FOLLOW-UP STUDY FROM A SEVEN YEAR PERFORMANCE CONTRACT ENDING IN 2010

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ABSTRACT

The Swedish Transport Administration aims at improving procurement of road construction and maintenance to create incentives for contractors to develop their skills and efficiency. Introduction of performance requirements is believed to encourage new technical solutions that are more adapted to object specific situations. In order to develop procurement procedures for performance contracts, the Swedish Transport Administration has initiated a number of pilot projects.

Pilot project Road N610 included design, construction, maintenance and operation of a new road. It was initiated in 1999 by developing procurement documents and finally opened for traffic in 2003. The bids were evaluated following laws of public procurement based on technical solution, price, organization, quality assurance and references. The winning bid scored about average in these categories. In 2010, the contract ended and the responsibility was handed over from the contractor to the road administration. The requirements were related to both pavement layers (wear resistance, durability, stability) and road surface (friction, rutting, evenness, cross fall, cracking and ravelling). To ensure the long term performance, a requirement was also employed on the road's structural strength based on a falling weigh deflectometer index. A bonus-malus system was tied to the requirements. The pilot project has been monitored closely and reports have been issued from the development of procurement documents and from the procurement and construction phases.

This paper report experience gained with emphasis on the technical outcome. Observations from the construction stage and data from verification of performance confirm that the contractor has taken necessary measures to meet requirements and consequently adapted the pavement design and construction during the whole contract period to minimize costs and risks. A number of issues are identified with respect to future improvements in procurement procedures. A major client risk in performance contracts is related to ensuring long term performance at acceptable costs for maintenance and to identify responsibilities for inferior performance.

1 INTRODUCTION

This paper report findings and experience from a seven year Design-Build contract with performance requirements and incentives.

1.1 Background

The construction sector has been considered to suffer from slow development and low efficiency in a number of reports (e.g. Latham et al, 1994; Egan et al, 1998), also noticed in a public inquiry of the Swedish construction sector (SOU, 2002). The inquiry triggered initiatives within the Swedish sector to identify problems and suggest changes. Another report from 2009 stated that not much had changed (Statskontoret, 2009). Examples of problems reported are fragmented organisations, low drivers for changes, low drivers for education and implementation of research and innovations. The Swedish Transport Administration, with support from contractors, has responded to the problems by development and implementation of procurement procedures, such as Design-Build contracts. In 2007 a major effort was launched by the Swedish Transport Administration with the goal to reach a volume of a third being Design Build and ten projects being Design-Build-Operate-Maintain projects.

Development of procurement procedures has naturally been an on-going effort. During the 1990-ies more than a dozen projects were procured as Design-Build with various degrees of performance requirements and various successes. During the first years after year 2000, two projects based on a Design-Build-Operate-Maintain approach was launched to further develop and test ideas on how to improve efficiency in the construction sector: N610 and Norrortsleden. N610 was opened for traffic in 2003. By then, the problems identified in the above mentioned reports was addressed as a reason for further development of procurement in which the contractor is responsible for design and performance of the produced outcome, rather just being responsible for material use and handling as in traditional contracts. Today, the previous procurements represent a useful source of experience for the future development of procurement procedures and it is believed that structured follow studies on these projects will play an important role in the next step towards a more efficient construction sector.

1.2 Project N610

The project involved design, construction, maintenance and operation of a new road. This new road was partly in a new location, partly along the same route as an older road. The cross section was divided in two lanes which had to conform to the Swedish design guide for 90 km/h, AADT 8500, and 5 % heavy traffic. For pavement design purposes, additional requirements were a traffic load of 3,0 million 100 kN standard axles and 15 – 20 % share of studded tyres as a mean over the whole duration of seven years. The client had done a rough design to allow for the legal claim of land for road construction and use. The rough design, with the exact legal boundaries for the project and design of crossings, and geotechnical information comprised the technical situation specific data.

1.3 Goal and purpose

This study has the purpose to contribute to the development of Design-Build procurement practices and have the following goals:

- Document the project
- Report experience on the outcome technical parameter values and the possibilities and limitations when designing technical requirement
- Contribute to the understanding of effects of bonus and malus

- Contribute to methodology for analysis of how requirements and incentives influence technical outcome as well as costs and benefits to road managers and society.
- Identify risks involved and potential for development.

2 TENDER AND PROCUREMENT DESIGN

The purpose of this section is to describe the parts of the tender documents aimed at ensuring an efficient construction and future performance, thus achieving optimised utility with respect to costs. The section describes requirements, incentives and the procurement process including evaluation of bids, of which all these parts are intended to act as a system. The overall purpose of the procurement design was to introduce a freedom to the contractors to use their skills in finding adapted solutions and achieving effective results.

2.1 Performance requirements

Requirements were set on both pavement layers and on pavement surface as described in Tables 1 and 2 below for the traffic opening stage. Today, requirements for Design-Build for construction of new roads are mainly set on the pavement surface properties, and for maintenance contracts mainly on pavement layers, especially if contracts are of short duration. In this case, a few requirements were set on bound pavement layers to early ensure that these performed satisfactory. For the contract period of seven years, the requirements were only set on the surface properties, see Table 3. The consequence of not fulfilling a requirement was to perform actions such as replacing inferior materials or layers. These actions are associated with costs that vary substantially and can be regarded as a monetary penalty in relation to the bonus malus system described in the next section.

The purpose of the target values reported in the tables below was to show the expected values and did not pose a requirement. Target values became useful when deciding on levels for incentives and requirements as well as for this follow up study to assess if the actual intentions of the clients became realised.

Table 1: Requirements on pavement layers.

Performance indicator	**Method**	**Control parameter**	**Target value**	**Required value**
Resistance to wear	Prall	Worn mass	27	<36 (Wearing c.)
Water sensitivity	ITSR	Difference in strength	60% 75% 75%	≥50% (Bound base) ≥60% (Binder layer) ≥63% (Wearing c.)
Stability	Dynamic creep test	Permanent strain	Target <25 000 microstrain for layers below wearing course.	

Table 2: Requirements on pavement surface and structural strength before opened to traffic.

Performance indicator	Method	Control parameter	Target value	Required value
Skid resistance	VVMB 104	Wet friction, mean 20 m	-	>0,5
Homogeneity	DOR (Density on the Run), just follow up. No requirement.			
Longitudinal evenness	VVMB 111	IRI_{20} och IRI_{400}	IRI_{400} 1,20	IRI_{400} <1,65 IRI_{20} <2,4
Longitudinal evenness adjacent to bridge	1 m straight edge	Deviation in height for each	<6 mm	<10 mm
Crossfall	VVMB 111	Deviation from design (400 m)	Zero. Design value from guide	s ≤ 0,35 % ± (0,40 - 0,4 s) %
Structural design life	VVMB 114 (FWD)	Index for bearing capacity	P85 > BF1-1 P100 ≥ BF2	P85 ≥ BF2 P100 ≥ BF3

Table 3: Requirements on pavement surface during contract period.

Performance indicator	Method	Control parameter	Target value	Required value
Transversal evenness (rutting)	VVMB 111	Rut mean 400 m	8 mm	<17 mm
Longitudinal evenness	VVMB 111	IRI_{20} och IRI_{400}	IRI_{400} 1,60	IRI_{400} <2,20 IRI_{20} <4,00
Longitudinal evenness adjacent to bridge	1 m straight edge	Deviation in height for each	<9 mm	<16 mm
Crossfall	VVMB 111	Deviation from design (400 m)	<0,5 %	<1,2 %
Cracking	Assessment guide	Damage classified by ATB Väg 2000	1	better or equal 3
Skid resistance	VVMB 104	Wet friction, mean 20 m	-	>0,5
Stone loss	EN13036-1 ("Sand patch")	Difference between damaged and undamaged area	-	≤20 %

2.2 Incentives through bonus malus system

The limited space here does not allow full details of the bonus malus system to be described. Examples are given in the table below to enlighten how the system was designed and what consequences this might have for the contractors and the final outcome. Intentionally some of the requirements were asymmetric with respect to levels of bonus and malus. The reason was to reflect the proportionally larger costs for road managers and society associated with inferior performance.

Table 4: Some examples of bonus and malus at different parameter values at the end of contract period.

Performance	Units	Bonus		Malus			Req.
Transversal evenness	[SEK/m^2]	5	10	- 5	- 10	- 20	
	value[mm]	4 - 6	< 4	10 – 12	12 – 15	15 – 17	<17
Longitudinal evenness	[SEK/m^2]	5	10	- 5	- 10		
	value 400 [mm/m]	1,20-1,40	<1,20	1,80- 2,00	2,00 – 2,20		<2,20
Crossfall	[SEK/m^2]	2		-2	-5		
	Deviation [%]	< 0,4		0,6 – 0,9	0,9 – 1,2		<1,2
Cracking	[SEK/m^2]	0		- 4	- 10		
	Class			2	3		3

2.3 Procurement process

The project was initiated in 1999 and started by developing the tender documents from March 2000. In June 2001, the tender was distributed to pre-qualified bidders who got four months to deliver bids. Due to an appeal, the final decision was delayed to February 2002. Most of the construction work was ready in December 2002 while the project was finished and opened for traffic in May 2003. The final payments were regulated in 2010 after the final survey and inspection. The stages of preparation of tender documents and procurement process were evaluated in a report (Falk and Larsson, 2001).

The bids were evaluated following laws of public procurement based on technical solution, price, organization, quality assurance (QA) and references. The scores of the categories were evaluated by weighting the categories. Technical design and price was given the largest weight. The winning bid (No. 4 in Table 5) scored about average in these categories.

Table 5: Marking system for evaluation of bids and marking categories with final scores for the five bidders. Bidder 4 won the contract.

Assessment category	**1**	**2**	**3**	**4**	**5**
1. Technical design (30 %)	4,5	2,2	2,2	3,7	4,6
2. Bidding price (30 %)	2,2	4,7	5,0	3,3	1,0
3. Organization (20 %)	4,4	4,1	4,2	4,8	4,1
4. Quality Assurance (10 %)	4,4	3,0	3,6	4,6	4,4
5. References (10 %)	4,0	4,0	4,0	4,0	4,0
Weighted average (100 %)	**3,70**	**3,59**	**3,75**	**3,92**	**3,32**

3 RESULTS OF THE FOLLOW-UP STUDY

The requirements and incentives system demanded extensive monitoring of parameters from traffic opening throughout the contract duration. Apart from measurements before opening for traffic in 2003 and ending the contract in 2010, the years 2004, 2006 and 2008 was selected for control of performance requirements. This gives a substantial amount of condition data to use in the evaluation.

3.1 Construction phase

The construction works on the north part (2,5 km) started in April 2002 and opened for traffic in June, including one bridge. The southern part (2,1 km) was opened for traffic in December 2002. In May 2003 the wearing course was placed and the verification measurements were then performed. The project was evaluated up to stage of opening the whole road for traffic in

May 2003 and reported by Larsson and Sandberg (2003). The contractor expressed concerns over the tight time schedule for the bridge and two bicycle underpasses. The work was carried out more or less as in traditional Bid-Build contracts, with some extra attention given to compaction of materials and quality control.

3.2 Requirements related to pavement layers

The north part of the project showed wear resistance (Prall) and water sensitivity (ITSR) in line with bonus levels while the south part was in the neutral zone. Stability (Dynamic creep) was only controlled (no penalty was related to the requirement) and found to be well above the target value.

3.3 Requirements related to surface or structure after construction

Properties of the road surface may change very rapidly after opening the road to traffic. Part of the road was constructed in the same location as the old road and there was a need to reduce the negative impacts of road works. Therefore parts of the road were open before the project was finished and then the wearing course was placed on the whole length just before the final survey and inspections. In this way traffic compaction of the binder layer could be utilised.

The surface properties were in general very good and fulfilled the requirements with a margin. The longitudinal evenness can be considered to be very good with IRI 400 m average sections between 0,50 and 0,65 mm/m. However, it should be noted that the road's subgrade mainly consist of a sandy soil.

3.4 Requirements related to surface or structure during the contract period

The only significant problem with respect to surface requirements was cracking occurring in the south part during the last years of the contract duration. These sections also observed accelerating rutting and had the lowest bearing capacity (high FWD deflections). Otherwise, the condition of the road was in general very good, especially the longitudinal evenness (IRI). Data down to 20 meter average was collected, however the space here does not allow more detailed data to be presented. The exact location of related each data was identified as a problem, especially for the requirements using 20 meter average data, but facilitated by easily identifiable wearing course interfaces.

The tables below with different statistical parameters are intended to give a background to the challenge of designing requirements and setting acceptable levels to respond to different needs from society, road users, road managers and contractors. Not being aware of the natural statistical variation in parameters may pose a great risk for contractors when meeting requirements. Maximum values are intentionally not given, only up to 99 % percentiles, since erroneous results from measurements processed by automated procedures appears difficult to avoid. Especially start, stop and crossings pose a challenge to automated monitoring. However, single point damages such as potholes and bumps also need requirements, which is another important issue when designing requirements.

There is no clear explanation for the significant difference between south bound and north bound data for rutting. A significant difference can also be observed between the north and south parts of the project, which can be explained by a difference in time of construction and traffic volume.

Table 6: Rut depth statistics from 2003 to 2010.

				Percentiles			
	Year	**Mean**	**Std dev**	**75 %**	**90 %**	**95 %**	**99 %**
South bound	0	3,10	0,68	3,50	4,10	4,30	4,75
	1	4,26	1,02	5,10	5,50	5,80	6,82
	3	4,87	1,19	5,80	6,60	6,70	7,30
	5	5,85	1,47	6,90	7,80	8,37	9,27
	7	6,30	1,65	7,50	8,54	9,00	9,85
North bound	0	2,30	0,62	2,8	3,1	3,2	3,574
	1	3,87	0,82	4,4	5,1	5,4	5,6
	3	4,36	1,10	5,1	5,9	6,07	6,75
	5	5,05	1,30	5,8	7	7,4	7,9
	7	5,29	1,43	6,35	7,24	8,04	8,55

Table 7: IRI statistics from 2003 to 2010.

				Percentiles			
	Year	**Mean**	**Std dev**	**75 %**	**90 %**	**95 %**	**99 %**
South bound	0	0,59	0,20	0,60	0,80	1,00	1,40
	1	0,60	0,24	0,65	0,90	1,10	1,50
	3	0,66	0,30	0,70	0,90	1,17	1,80
	5	0,64	0,29	0,70	0,95	1,18	1,90
	7	0,72	0,38	0,80	1,04	1,40	2,35
North bound	0	0,57	0,20	0,60	0,74	0,80	1,65
	1	0,61	0,21	0,65	0,80	0,97	1,40
	3	0,66	0,25	0,70	0,90	1,10	1,73
	5	0,66	0,29	0,70	0,90	1,27	1,98
	7	0,70	0,32	0,80	1,00	1,27	2,08

4 PROJECT COSTS AND PERFORMANCE

The success of a road construction project is difficult to assess since it requires a holistic view. Total project costs need to be assessed in the light of technical challenges, project management challenges, environmental considerations, quality and utility. A full and fair assessment is not possible here and therefore limited to comparing costs with other projects and commenting on the technical quality achieved.

4.1 Bid price and additional costs

The bid included design, construction and maintenance and operations costs until May 2010. Limited additional costs (2 %) on top of the bid price were included in the total cost due to unforeseen bedrock and change of type of barrier system, which is less compared to traditional contracts. The total cost of 31 million SEK (3,3 M€) was compared to other similar projects and found to be similar (Larsson and Sandberg, 2003). Unfortunately, the project influenced an adjacent Bid-Build project awaiting final bridge design by the contractor of the Design-Build project, causing considerable additional costs that possibly could have been avoided if handled by one responsible body.

4.2 Bonus and malus compensations

The maximum possible bonus was in total almost 2,6 million SEK (280 k€) and the total maximum penalty was 4,0 million SEK (430 k€). These levels were in the order of 10 % of the total contract. The final total outcome of the compensations paid is summarised in Table 8 below. The contractor managed to receive almost 50 % of the total possible bonus. Longitudinal evenness and evenness adjacent to bridges together comprised almost half of the possible maximum bonus, which was successfully received to 100 %. It is also worth to note that cracking was the only category not having the possibility of a bonus, and furthermore only comprised 10 % of the possible maximum penalty.

Table 8: Final compensations for bonus and malus.

		Max bonus	Max penalty	Outcome	~%
Layers	***Wear resistance***	79 200	-79 200	43 830	55 %
	Water sensivity	140 400	-93 600	65 745	47 %
	Total - layers	219 600	-172 800	109 575	50 %
Surface and structure	***Evenness longitudinal***	804 150	-1 206 000	804 150	100 %
	Evenness transversal	396 000	-792 000	135 000	34 %
	Evenness bridge	360 000	-624 000	360 000	100 %
	Bearing capacity	792 000	-792 000	36 000	5 %
	Cracking	-	-396 000	-178 000	-45 %
	Total – surface and structure	2 352 150	-3 810 000	1 157 150	49 %
	Total	2 571 750	-3 982 800	1 266 725	49 %

5 DISCUSSION

The use of performance requirements imply that clients and contractors know that the parameter values set as requirements and in incentives are transparent and corresponds to a need as well as are possible to achieve in a predictive manner. However, a project like this show the complexity of information, the knowledge needs and the risks associated with not being in control over the process from design to production. Research and development efforts are means of mitigating these problems. Very few studies are reported on experience gained from this type of procurement designs on construction of new roads.

5.1 Incentives

Many stakeholders have identified a need to develop the construction sector to become more efficient. Increased efficiency may serve slightly different purposes for these stakeholders such as increasing utility per spent money or increasing profit margins. The focus of the procurement procedure is to match client expectations and contractor abilities to deliver at a certain price, thus minimising costs and increasing efficiency. The price for certain product, result or property may vary substantially for reasons such as variations between the contractors' equipment, available resources, chosen designs, etc., all parameters varying in time. Consequently, prices offered by contractors are elastic and dependent on how well the contractors can adapt to the situation and the requirements set in procurement, revealing further potential for increased efficiency. If the requirements are rigid, the price elasticity cannot be taken advantage of. Similarly, the client's willingness to pay has a certain elasticity related to the utility gained. When designing the incentive system in this case, matching the client's expectations (including third party utility such as road user costs) and contractor's prices is the goal, thus maximising utility per spent money. The target values given in the bonus malus tables intended to indicate the expected road condition leading to optimum during normal conditions.

In this case the resulting road condition indicators, on average, revealed a better road condition compared to target values. It is clear that the contractor has adapted their efforts to match the incentives, at least with respect to the road longitudinal evenness, being far better than usual. As discussed above, this could mean: (1) a deviation from optimum total costs, or if the bonus malus system worked as intended, (2) extra value was gained by adaptation to the situation section by section, e.g. creating better road conditions where possible or slightly worse conditions when the efforts were too high to reach target values. To fully assess if the bonus malus system reflected the societal costs require a complex analysis in which many relationships are currently missing. Consequently, an answer to if the incentives was successful in minimising costs cannot be given. A few comparisons between incentives and societal costs were made such as reduced fuel consumption due to lower IRI. The lower IRI corresponded to a reduced cost of about 600 000 SEK (about 60 k€), with fuel consumption calculated by the VETO model (Hammarström, 1989) and fuel costs from the Swedish Road Administration (Vägverket, 2008). Given that reduced fuel consumption is one of several benefits of lower IRI, the level of bonus and malus could be considered feasible. On the contrary, consequences of cracking are probably an issue not fully covered by the penalties, which will be further discussed in the next section.

The incentives design reveals the importance of the client being able to specify their exact needs. In a traditional Bid-Build contract needs are specified within the road administration itself and no detailed presentation of consequences for future maintenance and road users are required, as long as the result conforms to the usually expected performance. In Design-Build contracts with performance requirements, however, the contractual interface is shifted towards more road user orientated needs and demands, expressed in terms of performance indicators, revealing a greater need to be able to match society's needs and willingness to pay as well describing needs and requirements in a more transparent manner.

5.2 Risk assessment

What were the risks involved in the project that was specific to the contract type? Examples from the client side were performance and maintenance costs beyond the contract period, changes needed during the contract period and third party considerations. From the contractor side important examples of risks were related to being able to predict:

- project management and construction circumstances based on available technical information and time plan
- future road condition from design
- future road condition from practices and quality control during construction
- bonus, penalties and other costs based on quality control, initial measurements and available countermeasures (such as maintenance)

Requirements related to cracking and bearing capacity are good examples of risks for both clients and contractor that become of major importance. Cracking and inferior bearing capacity is difficult to measure and predict, costly to improve and have major negative long term consequences far beyond the contract duration. In this case cracking was afflicted with monetary penalties and the penalty of having to repairing cracks. No bonus was possible. In this case incentives/requirements and risks was not matching, since the client risk was related to having a pavement prone to cracking with large costs for maintenance in the future and the incentives/requirements given by the client only addressed the appearance of cracks. The penalties did not address the reason for cracking, since crack repair do not solve the problem of future cracking. By having incentives and requirements on bearing capacity the client reduced the risks of having excessive costs for maintenance. Interestingly, some of the sections showing inferior performance were experiencing drainage problems related to a lack of information and third parties; agricultural drains led water into the pavement structure. Consequently, incentives and requirements on cracking and bearing capacity needs to be further developed to further reduce risks, taking into account the negative consequences of inferior performance in these respects.

6 CONCLUSIONS

The following conclusions from this follow up study are emphasised:

- Only a few projects have been followed up to this extent and great need for experience and knowledge of Design-Build procurements are needed.
- In general, this project is considered to have been successful, especially from a road user perspective. However, cracking was observed on the object and raises the questions on the long term costs for maintenance in a life cycle cost perspective and how the requirements should have been designed to avoid cracking.
- The bonus-malus system has influenced the measures and actions taken by the contractor. The corresponding payments and the needs of the requirements were well defined, measured and transparent, thus avoiding any suspicions of fraud.
- Great demands are on the measurement methods used for verification of requirements. Objectivity and acceptable precision are two important parameters to reach levels of reliability that can be accepted by both clients and contractors for settling payments and penalties. Uncertainties associated with large costs and penalties leads to extra costs for control and risk premium. These risks can be reduced by proper design of requirements. Problematic examples are exact location of measurements and requirements related to crossfall and cracking.
- The contractor needs as much information as possible to assess and mitigate risks, which is in contrast to the costs for the client and the observation that more detailed information given by the client seems to open for errors in information. Errors that can be used as an excuse by the contractor to avoid penalties. Examples are location and quality of bedrock and the location of agricultural drains. Means of clearly dividing risks, responsibilities and associated costs between contractor and client should be developed in these cases.
- Shifting the contractual interface from technical specifications to performance specifications emphasize the importance of clear and transparent optimisation of needs and costs related to levels of performance. It is important to develop means for designing requirements and incentives with a system perspective where societal costs and benefits, road manager costs and contractor risks, costs and alternative actions can be analysed.

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