Stockholm.

Silfwerbrand, J. (2007). Technical demands for preventive bridge maintenance – A critical review. Paper presented at *Fib Symposium*, Dubrovnik, Croatia.

Stenbeck, T. (2007). *Promoting Innovation in Transportation Infrastructure Maintenance.* TRITA-BKN Bulletin 91, Dept. of Civil and Architectural Engineering, Royal Institute of Technology (KTH), Stockholm, PhD thesis.

Sundquist H., Mattsson, H-Å., James G. (2004). Procurement of bridge management based on functional requirements. *Second International Conference on Bridge Maintenance, Safety and Management, IABMAS,* Kyoto, Japan, Conference Proceedings, pp. 185-186.

Swedish Competition Authority (2007). Konkurrensen i offentlig upphandling. (Competition in Public Procurement). Stockholm, Sweden.

SRA (Swedish Road Administration) (2002). ATB Brounderhåll 2002. (General Technical Regulations for Bridge Maintenance). Publ 2002:48, Borlänge, Sweden.

SRA (2006). ATB Brounderhåll 2006. (General Technical Regulations for Bridge Maintenance). Publ 2006:146, Borlänge, Sweden.

Vickerman, R. (2004). Maintenance incentives under different infrastructural regimes. *Utilities Policy*, vol. 12, no. 4, pp. 315-322.

Williamson, O. (1975). *Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization*. Free Press, New York, USA.