TRUST, CONTROL AND KNOWLEDGE INTEGRATION IN A ROCK TUNNEL PROJECT

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Rock tunnel projects that experience geological uncertainties tend to be both lengthier and more costly than planned. Traditional contract arrangements have proved to be less suitable when uncertainty is high; problem-solving being further hampered by contract-related distrust, communication failures and disputes. To efficiently respond to uncertainty and control risks of time and cost overruns, the knowledge of specialists in different firms needs to be mobilized. Findings from a case study of a railway tunnel project in Sweden aim to describe knowledge integration, communication and decision making related to geological conditions, comprising both formal and informal aspects. Findings show that formal and informal aspects are often complementary, also when they are contradictory, but that knowledge integration may suffer from a more formalized communication. Further, it is also important to consider relationships within the main actors' organizations as well as relationships and structures extending beyond the individual project.

Keywords: communication, control, knowledge management, relational contracting

INTRODUCTION

Urbanization increases the demand for land in central city locations and many public and private interests are competing for urban space. Underground facilities for transportation, then, are more expensive but cause less harm to other city functions. New interregional rail transportation to shorten commuter time and reduce climate impact also contributes to a likely increase in future underground construction.

Past experiences show that underground projects tend to encounter problems in terms of contracting and cost control. Risk is often considerable since geological conditions are never fully known until actual construction starts. A worldwide survey showed that at least 30% and probably more than 50% of underground projects experienced significant cost and schedule overruns (Reilly and Brown 2004). In a study of major European infrastructure projects by Hertogh *et al.* (2008), it was mainly tunnelling projects encountering unforeseen geological conditions and projects depending on the

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development of new technology that experienced cost increases and delays during the construction phase.

In Sweden, many underground projects involve rock construction. In the past, several Swedish rock tunnel projects have experienced high cost overruns and expensive litigation, partly associated with tighter environmental restrictions regarding leakage. At the backdrop of a particularly large lawsuit in the Southern Link project in the Stockholm area, a general industry initiative "Renewal in the Civil Engineering Industry" to improve relationships in the civil works sector was started in 2003. One subprogram specifically focused on relationships in rock construction.

Following from the dissatisfaction in the Swedish rock construction sector with current ways of managing and contracting for rock tunnel projects, a research project has been started with the aim of studying decision-making and communication in rock construction more in depth. This paper reports the findings of a pilot study of a rock tunnel project, aiming at identifying focus and issues for further research. The main question is: In the light of the past experiences of highly conflict-ridden projects, how do formal and informal aspects of control interact in shaping decision-making and knowledge integration regarding rock construction?

Contracting for rock construction

Specific contracting models have been developed and are regularly used to handle variations in geological conditions (ITA 1996; van Staveren 2006). These are based on classification of rock (or soil) categories, each associated with a technical design and a price list. As construction proceeds, rock quality is regularly assessed and the appropriate design, for example the level of grouting for reinforcement and sealing, is chosen. To make necessary adjustments and negotiate monetary compensations, continuous communication between the client organization and the contractor organization is required, thus, specialist technical functions are regularly involved in decisions affecting contracts and project costs.

However, assessments of rock quality are not unambiguous and actual construction costs do not always correspond to the prices of quantities defined in the contract. Reinforcement and sealing at the tunnel front is especially problematic and costly. This is because tunnel excavation progresses in one direction only and is dependent on heavy and expensive equipment, which means that standstills quickly lead to high cost increases. Further, the temporary reinforcement needed during tunnel construction is the responsibility of the contractor, while the permanent design - under a traditional contracting scheme - is the client's responsibility (ITA 1996). All these aspects contribute to disagreements and disputes when geological conditions depart much from what is predicted (van Staveren 2006).

Research on inter-organizational relationships in the construction area, both generally and specifically in tunnel construction, has most often been related to the relationship between the client and main contractor (Reilly 2000; Kadefors 2004). However, the client is not represented by one person or even by a homogenous group of client employees. Instead, the client project management organization in Swedish infrastructure project often consists to an important part of consultants. On the contractor side, several companies are generally engaged as subcontractors to a main contractor. Engineering consultancy firms contracted to make designs also use sub-consultants when needed. Hence, a great number of specialized organizations are involved in decision-making.

Formal and informal relationships

The relationship between formal and informal aspects of an organization has gained much attention in research on inter-organizational relations. Trust research has shown that the relationship between trust, collaboration and contracts is ambiguous and potentially contradictory (Biljsma-Frankema and Costa 2005). As noted by Argyres *et al.* (2006), the tendency in management research has been to view detailed formal contracts as unnecessary or even harmful to trust and collaboration (Macaulay 1963). More recently, however, researchers have increasingly considered effects related to sensemaking and learning (Vlaar *et al.* 2006; Poppo and Zenger 2002). Ring and Van de Ven (1994) describe the development of collaborative relations as a cycle, where informal trust building and formal commitments are two dimensions that interact to reinforce the relationship over time. Thus, relational and contractual governance in combination, not only separately, affect the relationship between a client and a supplier (Vandaele *et al.* 2007).

These aspects may interact in different ways; the informal and the formal organization may supplement and reinforce each other, or the two systems may be only partly aligned and emphasize different aspects. As argued by Gulati and Puranam (2009), the informal organization is the more persistent of the two, and the formal organization often focuses on behaviours that are not adequately supported by the informal organization. Thus, Gulati and Puranam (2009) suggest that by having formal and informal organizations that push in different directions, organizations may pursue desirable but organizationally incompatible goals (such as simultaneous exploration and exploitation). However, the system for producing informal understandings is less obvious, and is based on relational interaction that may take place in formalized meetings as well as on purely informal occasions. This implies that the informal system is also harder to control, so that important underlying cultural elements may be unintentionally lost over time.

In a study of Swedish rock construction, Styhre (2009) stresses that managing knowledge is about managing social relations and that everyday practices in the specific context therefore need to be considered. He emphasizes the role of oral and informal communication for knowledge sharing in the production phase, and claims that such communication is often expected to occur spontaneously, without explicit managerial initiatives. In effect, it is often dependent of the existence of physical shared arenas where actors can meet. Styhre expresses similar concerns as Gulati and Puranam (2009) that relying too much on informal channels may be both inefficient and risky. Thus, informal relationships are important and often needed to complement formal relationships, but also risk being under-managed.

METHODOLOGY AND DATA COLLECTION

The qualitative case study approach was chosen to get an in-depth understanding (Yin 2008) of the communication channels that might not be revealed by studying contracts and formal documents alone. Data was collected through five site visits over one year's time including eight semi-structured interviews. Interviewees were two project managers, two rock construction managers, an engineering geologist, an environmental coordinator and an assistant contract engineer in the client and contractors' organizations. Additionally, one client rock construction manager was observed during three of these days, including attendance at two different construction site meetings. Two interviews with engineering consultants were also performed at the premises of their firm.

The initial, client, interviews were not recorded to keep discussions more relaxed and informal. These were summarized, and if anything was unclear the file was sent to the interviewee who had the opportunity to correct and elaborate if needed. The later interviews with contractors and engineering consultants were recorded and summarized into text documents. All collected data were analysed to detect communication patterns and decision routes, as presented below.

THE PROJECT ORGANIZATION

The case study concerns a rural project including a two kilometres rock tunnel within a larger infrastructure development program. The tunnel, excavated with the drill and blast technique, was considered to be relatively uncomplicated by the client organization, although there were minor so called GK3-areas of more difficult rock conditions. It was a traditional contract, meaning that design was specified in detail and the client retained design responsibility through employing an engineering consultancy firm. However, there existed a partnering-like add-on called Increased Cooperation (IC) to the contract between the client and main contractor. What could be considered special within the project was that there were around-the-clock excavations with a client rock construction manager on duty, due to a tight deadline.

Client organization

Of the seventeen members in the on-site client project management team, only the project manager was an employee of the client organization. The other members were a mix of consultants from several consultancy firms. In addition, some in-house client support functions were active in several projects and not located on-site. These included PR and technical managers, such as a rock specialist.

Among the consultants, the three rock construction managers had the most central role for tunnel progress, making necessary everyday decisions and performing inspections to see that construction corresponded to specifications. Often the decisions were made in collaboration with, or based on information from, an engineering geologist who was responsible for inspecting the rock's characteristics and ordering the permanent reinforcements. The ground/bridge manager handled all contact with the engineering consultant firm, including tunnel related issues.

Several of the consultants in the on-site organization had been involved in one or two other tunnel projects in the overall program prior to this project and knew each other quite well. Among these were the assistant site manager, two of the rock construction managers and the engineering geologist.

Engineering consultant organization

When creating the designs more than 40 people, including sub-consultants, were usually engaged simultaneously in the engineering consultant's team. In the construction phase the engineering consultant provided construction support and the official organisation was reduced to a handful of people. A construction support manager, who previously had had another role in the project, was appointed to act as the engineering consultants' contact towards the client.

Contractor organizations

The main contractor was active in three road and rail projects within the program, making this rock tunnel project only part of their everyday concern. In this project the main contractor was responsible for informing the client on construction progress and handled all the formal contacts, but did not perform any actual tunnel excavation

activities. Instead, a tunnel subcontractor was engaged to execute the drill and blast procedure, in turn employing two second-tier subcontractors to perform mechanical tunnel cleaning after blasting and to remove loose rock and gravel.

At the time of the contractor interviews, the personnel in the main contractor site organization had worked together within the program for three or four years. However, this was the first time that the main contractor worked with this specific client team. As for the subcontractor, who entered the project later, this project was the first time to work with both the main contractor and the client organization teams.

Within the subcontractor organization, all roles obviously were related to the tunnel works. The project manager and the assistant project manager handled administrative tasks such as cost estimates. The site manager directed the works supervisors, with work environment and budget responsibility. Works supervisors were responsible for the performance at the tunnel front.

COMMUNICATION CHANNELS

Even though most decisions, including tunnel related ones, were formalized there existed both formal and informal settings were the project activities were discussed.

Formal communication

For formal communication, a document procedure was implemented in the preceding rock tunnel railway project in the program. It was introduced by the client's assistant site manager, who had come across it in a previous project. This specific document format had then spread to all other projects in the program.

The system organized the communication, so that if for example a subcontractor encountered a problem or wanted to make a suggestion they filled in a form that was sent to the client via the main contractor. The assistant site manager in the client organisation investigated the issue, consulting relevant expertise in the client organization, and formulated a response. If needed, the ground/bridge manager communicated issues to the engineering consultant's support manager via weekly meetings, emails or telephone. Responses were then sent back to the contractors the same way. Many tunnel-related issues had a technical character, such as requests for using another specific component than that stated in the documentation. The client's response could be requests for justifications that, in turn, were answered and finally approved or not. This meant that the procedure could be repeated in several iterations until an issue was resolved.

There were also a number of formal meetings connected to the system. All actors had their own weekly internal production-related meetings to discuss project progress as well as the upcoming week's goals. Issues were usually brought up then, prior to putting them into text. The contractor additionally had subcontractor meetings where tunnel excavations were discussed together with other subcontractor issues. These meetings usually took place before a weekly, joint client and contractor meeting at the client's site office. The tunnel subcontractor was in fact allowed to participate during the first part of these client-contractor meetings since that part concerned the tunnel progress. Main and subcontractor participants were usually six to seven members of top or middle management. From the client organization most of the personnel participated. More overall issues such as budget changes were dealt with in other monthly meetings between the client's and main contractors' top management.

Another rock-related dialogue that affected the production was of a more irregular character. When the excavation reached a more complicated area, according to predefined specifications, an external so called GK3 expert was called upon. This specialist, who had also reviewed the designs, would confirm or reject the temporary and permanent reinforcement solutions proposed by the onsite personnel. Either the expert would visit the site personally or the rock construction manager and the engineering geologist would call and brief the expert after inspecting the tunnel, who then gave a final decision. The GK3 expert was employed by the same consultancy firm as one of the rock construction managers and the engineering geologist.

The client was satisfied with the main contractor as a single contact point for all issues regarding contractor issues. Similarly, the consultant's construction support appreciated not having any direct contact with the contractors, since the consultancy firm did not have the mandate to make decisions on the client's behalf. The rock subcontractor, on the other hand, would have preferred to have more opportunities for a direct, formal dialogue with the client. It was mentioned that it could be difficult to gain approval on certain suggestions, especially when there was no obvious gain in the client budget, and even if the reason for a rejection probably was acceptable it was seldom explained.

The subcontractor's project manager also missed the possibility to communicate directly with the engineering consultant; he would have found this reassuring and also time-saving, since the consultant then could start to investigate the question before it formally arrived. Neither did the rock construction managers have any direct contact with the engineering consultant. They considered this to be the ground/bridge manager's job, but still commented during the interviews upon aspects in the design documents that they were not satisfied with. Some issues, they said, had not been changed although they had been pointed out during design document reviews.

A client rock construction manager stated that without documentation, referring to the formal document procedure, it would be difficult to know what had already been decided by the client organization, since the rock construction managers worked shifts around the clock. Also at the subcontractor the time issue was mentioned: since construction employees worked in shifts while the administrative staff did not, there could be difficulties informing everyone of updates in the weekly meetings.

Informal communication

Although the formal communication route generally was followed, there was also communication at the tunnel front, primarily between the subcontractor’s works supervisors and the client’s rock construction manager and engineering geologist. The communicated decisions were formally the rock construction managers’ but informally often made jointly with the engineering geologist. Informal decisions or agreements at the tunnel front were often formalised ex-post in the formal procedure.

In these discussions, it was important for the rock construction managers not to interfere with contractors responsibilities. When an experienced rock construction manager saw that the contractor was doing something that he thought could be done better, he was careful to formulate his opinion as advice: “In that situation I would have used Z to accomplish Q”. This way the rock construction manager could share knowledge without issuing orders and thereby assume responsibility for worker safety that justly belonged to the contractors. If formulating it as an order, an invoice for a change order would probably appear as well.

To reduce meeting time and not overwhelm the other disciplines, there also existed informal tunnel related meetings between the client, the main contractor and the subcontractor. Usually, the purpose was to go into depth of something specific in production, possibly before bringing it up on the weekly meeting, but the meetings could also be used to simply check that all parties were on the same page.

Relations and collaboration

The project manager did not have any former experience of rock works or tunnels and relied on the rock construction managers' expertise, trusting their opinions and decisions. All client interviewees claimed that the working climate was very open within the client organization. Client-contractor relations were also good, and one rock construction manager said that "you should be able to have a big disagreement and then take a coffee break together", implying that this was the case in the project. The contractor and subcontractor as well agreed that there was a good climate in the project. That client and contractors' site offices were located within walking distance from each other was considered helpful to the positive atmosphere.

The contractors were located in the same building and had daily interactions. There was a trust in each other's expertise and neither party interfered in the other's responsibility. The organizations supplemented each other in some ways, i.e. since the main contractor had an experienced environmental coordinator the subcontractor could employ a less experienced one. It was suggested that this could be taken one step further, e.g. by giving the client's environmental coordinator mandate to make decisions in all three organizations instead of each actor having their own specialist.

Several of the client's consultants, as well as the subcontractor's project manager, mentioned that the rock works industry is small in Sweden. Most of them had come across each other over the years in other projects and then often in other roles, both in client and contractor organizations. Lessons were also learned from own former projects or from projects that had become public knowledge. The conflict-ridden Southern Link project, mentioned initially in this paper, was brought up spontaneously by several interviewees as an example of practices and relationships they wished to avoid.

As a consequence of the IC element, the client and contractor employees participated in workshops twice a year to discuss collaboration. Opinions on these exercises differed, the main contractor interviewee and the client's project manager were positive, even though some possible improvements were mentioned. The subcontractor's project manager participated in the workshops but did not feel involved in IC apart from this. Some client members saw the workshops as somewhat unnecessary and had given them a slightly condescending nickname, "hugs-and-kisses-meetings". The engineering consultant was not involved in IC at all.

DISCUSSION AND CONCLUSIONS

Clearly, formal communication in writing, formal meetings and informal, everyday communication were of central importance in the project. There is a tradition in construction that client representatives communicate decisions in oral discussions on site, but formal systems are increasingly used to regulate such communication and reduce the risk of confusing informal communication and change orders (Kadefors 2005). The formal system in this project was relatively new to the participants and generally well received. It was not perceived as a control mechanism or sign of distrust. Rather, the parties welcomed the reduced ambiguity and documentation of

decisions, which was useful also for internal communication purposes (Vlaar *et al.* 2006). In many cases, the formal system was complemented by informal communication fora, and then functioned to confirm decisions already discussed in face-to-face interactions in explicitly informal technical meetings or at the tunnel front (cf. Ring and Van de Ven 1994; Styhre 2009). Table 1 shows identified interactions between actors, which was most extensive both formally and informally between individuals on site.

Table 3 Actors formal (top of cells) and informal (bottom of cells) means for communicating or controlling tunnel related issues. The top row indicates what actor that uses what means to interact with the actors listed in the left-hand column.

	Client	Main contractor	Subcontractor	Engineering consultant
Client	GK3 expert	Joint meetings	-	Document-ation
	Documentation	Documentation		
	Internal meetings			Meetings
				e-mail
	Everyday interaction	Informal meetings	Informal meetings	Telephone contact
			Queries in tunnel	
Main contractor	Inspections	-	Sub-con meetings	-
	Documentation			
	Joint meetings			
	Informal meetings	-	Informal meetings	-
Sub-contractor	Joint meetings	Meetings	Internal meetings	-
		Documentation		
		Colocation		
	Informal meetings	Informal meetings	Everyday interaction	-
	Advice in tunnel			
Engineering consultant	Meetings	-	-	Internal experts
	Documentation			Email
	e-mail contact			
	Telephone contact	-	-	Everyday interaction

However, there were some trade-offs and drawbacks in the area of knowledge integration. One aspect was that information exchange at the tunnel front was hampered somewhat by the client's concerns to avoid additional costs and responsibilities. Another aspect concerned processing of suggestions and requests from subcontractors. The formal system followed the contractual hierarchy, and less centrally placed parties suffered from longer communication channels. In the rock area, expertise was found in the client organization (one central expert, the on-site rock managers and engineering geologist), the engineering design consultancy firm, the tunnel subcontractor firm and the GK3 expert. There were few opportunities to process suggestions from the tunnel subcontractor informally with knowledgeable expertise on a higher management level.

In line with the findings of Gulati and Puranam (2009), the formal system was introduced to come to terms with inadequacies of the informal system, which risked producing unclear responsibilities and disagreements about costs. However, the formal system also relied upon a complementary informal system, compensating for the lengthy formal processes, in which communication was restricted to writing and passed several functions which lacked rock construction expertise. Between some actors, semi-formal meetings were held, and communication was also enabled by co-location or physical meetings on-site (Styhre 2009). Subcontractors then could partly compensate for their formally peripheral position by their central position on site. The main contractor had a formally strong position, but informally it was weaker. The engineering consultant had a weak position formally as well as informally, which impacted negatively on opportunities to share knowledge within the project regarding rock-related issues. Interestingly, only the rock subcontractor saw this as a problem, but the lack of integration still indicates a potential relational weakness that may be a breeding ground for conflicts in the case of more important technical problems.

Another important issue concerned internal relationships within each major actor. Clearly, the client project manager showed a substantial level of trust towards the consultants acting as client representatives, especially those in the field of rock construction where she had little knowledge. The rock construction manager and the other client project management consultants together acted on behalf of the client in many decisions affecting cost and quality. Formal control mechanisms in these relationships existed primarily in the purely technical area: the independent GK3 expert checked construction in difficult rock areas, and the client's internal rock expert also checked technical solutions.

Further, it was clear that relational control could not be understood without considering also relationships beyond the individual project. It was stated by several interviewees that relationships developed in previous projects within the same program helped to create the friendly atmosphere and smooth communication in the organization, for example between the engineering geologist and the rock construction manager. Also client-contractor relations extended beyond the project, and that the subcontractor was new to the program probably contributed to their perceptions of being less involved. Further, the Swedish rock works industry is quite small. Information and knowledge is shared between individuals who acquire common frames of reference. Reputation regarding the competence and attitudes of individuals on both sides spread efficiently, functioning as informal behavioural control systems.

Thus, the opportunities of an ambidextrous strategy, formally emphasizing one set of values and behaviours while strongly relying on behaviours produced within a partly contradictory informal system (Gulati and Puranam 2009), is sustained by interaction taking place within long term relationships between individuals who meet in different projects and in different roles.

FUTURE RESEARCH

We conclude that to understand knowledge integration in rock construction it is necessary to examine formal and informal relationships in interaction. Since rock-related expertise is often less centrally placed in organizations, mechanisms enabling lateral communication bypassing the formal system are important, as well as norms and understandings produced in longer term relationships.

Further, the issue of internal client relationships is a neglected area: To what extent is knowledge sharing, for the purpose of reducing construction costs, environmental impacts or client management costs, supported by formal and informal systems? And when client functions are increasingly outsourced, how does the more long term informal control system develop in interaction with contract-based project governance systems?

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