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Comparing Procurement Methods in Road Construction Projects

Influence on Uncertainty, Interaction and Knowledge

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Abstract
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The construction sector is often considered to show a number of limitations regarding efficiency and effectiveness, conclusions normally drawn irrespective of project procurement method used, and despite the common assumption that differences among approaches exist regarding these aspects. The study investigates differences and similarities among procurement methods using a longitudinal multi-case study based on two comparatively large infrastructure projects: a traditional so-called *design-bid-build* project and an unconventional so-called *design-build-maintain* project. The empirical part of the investigation, which in addition to the two focal projects mentioned also includes a number of prior and subsequent projects, was conducted based on literature studies, interviews and observations. The complex organizational phenomenon associated with each case was studied partly by interpreting each focal project as a small temporary network comprising a client, a contractor and a consultant, and partly any connections from the focal project to other projects of the organizational context. The influence of the procurement method was investigated using a model comprising the three concepts of uncertainty, interaction and knowledge. The empirical findings suggest that significant differences exist between the two approaches investigated regarding all three concepts. In principle, the traditional procurement approach resulted in low degrees of uncertainty, interaction and knowledge, while the unconventional project resulted in higher degrees. Although differences regarding the procurement methods can be observed by directly comparing the two focal projects, the influence of procurement method on uncertainty, interaction and knowledge gained becomes even more interesting if the time-frame is extended beyond the immediate projects studied. In particular, the comparison of the two cases presented indicates differences regarding the establishment of inter-project connections. The theoretical framework utilized in the study contributes to previous research by providing a way to characterize procurement methods, differences among them, and how knowledge is gained in relation to interaction and uncertainty.

Keywords: Procurement methods, uncertainty, interaction, knowledge, construction, network, project

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Stockholm 2013-04-15

Robert Lundström

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LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

During the last couple of decades, the construction sector has received a lot of media attention and a number of international reports have been produced where the performance of the sector has been called into question (e.g. Latham, 1994; Egan, 1998). In the early 2000s, the Swedish government also decided to appoint a commission to review the Swedish construction sector regarding competition, production costs and product quality, partly in response to the results presented in the above-mentioned reports but also to domestic criticism, from, among others, the Swedish Competition Authority. The findings presented (cf. SOU, 2002) indicated similar problems as those emphasized in the other reports mentioned, which led to calls for changes in the way construction products are delivered. Although not conceived as the sole panacea for the challenges of the industry (cf. Bresnen, 1991; Scarbrough et al, 2004a), the initiatives proposed influenced a number of large domestic clients, such as the Swedish transport administration (STA), to reconsider their current procurement strategy in favour of more so-called unconventional procurement methods.

1.1 CONSTRUCTION PROJECT BUSINESS

The construction industry, and certainly the part devoted to the establishment of physical infrastructure e.g. roads, tunnels and bridges, has often in the literature been characterized by complex large-scale undertakings organized as projects, procured on a one-off basis by professional public clients in accordance with prevailing institutions emphasizing both product standardization and extensive use of subcontracting where the production is to a large extent achieved by craftsmanship (e.g. Hughes, 1989; Bresnen and Haslam, 1991; Shirazi et al, 1996; Gann, 2000; Pryke, 2004; Scarbrough et al, 2004a, b). The characteristics indicated show several important consequences for business and have resulted in the construction industry typically engaging in organizational systems located somewhere between traditional market and hierarchy models. In principle, the industry is characterized by construction works being procured based on a market model, while subsequently managed within a hierarchical but temporary project context, which depends on

the buying procedure and contract type used (Eccles, 1981b; Söderberg, 2005; Winch, 2002).

1.1.1 CONSTRUCTION PROJECT PROCUREMENT METHODS

The uniqueness and complexity inherent in projects of some size result in a number of important consequences for business within the construction sector. For example, since a client seldom possesses the resources or the economic motives to develop own resources to eliminate all uncertainties associated with a constructed facility and its transaction, it is seldom possible to obtain it from the market in a way that financial and technical confidence for the final product is complete (Reve and Levitt, 1984). Due to these uncertainties, it is generally held that procurement, i.e. the often time-consuming and project-specific transaction process and agreements regulating relations among the actors involved, is one of the most important aspects of construction project performance whether it concerns economic efficiency, technical quality or degree of expected innovativeness (McDermott, 1999). The subject of procurement methodology is also one of the more explored within construction management. However, the term procurement method[1] is often used to indicate almost everything from the way a client chooses to promote market competition and distribute responsibilities to compensation for the work carried out. Given the wide topic and scope of the current study, the term procurement method is utilized here to refer to the way the client invites actors, e.g. contractors and or/consultants, to work in a given construction project from inception to finalization. Such a procurement method may utilize different contract conditions, payment models, and agreements regarding cooperation as well as types of technical requirements. It is often convenient to characterize the array of conceivable procurement methods according to the essential features

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[1] The terms procurement method, delivery system and contract type often are used more or less interchangeably despite the fact that they may have different meanings. For instance, the STA distinguishes between the terms procurement method ("upphandlingsform"), contract type ("entreprenadform"), compensation ("ersättningsform") and collaboration ("samverkansform") models, within their business models to ensure adequate competition, distribution of responsibilities, driving force and cooperation, respectively (STA, 2011).

of the product and its transaction. For the sake of the current study, the discussion is primarily restricted to two types of procurement methods: the traditional one and unconventional ones.

The traditional procurement method

For most of the twentieth century, by far the most prevalent procurement method in the construction industry has been the traditional or so-called *design-bid-build* (D-B-B) approach (Grennberg, 1998; Taylor, et al 1999; Pietroforte and Miller, 2002). In short, this method is characterized by the client being responsible for functionality, or performance, and detailed design, produced either by in-house staff or by external consultants, while an awarded contractor is responsible for realizing the project based on the documentation provided by the client. In most cases, the works are contracted on fixed price despite the possibility of utilizing variable or different incentives. The design obtained from the client is normally manifested by detailed drawings and descriptions referring to publicly available material and production methods (so-called *procedural specifications*). When the essential construction works finally end, the client resumes responsibility for the facility including any future maintenance and operations works, which nowadays for Swedish road infrastructure are procured by the STA in separate contracts.

The traditional approach is often preferred by clients, not only due to the fact that it has been commonly applied and is consequently well-known, but also since it is ideologically supported by procurement- and competition-related legislation. An important characteristic of procedural specifications is that both interpretation of tendering documents and evaluation of bids become relatively simple since the principal difference between competing bids is price. Another competition-related aspect is that the method is perceived to enable relatively small contractors, without substantial administrative capacity, to participate in bidding. Hence, the traditional approach fosters competition that is essentially based on minimizing the cost of performing the construction activities. An additional pro of the approach is that the detailed work description not only allows the scope of a given project and associated uncertainties to be easily communicated and minimized, respectively: the requirements are also comparatively easy to verify during inspec-

tions (Winch, 2002). However, although the traditional approach shows many pros, a number of cons have also been mentioned. Among the cons emphasized, several are related to the practice of procuring contractors in a market-context and subsequently managing the relationship in a bilateral monopoly, which means that any change in specifications, once the contract has been signed, opens the door to opportunism (cf. Eccles, 1981a; Williamson, 1985; Winch, 1989). Consequently, the traditional procurement approach may not only affect the degree of uncertainty but also the way the actors behave towards each other as a consequence of this uncertainty. Another important limitation of the D-B-B approach is its emphasis on certain materials and production techniques, rather than the way the final product actually performs. Since the client assumes the principal liability for the functionality by sanctioning the technical standards and descriptions[2] referred to in the tendering documentation, few incentives to any process and product development as well as management of such knowledge persist for other actors. Consequently, while the traditional procurement approach adheres to the short-term perspective, it is often accused of ignoring innovation as a means of competition due to the resulting formal, non-relational and fragmented construction process where the responsibility and efficiency of individually important phases such as design, construction and maintenance are distributed among different actors.

Unconventional procurement methods

The traditional D-B-B approach indicated above can be contrasted with later, more or less common, procurement approaches developed during the course of the twentieth century, methods that have been sporadically utilized by many public clients such as the STA. The rationale of employing unconventional methods has largely been motivated by these counteracting the negative effects of the traditional approach previously described. Unconventional procurement approaches are primarily characterized by a so-called single point responsibility being offered for a comparatively broad range of project phases and activities, e.g. both

[2] *Hereafter simply referred to as technical standards even though principle differences exist.*

design and construction (so-called *design-build*, or D-B, projects) and in some cases also maintenance work (so-called *design-build-maintain*, D-B-M, projects). Figure 1.1 illustrates the main differences between the traditional D-B-B and the unconventional D-B and D-B-M approaches regarding activities contracted. As indicated in the figure, the D-B-B approach means that a contractor is only responsible for the actual construction works, while the D-B and D-B-M approaches also imply a responsibility for design and design and maintenance, respectively. As in the case of the traditional approach, the contractor normally contracted in an unconventional approach may contract consultants for significant parts of the works including design. Each procurement method indicated typically includes a warranty period. In the case of the traditional approach, this warranty period often corresponds to five years for work carried out. In the case of the unconventional approaches, the warranty period varies considerably since it constitutes an inherent characteristic of the approach.

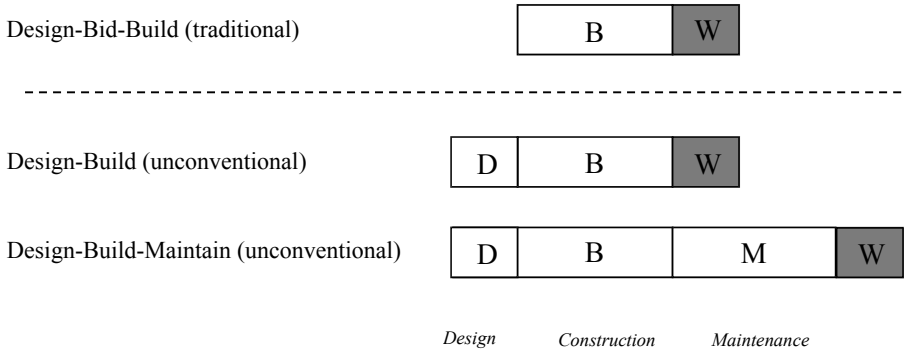

Figure 1.1 Three procurement methods and the activities contracted to a main contractor. Shaded area denoted with letter W indicates warranty period.

Apart from activities covered by the contract, unconventional procurement may also include responsibility for financial arrangements as well. The term DBFO (design-build-finance-operate) exemplifies an even more far-reaching arrangement than the approaches mentioned above,

since it denotes construction projects not only designed, built and operated according to one and the same main contract, but also that some kind of financing scheme is incorporated as well[3].

As indicated in Figure 1.1, contract length and number of activities contracted may represent two main features of procurement methods. In essence, the broader the scope of activities included in a given contract, the higher the degree of integration of technical and financial aspects. Furthermore, the longer the contract, the larger part of the total life-cycle costs may be subjected to competition. A main idea behind such a bundling, or combined delivery, of activities within one and the same contract is to decrease project fragmentation and facilitate knowledge transfer between subsequently following activities within one and the same organization rather among activities distributed among several different organizations (e.g. Lind and Borg, 2010). Consequently, knowledge may play a considerably different role in unconventional approaches than the traditional approach as responsibility shifts from the client towards the actor contracted.

Although the unconventional approaches mentioned are often highlighted as examples of organizational innovations and improvements over the D-B-B approach, they have still been accused of displaying some general limitations. An important limitation often referred to is that unconventional methods still do not necessarily specify any functionality of the product in apparently objective and quantitative terms. Hence, the ultimate performance may still be evaluated at inspections close to the end of production solely based on standards, established drawings and detailed descriptions. However, in contrast to the *procedural specifications* associated with the traditional approach, the unconventional approaches previously mentioned can be based on so-called *performance specifications* where the technical quality of a given project is contractually evaluated based on more objectively measurable end-

[3] Historically, public infrastructure projects in Sweden have been financed through public budgets, while alternative financing is considered to constitute alternative means such as loans, designated governmental loan warranties or off-budget financing in cooperation with private concessions: so-called public-private partnerships (PPP).

product specifications or, simply put, functionality. For example, instead of determining the type and amount of materials to be used within a given project based on technical standards, the technical quality may be explicitly characterized by physical parameters using automated testing procedures in the course of any given contract period. Figure 1.2 illustrates an example of a requirement hierarchy for road infrastructure projects where user requirements, i.e. the demands car users have on the infrastructure, and detailed procedural requirements via intermediate requirements associated with performance (indicated within the red box) are given. In principle, all five requirement categories indicated in Figure 1.2 could be used within a contract. However, as observed, the higher up in the hierarchy, the greater the freedom for the contractor to choose materials and production methods since the requirements successively become less specific, both with regard to number and any product used. For example, adequate road evenness, friction or noise (at level 2) could be achieved using several different techniques compared to if procedural specifications are defined for certain materials. However, while the freedom increases for the supplier higher up in the hierarchy (cf. Figure 1.2), it likely requires additional knowledge about materials, measurement technique and modelling of the performance based on the characteristics lower down in the hierarchy.

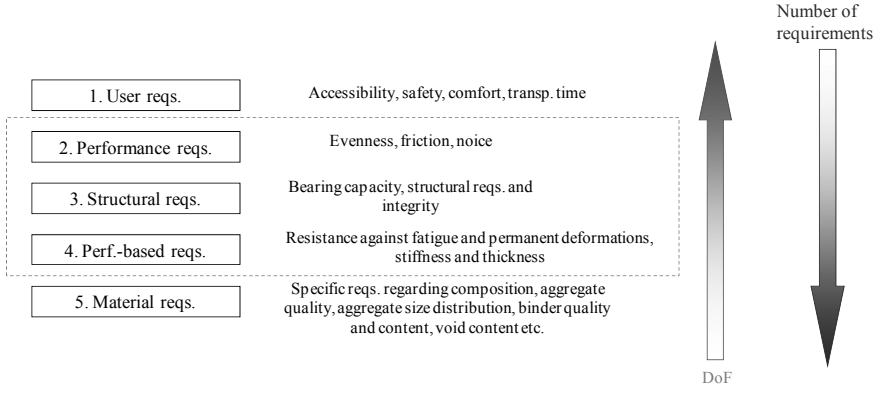

Figure 1.2 Type of specifications, hierarchical relation and effect on number of requirements and degrees of freedom (DoF) for the contractor (based on Korteweg, 2002).

In essence, performance specifications combined with extended responsibility provided by a D-B-M arrangement is intended to achieve improved flexibility during design, since the contractor responsible may use any technology found suitable, while at the same time minimizing the corresponding risks for the client since the increased contractor flexibility is compensated by making him responsible for any resulting default costs during the comparatively long contract period. In addition, the approach is also intended to provide possibilities to reduce production costs during the course of the project *ex post* by allowing design flexibility as construction work progresses on site. Compared to the traditional approach previously presented, the unconventional approaches mentioned are to a large extent based on a higher degree of integration between project phases with the purpose of improving efficiency as manifested by reduced time of project realization as well as ability to delegate responsibility for choosing materials and production methods to the actor who presumably is best suited for it. Any improved efficiency is believed to result from enhanced information flows, including feedback between design and construction activities, and risk management, e.g. by taking site-specific conditions and climate into account during production. In the long run, unconventional procurement methods are intended to provide incentives to technical innovations by allowing competition utilizing materials and production methods not necessarily yet standardized or even tested. However, as indicated by the last sentences, unconventional procurement methods may not only imply different degrees of uncertainty and requirements to manage knowledge for the actors involved, but also a different need of interacting with each other.

1.2 STUDIES DEVOTED TO PROCUREMENT METHODS

As indicated at the beginning of the chapter, procurement methods are often assumed to affect the performance of individual construction projects, and, thereby, be a potential means of reducing the problems sometimes associated with the entire industry. Accordingly, the subject of procurement methods and their effect on project and industry performance also represents a widely covered subject in contemporary management research.

1.2.1 *MAIN RESEARCH THEMES*

Of the extensive research associated with procurement methods, both case studies and statistical investigations have been devoted to unconventional approaches and whether they show any advantages over the traditional approach. In the case of the former type of research, several seemingly unprejudiced studies of Swedish road projects have been presented (e.g. Hansson, 1994; Grennberg and Grönvall, 1996; Olsson, 1993; Lövmar, 2000; Larsson and Sandberg, 2003, 2004; Grönvall and Grennberg, 2006). Of the conclusions drawn in these reports, a common theme is that unconventional procurement methods provide incentives to innovation (e.g. Grennberg, 1998). However, this conclusion appears mainly to be of anecdotal nature since any solid evidence of new improved products or processes is scant. Furthermore, although the studies indicated provide examples of how projects are managed in practice, any differences with other procurement approaches are only indirectly given.

Several investigations regarding efficiency of different procurement methods have also been framed from a more general project management perspective by studying project delivery time, cost and quality. Of the studies presented, some indicate that unconventional procurement methods show a number of positive effects compared to traditional projects, e.g. reduced project delivery time (Gransberg and Molenaar, 2008; Shrestha et al, 2012), fewer change orders and claims, as well as improved cost predictability (Warne, 2005) but also risk distribution among project participants (e.g. Songer and Molenaar, 1996; Grennberg, 1998; Gruneberg et al, 2007; Migliaccio et al, 2009). Unconventional approaches have also been referred to in discussions regarding risks of illegal price agreements since product heterogeneity is allowed as a basis of competition (Nilsson et al, 2005; Priemus, 2009). However, even though comparisons of different procurement approaches are important, few of them provide any deeper insights as to how important choices were made, e.g. how uncertainties and knowledge were perceived and managed, respectively, by the actors before decisions were taken and executed, aspects that are of relevance to judge whether significant differences actually exist between the approaches investigated.

In addition to management research, procurement methods have also been a frequently utilized context to motivate more technical research, both regarding production technique and technical quality. For example, many postgraduate studies financed by the industry are motivated by the need to increase knowledge about the performance of different techniques and how this performance should be evaluated and predicted by theoretical models. However, there are still few studies that compare different procurement methods regarding technical aspects, e.g. whether any of the approaches previously presented result in systematic quality differences compared to another approach. In a survey study presented for a U.S. authority, respondents suggested no overall difference between the traditional approach and the unconventional D-B projects investigated (USDOT, 2006). Among the few statistical studies devoted to comparing technical quality among different procurement methods, Rosner et al (2009) found that D-B projects performed better than D-B-B projects in terms of required modifications.

As indicated above, there are both case studies and statistical investigations suggesting that unconventional procurement methods may show advantages over the traditional approach. However, the relatively few conclusions drawn are sometimes moderated by taking into account the different actor perspectives. Fahmy and Jergeas (2004) presented a summary of the five main arguments promoted by contractors in favour of D-B arrangements: *single point responsibility*, *costs*, *product quality*, *price certainty* and *early completion*, as well as the, often opposite, opinion of the two other main actor categories, the client and consultant, regarding these five aspects. The latter publication indicates that pros and cons of a given procurement method is not only affected by the aspects studied per se but also by the actor perspective assumed, which suggests that procurement approaches may also have dynamic effects as the different actors try to position and adapt themselves to the situation. To the knowledge of the author of this study, no investigation has thoroughly compared whether different procurement methods result in different intra-project interaction.

As previously indicated, a particularly significant argument emphasized in the literature on procurement methods concerns whether unconven-

tional procurement approaches provide incentives to product and process development, and, thereby, improved effectiveness through competition by innovations (e.g. Bröchner et al, 1999; Dubois and Gadde, 2000; Styhre et al, 2004; Stenbeck, 2007). However, few studies have actually provided any solid evidence of innovations or efforts to develop knowledge or capabilities for such. On the contrary, there are studies devoted to unconventional procurement (e.g. Leiringer, 2003; Österberg, 2003; Borg, 2011) that have provided both theoretical arguments and empirical findings indicating that unconventional procurement may not provide any significant effects in the form of improved efficiency or explicit innovations. Österberg (2003) and Stenbeck (2007) provided results from Swedish road maintenance contracts indicating only limited technical development and innovations. Lind and Borg (2010) even questioned any positive effect of bundling construction and maintenance activities by referring to the limited ability to actually utilize innovations within the industry. Similar findings have also been presented for Swedish and international PPP-projects (cf. Leiringer, 2003; Juriado, 2008), and, thereby, indirectly arguments in favour of the traditional D-B-B approach. In addition to the debate within academia, the benefits of unconventional procurement methods have also been called into question by public authorities. For example, recently the Swedish national audit office (RR, 2012) expressed severe criticism against the STA concerning their intended use of the D-B approach based on the discrepancy between stated benefits and lack of evidence and evaluations. Consequently, despite the efforts made to analyze and compare different procurement approaches important knowledge gaps still exist.

1.3 RESEARCH PURPOSE

As indicated in previous sections, the Swedish construction sector devoted to civil engineering can be considered to be experiencing a transformation by the utilization of new project procurement methods in order to improve the industry regarding competition, production costs and product quality. Each of the different procurement methods discussed is associated with both pros and cons. However, although extensive research has been carried out over the years, there is still no definitive answer as to whether and in which case how certain procurement

methods actually differ regarding important aspects such as efficiency in the short term, e.g. number of competitors, character of bids and transaction costs, and long- term effectiveness, e.g. as characterized by number, rate and significance of innovations.

One reason for the lack of consistent results is the inherent complex task of investigating procurement methods given the multifaceted phenomena, the number of different actors involved and time-frame considered. Most empirical studies presented have been directed at one or a few projects during design, procurement and/or construction phases, while very few have analyzed circumstances occurring years after the product has entered service. The studies indicated often describe what occurs in the projects but seldom by reflecting what uncertainties, options and arguments the actors confront before any decision was taken. Such studies often provide only limited understanding regarding any pros or cons of a given procurement approach since support from theoretical concepts is often limited. Consequently, since any theoretical lens used to study a phenomenon directs the attention of the researcher, it is also important to develop and utilize theoretical approaches to adequately address and characterize which aspects are of most importance for the projects and the way they are procured.

Although many questions regarding procurement methods still need to be answered, the perhaps most urgent area seems to be related to the capturing of effects in the longer term. One potential reason for the difficulty of observing differences among procurement methods may be that attention within most studies presented seldom is devoted to emphasizing the influence of the temporary and spatial contextualization of construction projects (cf. Bresnen, 1991; DeFillippi, 2001; Sydow et al, 2004). Although studies question the potential of unconventional procurement methods, few attempts have actually been made to investigate sustained project procurement over longer periods of time. For example, innovations often occur outside a given construction project, which makes it difficult to trace if the study is limited to a certain project. Even though an innovation suddenly appeared in the project studied, the investigation does not necessarily provide any answer regarding the aspects of the procurement method that have contributed most to its ap-

pearance. For instance, was the type of technique utilized associated with any uncertainty and what measures were taken to affect it? This question is particularly evident in the case of causes and effects over longer times, e.g. beyond the immediate project undertakings at hand, and especially as norms and routines are successively institutionalized if the procurement approach has just been introduced in the industry. Hence, in order to compare procurement methods it is important to both understand actions within a given project, how the actors behave when they confront challenges, make decisions, and how they manage knowledge beyond the project depending on procurement approach. From an empirical standpoint, there is a general knowledge-gap regarding how organizations utilize intangible resources such as administrative and technical knowledge to develop capabilities useful for different actors in subsequent projects (Argote et al, 2003). In order to understand the evolution indicated, it may be necessary to examine the behaviour within the system by extending the analysis beyond the narrow focus of a given project and to link cumulative changes between successive projects since innovation and other forms of development may be associated with incremental changes and successive learning and knowledge management (cf. Berggren, 1993; Ekstedt et al, 1999; Sahlin-Andersson and Söderholm, 2002; Engwall, 2003). Although, the shortage of longitudinal case studies has been recognized as a major weakness, not only in construction management (Anheim, 2001; Tawiah and Russell, 2008), but also in more general research (e.g. Hawkins, 1994; Berggren, 1993; Brady and Davies, 2004; Eisenhardt and Martin, 2000), the need for such studies appears particularly relevant when comparing procurement methods due to the complex context. However, given the potentially high degree of complexity involved in such an endeavour, not only are important theoretical concepts guiding the investigation necessary, but also a clear picture of the organizational phenomenon. Consequently, both empirical and theoretical evidence and models are needed to further characterize procurement methods in order to provide answers regarding any pros and cons.

Based on the above discussion, this thesis is devoted to studying differences and similarities among procurement methods.

2 THEORETICAL FRAMEWORK

This chapter comprises the essential theoretical basis of the investigation and begins by introducing the perception of projects and a framework comprising three theoretical concepts: uncertainty, interaction and knowledge (Section 2.1). Section 2.2-2.4 elaborate on each concept mentioned by providing both a general theoretical background as well as aspects used to operationalize each concept in the rest of the study. In Section 2.5, the chapter is summarized.

2.1 MAIN THEORETICAL CONCEPTS EMPLOYED

In order to operationalize the purpose of the current study, i.e. study differences and similarities among procurement methods (cf. Section 1.3), two important theoretical approaches are relied on and presented below. The first approach of interest concerns the way the complex organizational phenomenon is characterized. As discussed in Chapter 1, procurement methods have been extensively investigated during several decades where the main actors of interest seem to be the client, contractor and consultant. However, most previous studies performed on procurement methods have seldom emphasized any hierarchy or market but have mainly been devoted to a limited part of a given, often single and isolated, project´s comparatively long life-length. Since prior history influencing the project and circumstances occurring after the essential product has entered service are almost never analyzed, these issues seem to be of particular interest to investigate from a project procurement perspective as new complex contractual arrangements may result in significantly different contexts for the project participants, compared to more common and established approaches, which may both result in uncertainty for the actors involved, trigger different behaviours, e.g. how the actors interact, as well as result in other forms of outcomes, e.g. knowledge. However, in order to perform such an investigation it may both require that the organizational phenomenon is described in sufficiently great detail and, at the same time, provide an overview that, due to the high complexity, only emphasizes the essential features of the phenomenon desired to study. In order to achieve this, the organizational phenomenon of the current study is based on a net-

work approach where the behaviour of the three actors of interest (client, contractor and consultant) is both characterized within a temporary project as well as related to other projects within the market constituting the different hierarchies. The approach used is described in more detail in Section 2.1.1.

Many topics may be of great interest when studying procurement methods as evident from the broad set of questions emphasized regarding competition, production costs and product quality (cf. Chapter 1). Product quality is probably an important technical aspect which in itself may motivate further research. Competition is another important aspect of procurement methods as well as a major question for the industry, which has historically received, but also deserves additional, attention. However, both questions are larger and more complex than only emphasizing *ex ante* and/or *ex post* results of individual projects or procurement methods at a given point in time. Instead, these questions are intimately associated with a third major research area of interest concerning the construction sector, namely the question of expected future innovation which successively improves productivity and effectiveness. Given the presumed differences among procurement methods, limited support of benefits from unconventional procurement in existing literature and lack of studies emphasizing the wider context, the most interesting aspect of procurement methods appears to be whether and to what extent any approach supports successive competition by use of knowledge. In this case, knowledge seems like a more fruitful concept than innovation, not only from the point of view that previous research has only found scant evidence thereof but also, since it is both widely covered in theory and may be considered as related to innovation. Another major concept of interest regarding procurement methods is uncertainty. Although, few studies have emphasized this concept from a construction procurement perspective, several circumstances indicate that uncertainty may be of importance; in particular, as it is an important feature of the particular industry as well as projects in general but also since the concept can be related to knowledge. A third important issue of relevance to procurement methods concerns the behaviour of the actors involved, what measures are taken, how they are motivated and decided. Such behaviour may be theoretically conceptual-

ized by the concept of interaction. As indicated above, the second theoretical approach relied on in the study concerns a model comprising the three interrelated concepts uncertainty, interaction and knowledge gained, which is utilized to investigate differences between two procurement methods. Although interaction arguably may implicitly cover the other two concepts (cf. Håkansson, 1982), the importance of uncertainty and knowledge gained is considered to motivate that they are conceptually separated from interaction. The three concepts mentioned stem from the empirical context, research purpose but also the network perspective chosen as discussed in the following sections.

2.1.1 PROJECTS AS TEMPORARY NETWORKS

The term *network* has for decades been employed in a variety of ways and purposes to characterize organizational phenomena, either as a mode between markets and hierarchies, a combination thereof, or as a distinct third way of governance (e.g. Cook and Emerson, 1984; Thorelli, 1986; Nohria and Eccles, 1992; Larson, 1992; Håkansson and Snehota, 1995; Archol and Kotler, 1999). From an empirical standpoint, interpretations of organizational phenomena as networks can be supported by the rapidly increasing number of publications within the area (Borgatti and Cross, 2003) and the seemingly increasing perception that prosperous industries apparently have sought ever more collaborative cooperation with suppliers and customers rather than traditional arm´s length relations or trying to integrate associated activities into existing hierarchies. Accordingly, the rise of networks as a rather distinguished organizational form can in some respects be compared to the anecdote when the hierarchy emerged during the industrial revolution; achieving efficiency of mass production by internalizing transaction costs and thereby replacing the existing small companies operating under conditions approximated by assumptions of ideal markets. However, in contrast to the transition from markets to hierarchies, the rise of networks can be rationalized by a need of adapting to the complexity and dynamics of modern business where knowledge has replaced traditional resources, particularly materials and labour, as the most essential resource. Although several different network approaches have been presented in the literature, a common denominator is the ambition to characterize or-

ganizational phenomena by referring to relational systems (e.g. Douma and Schreuder, 2008). In this case, all organizations, whether they refer to markets, hierarchies or any hybrid thereof can be interpreted as social networks[4] (e.g. Håkansson and Snehota, 1995).

Background

This section provides a brief theoretical description of projects as temporary networks, which is based on one specific network approach.

The industrial network approach (INA)

The so-called industrial network approach (INA) is a conceptual framework comprising a number of more or less interrelated models[5], formulated by researchers belonging to the so-called IMP-group[6], to characterize processes involving dynamic relationships among organizations in order to formulate normative management recommendations by descriptive richness (Ford et al, 2003). By expressing criticism against basic assumptions made in most rational approaches (e.g. Chamberlin, 1933; Scherer, 1980; Williamson, 1985) and their derivatives employed in strategy and marketing theory (e.g. Kotler and Levy, 1969; Porter, 1980; Barney, 1991), the INA belongs to a field of sociology presupposing industrial suppliers seldom encountering a large number of individually insignificant and passive customers only desiring occasional pur-

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[4] While approaches such as agency (Eisenhardt, 1989b), transaction cost (Williamson, 1985) and evolutionary theories (cf. Nelson and Winter, 1982) normally emphasize a comparatively narrow organizational range, network theory provides the possibility to characterize a broad range of actor levels including individuals, organizations, markets or cooperative constellations (Douma and Schreuder, 2008). Furthermore, in contrast to theoretical directions such as industrial organization (e.g. Bain, 1959, Scherer, 1980, Tirole, 1988), including its application to strategic management (e.g. Porter, 1980; 1985), Contingency (e.g. Thompson, 1967) and different institutional theories (e.g. Selznick, 1957; Powell and DiMaggio, 1991) that characterize the surroundings of organizations by abstract characteristics, a network perspective provides the possibility of more explicitly characterizing the environment of a given organization in terms of a set of nodes linked by relationships.

[5] For example, the Interaction approach (Håkansson, 1982) and the ARA-model (Håkansson and Snehota, 1995).

[6] IMP is an acronym for Industrial Marketing and Purchasing and has been used as a label for a European research programme originally initiated in the 1970s (cf. Håkansson, 1982).

chases of standardized products. Not only does the INA presuppose customers and suppliers to be active, business market participants are also assumed to show significant heterogeneity regarding both size and requirements where exchange normally involves complex and non-standardized products purchased on a cooperative, repetitive and long-term basis (Håkansson, 1982; Easton, 1992; Håkansson and Snehota, 1995).

Within the INA, networks of individual organizations are often characterized by referring to *actors* connected by *activities* and *resources* exchanged (Johanson and Mattsson, 1994; Anderson et al, 1994; Håkansson and Snehota, 1995). Although each structural concept of the so-called ARA-model (actors, resources and activities) indicated is conceptualized as comparatively distinct, and, hence, may attract smaller or larger portions of an empirical study, a basic assumption is that all three aspects are intrinsically interdependent since actors perform activities and control resources, while resources and activities are necessary to develop new resources. Hence, the INA goes beyond other institutional theories also emphasizing embeddedness[7] (e.g. Selznick, 1957; Williamson, 1985; North, 1990, DiMaggio and Powell, 1991) by more explicitly characterizing the organizational context by visualizing connections and interdependencies among actors. However, the open-ended character of such an endeavour may obviously result in certain ambiguities, of which the question of organizational boundary is one. In principle, industrial networks can be analyzed at four different organizational levels based on (1) single organizations, (2) the relationship, (3) the sub-network, comprising parts of, (4) the entire network depending on purpose of the study. The interest of actors beyond a given dyad is often rationalized by

[7] *Since Granovetter (1985) adapted the original term of Polanyi (1944), the concept of embeddedness, as the contextualization of economic activities in patterns of social relationships, it has enjoyed wide acceptance as a central organizing principle in economic sociology. By criticizing both the tendency of sociological institutional theory to characterize individuals as acting mainly based on inherent norms and values and the corresponding neoclassical assumptions for unrealistic idealizations, embeddedness implies that organizational studies should be performed using a balanced approach by broadly referring to the contingent nature of economic action where a broad contextual setting should be taken into account.*

the perception that a given relationship is contingent upon exchange in other relationships, e.g. the connection between two actors further upstream or downstream in a conceptualized value chain (cf. Thompson, 1967; Richardson, 1972; Pfeffer and Salancik, 1978; Porter, 1985) or horizontal competitors or non-business actors including media, trade unions and authorities (Håkansson and Snehota, 1995; Hadjikhani and Lee, 2006).

Projects as temporary organizations

Although a general and commonly accepted definition is difficult to produce, projects have historically been interpreted as *temporary organizations*, normally comprising *different hierarchical organizations*, *demarked in time* by distinct start and end dates, and *defined tasks* to be performed within *a given budget* (cf. Goodman and Goodman, 1976; Hadjikhani, 1992; Packendorff, 1995; Lundin and Söderholm, 1995). The definition implied stems from the common observation that projects in one way or another are unique regarding size, scope and/or number and type of actors involved. However, even though differences certainly exist, individual projects have historically been approached using similar tools and theoretical perceptions, which to a large extent have emphasized the internal and short-term perspective as expressed by time of project completion, costs and quality obtained. For example, project goals have generally been expressed in terms of time, cost and quality. However, many researchers (e.g. Hadjikhani, 1992; Kreiner, 1995; Packendorff, 1995; Sahlin-Andersson and Söderholm, 2002; Engwall, 2003; Sydow et al, 2004; Söderlund, 2004; Bresnen et al, 2005) have argued that the major limitation of the traditional project view is its neglect of contextual aspects such as inherent uncertainty and dynamics, as well as how different projects are interrelated, e.g. in the form of temporary networks, which renders characterization of important consequences such as interaction and learning problematic. In order to counteract such limitations, several attempts have been made within the INA to take the temporary character of projects into account using network analysis (e.g. Hadjikhani, 1996; Håkansson et al, 1999; Cova et al, 2002; Lind, 2006).

As in the case of the more general INA indicated in previous sections, projects can be considered as inter-organizational networks in a similar way as organizations. In general, projects can be interpreted as networks comprising (1) a set of relations, where no single actor represents a legitimate authority for the network as a whole, (2) where the network is open in the sense that there are no definite criteria by which the boundary of the network may be identified or controlled, and (3) where the network is temporarily limited, dynamically changing and (partially) reconstructed from one project to the next (cf. Hellgren and Stjernberg, 1995). According to Halinen and Törnroos (1998), individual projects can also be characterized as micronets embedded in larger network structures. A third way of analyzing project networks is exemplified by Håkansson et al (1999) who used the concept of connection to characterize learning in networks consisting of dyadic relationships. Also Cova et al (2002) characterized project networks by broadly referring to positions and ties among different actors. However, although projects can be characterized as networks in one way or another, exchange in project networks is typically, and in contrast to the continuous relationships implied in general INA-literature, characterized by periods of limited, or even negligible, exchange after which the seemingly sleeping relationship awakens and exchange once again is resumed (Hadjikhani, 1996). Consequently, projects are not necessarily one-off events but may involve interaction both within a given project and, via hierarchies constituting the immediate organizational context that results in, inter-organizational connections, which surpass the time required to realize the project in question (Bengtsson et al, 2001). In essence, characterization of interaction among actors in a project context is non-trivial and a number of different approaches are conceivable.

The perception applied during this study

As described in Chapter 1, procurement concerns how projects are conceptualized, bought by a client and delivered, which both affects the formal and informal organization of projects as well as effects. In order to characterize the organizational phenomena of the current study, a given focal project is considered as a temporary network comprising the three actors of main interest. However, the concept of project network is not only utilized to describe the temporary inter-organizational net-

work existing solely for the duration of the project (from a defined start to a defined end date), any resulting connections among different projects are also of interest. Figure 2.1 provides a conceptual illustration of a network comprising three inter-organizational projects. Each project represented comprises either two or three interacting actors, in this case a contractor, a client and a consultant, which at the same time are members of hierarchical organizations (as indicated by dashed lines). Actors, as represented by either individuals or departments, may thereby participate both simultaneously or sequentially in one or more projects. The arrows between the actors within each project represent intra-project interaction, while the bold lines between the projects indicate explicit connections resulting from dependency in the form of resources transferred from a project to the next (cf. Section 2.3.1). For a more detailed description of the approach used to characterize the organizational phenomena, the reader is referred to Section 2.3.2.

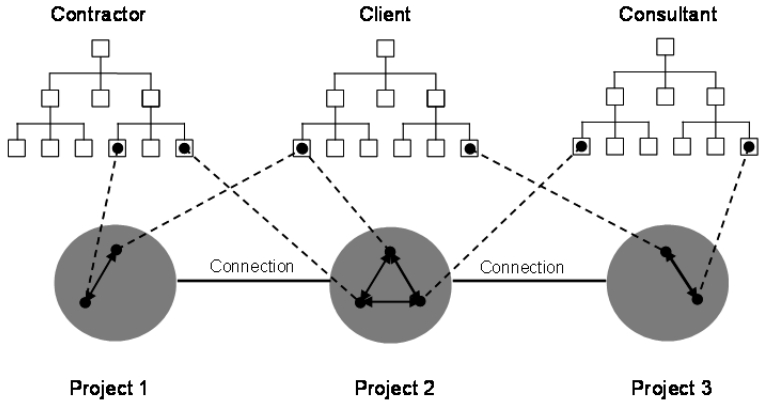

Figure 2.1 Illustration of market comprising three inter-organizational projects comprising actors of three hierarchical organizations (indicated by dashed lines). Arrows and bold lines among project participants and between projects indicate intra-project interaction and inter-project connections, respectively.

2.1.2 *THE THREE CONCEPTS AND BASIC RELATIONS*

As discussed in the beginning of this section, the empirical context, the purpose and the decision to utilize the network approach to investigate procurement methods suggest that the most interesting aspects to study may be obtained by the three theoretical concepts of uncertainty, interaction and knowledge gained. The current section provides a brief overview of the three concepts and their relation to procurement method and each other (cf. Figure 2.2), while each of them is described in more detailed in subsequent sections.

Uncertainty

Projects are generally interpreted as temporary organizations exhibiting significant uniqueness and complexity, either originating from within the project itself or from the immediate environment. An important negative consequence of these characteristics is uncertainty, the degree of which may be associated to procurement method utilized since the more unique and complex the procurement method, the more difficult it is to foresee consequences of decisions and actions. From the short description of the wide range of conceivable procurement methods (cf. Section 1.1), it is probably fair to say that the degree of uncertainty could vary considerably among them depending on type and amount of responsibility contracted and whether and to what extent the actors involved possess resources in the form of institutions, knowledge and capabilities to manage the situation. For example, an extensive undertaking based on a new type of contract may result in the actors involved being confronted by problems of interpreting what to do and how it should be done. Although uncertainty has been widely explored in management studies, only limited attention has been emphasized in construction project procurement literature. Consequently, uncertainty seems to be an important characteristic of both construction projects and procurement methods that can be used to distinguish projects for the purpose of an empirical study. However, as will be further discussed in subsequent sections, uncertainty may not only be considered a disadvantage in the form of potential need of additional interaction, partly due to efforts of reducing it, and, thereby, transaction costs, uncertainty can also be considered as intimately associated with knowledge, which

is obviously required for effective decision-making and actions. For example, a complex procurement approach may require additional meetings among the actors, which in turn result in clarifications, and, thereby, knowledge. In this case, uncertainty may constitute an important but implicit manifestation of driving forces for learning and knowledge such as common goals, reflection and dialogue, and motivation. For example, uncertainty may motivate actors to sit down together and negotiate goals. The potential linkage between the concept of uncertainty and the other two concepts of the study are indicated in Figure 2.2.

Interaction

The second concept used in this investigation is interaction, i.e. the mutual and reciprocal action occurring between human actors participating in business activities. In this study, this concept is treated as separated from the other concepts in order to both make a distinction among them but also since they not by default are consequences of each other. Not only are there few studies of how different actors perceive uncertainty resulting from certain procurement methods, even fewer have been devoted to comparing procurement methods regarding intra- and inter-project interaction including decisions, investments and organizational reconfigurations made to improve the likelihood of project success (e.g. Larsson and Sandberg, 2003; Stenbeck, 2007). In this case, interaction may, as in the case of uncertainty, either be a direct cause or consequence of, or indirectly related to, procurement method applied (cf. Figure 2.2). Interaction between a client and the industry may for example provide opportunities to discuss and improve a given procurement method. A given procurement method may provide different prerequisites and consequences for interaction, e.g. prescribe with whom to interact and classify type and number of meetings to be held. In the case of an indirect relationship, a given procurement method may provide a certain degree of uncertainty, which in turn results in interaction in the form of reflection and dialogue, and information search efforts towards other project participants or previous projects. A long range of researchers (cf. Section 2.4), argue that social interaction is necessary to eliminate or reduce uncertainty, since it provides access to both problems and possible solutions in the form of interpretations of experiences, inferences of casual relationships between action and outcomes.

Consequently, interaction is conceivable as an important intermediate link, emphasizing actions, links, connections among project participants, and, thereby, between the characteristics of uncertainty and any knowledge gained (cf. Figure 2.2).

Knowledge

The third, and last, concept investigated in this study concerns knowledge, the essential function of which is to rationalize consequences of different choice alternatives. Since interaction itself, at least to some extent, implies a learning process, the interest of the current study is directed towards knowledge as an actual outcome in the form of new knowledge gained by the actors involved, rather than focusing on a theoretically separated learning process. As in the case of the other two concepts indicated above, knowledge could, in principle, either be a direct consequence of the procurement method applied or indirectly related through the other two concepts. A procurement method already established in existing routines and technical descriptions may both imply and require different knowledge compared to an approach not as established in any corresponding institutions. Since projects are considered to show inherent characteristics negatively affecting the possibility for participating actors to learn and utilize knowledge from past and in current projects (Lindkvist and Söderlund, 2002; Cova et al, 2002; Scarbrough et al, 2004a), the type of procurement method may also affect the degree of interaction. However, at the same time, as knowledge gained by interaction may be inherently complex, it may in principle also be the contrary: knowledge gained within a project may result in subsequent interaction, which, in turn, may affect uncertainty and, ultimately, choice of procurement method. The execution of several projects utilizing a given procurement method may provide knowledge that this particular approach is inferior to another one, which provides reasons to modify or discontinue its use. This means that it is, at least in principle, conceivable that the project procurement method applied both affects the three characteristics mentioned and that each individual characteristic affects either one or both of the remaining concepts. Consequently, the concepts of uncertainty, interaction and knowledge gained can be considered as being more or less interrelated (cf. Figure 2.2), as well as overlapping, rather than a straightforward process,

where each concept may be individually demarked and affected by the procurement method utilized. In order to further discuss the three theoretical concepts identified, each of the following sections (Sections 2.2-2.4) comprises both a general part (2.2.1, 2.3.1 and 2.4.1), which represents a broader background of each area, and a more specific one (2.2.2, 2.3.2 and 2.4.2) emphasizing the aspects used in the empirical part of the current study.

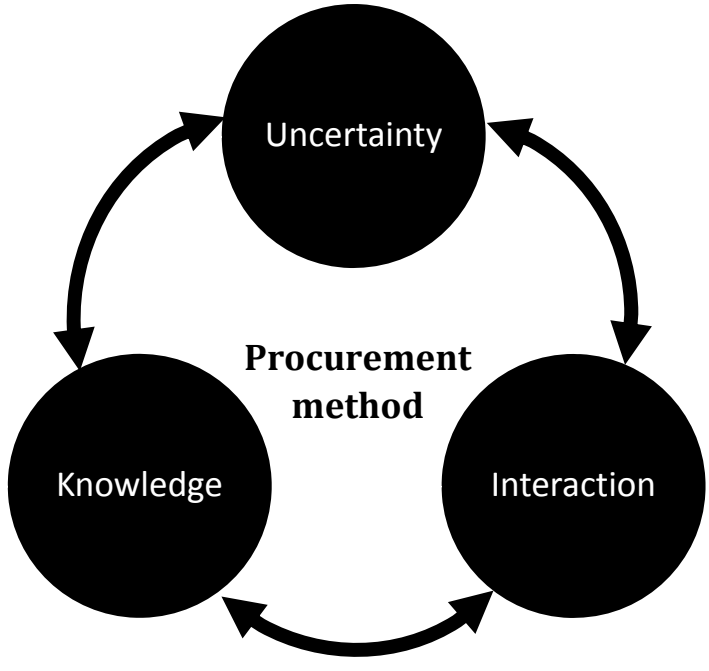

Figure 2.2 Illustration of theoretical concepts utilized to characterize project procurement method.

2.2 UNCERTAINTY AS RELATED TO PROCUREMENT

Uncertainty constitutes the first concept utilized in this study and the section is divided into two parts: 2.2.1, which provides a general overview and Section 2.2.2, which presents the more specific aspects used in the current study.

2.2.1 THE CONCEPT OF UNCERTAINTY

Uncertainty represents a main characteristic in both institutional economics and management theory (e.g. Knight, 1921; Hayek, 1945; Cyert and March, 1963; Akerlof, 1970; Williamson, 1985; Powell and DiMaggio, 1991) that has been discussed in conjunction with the construction industry and, in particular, regarding the execution of projects (e.g. Winch, 1989; 2002). In essence, this characteristic indicates that knowledge, in contrast to assumptions of perfect competitive markets in neoclassical microeconomics, is incomplete due to inherent uniqueness and complexity, which renders decision-making difficult.

Conceptualization of uncertainty

Uncertainty is a term often utilized, interchangeably with the similar term risk, to denote future situations where lack of knowledge may result in negative consequences. However, although the two terms mentioned share certain common meanings in practice, important theoretical distinctions may prevail. In particular, uncertainty generally refers to situations where decision-making takes place faced, not only with unknown outcomes *ex post* as in the case of risk, but also unknown *ex-ante* probability (cf. Knight, 1921). In other words, risk is a term often considered as something calculable while uncertainty implies no history providing empirical data to interpret any (statistical) probability of a negative or positive outcome. Hence, uncertainty can in some respects be interpreted as a logical precursor to risk. However, since uncertainty represents an important but often rather general situation, in order to utilize uncertainty as a concept in an empirical study, it needs further specification.

Uncertainty and bounded rationality

A major contribution to the perception of uncertainty in management research has been provided by Herbert Simon who suggested that human behaviour, in contrast to assumptions made in classical economics, should be viewed as bounded rational, i.e. limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make a decision (Simon, 1945). March and Simon (1958) later argued that organizational behaviour, particularly decision-making faced by uncertainty, is governed by rule-following rather than conscious calculation of consequences, a suggestion that has had a profound impact on many subsequent institutional theories. By solving problems in the short run by imposing plans, standard operating procedures and uncertainty-absorbing contracts, organizations try to avoid future constraints sequentially as they arrive by interpreting historical performance and adhering to prevailing routines (Cyert and March, 1963). Afterwards, the theory indicated has been further established by a series of theorists such as Kahneman and Tversky (1979) who, among others, explored systematic biases that separate beliefs of individuals from optimal behaviour of rational-choice models.

Application of uncertainty in management models

Uncertainty may take a number of forms depending on whether it concerns administrative (e.g. Simon, 1945), behavioural (e.g. Williamson, 1985) or technical aspects (e.g. Shenhar and Dvir, 1996). Håkansson et al (1976), for example, made a classification of the three categories of *need*, *market* and *transaction* uncertainty to characterize interaction between sellers and buyers. While need uncertainty, refers to difficulties in expressing and achieving business objectives such as quality versus price, the degree of complex internal and external communication structures and number of contacts, market uncertainty is considered to prevail in situations when significant differences exist among potential suppliers. High market uncertainty is characterized by there being comparatively large differences among potential suppliers and that buyers establish extensive contacts with those suppliers. The third category, transaction uncertainty, refers to problems of transferring a given product from the seller to the buyer due to restraints such as time and tech-

nology available. For example, the less standardized a given product and transaction process is, the greater the transaction uncertainty and, consequently, emphasis on delivery questions. As indicated by the classification mentioned, regulatory ambiguities or incomplete contracts have been recognized as a particularly interesting type of uncertainty in both projects and more permanent organizational contexts (Williamson, 1985; March, 1994). For example, the distinction among classical, neoclassical and relational contracting (Macneil, 1978) represents a manifestation of measures taken to facilitate exchange due to contractual uncertainty. The choice of so-called governance mechanism (choice between market, bilateral, trilateral or exchange within a hierarchy) should, according to Williamson (1985), take the decision-making process including influences of risks and uncertainties into account, and in particular, in cases where stronger forms of self-interest may exist. Hence, Williamson (1985) not only recognizes lack of communication as a precursor to uncertainty but also strategic opportunistic behaviour.

Another important context for uncertainty is project business, which requires particular attention to administrating decisions, quantity and quality of information as well as hands-on control in critical events (Cova et al, 2002). Nam and Tatum (1988) argued that uniqueness constitutes one of the main characteristics of construction projects and products, which affects among others productivity and rate of technological change. As indicated at the beginning of Section 2.2.1, the view on projects has during the years gradually recognized that projects have fewer characteristics in common than was previously assumed, which suggests that uniqueness constitutes an important aspect to be considered in project analyses (cf. Engwall, 2003). The degree of uniqueness also affects the extent which projects can be subjected to meaningful statistical analysis to determine risks and, therefore, related to uncertainty. A second characteristic of importance when characterizing uncertainty in projects and business in project contexts is complexity, i.e. the perceived state in which different and connected parts provide difficulties to understand and analyze occurrences due to difficulties in comprehending and expressing inherent and extrinsic characteristics. Complexity is recognized as a major aspect in both general project management (Cova et al, 2002) and construction management (Nam and Tatum, 1988) but

also the INA (Ford et al, 2003) that leads to uncertainty. In essence, complexity concerns the basic interdependencies among actors, resources and activities both within a given project but also from one project to the next projects, which results in uncertainties regarding activities to be performed, resources to be used as well as the probability of any positive outcome (Hadjikhani, 1996; Håkansson et al, 1999; Cova et al, 2002). However, as also indicated above, projects are not only affected by uncertainty, they can also be subjected to different measures including procurement strategies to reduce it: competitive tendering and market-based exchange may reduce uncertainties associated with the evaluation of bids, while need and transaction uncertainties can be reduced by more relational exchange (Håkansson and Snehota, 1995).

2.2.2 ASPECTS USED TO CHARACTERIZE UNCERTAINTY

As discussed hitherto, a wide range of characteristics can be attributed to business within construction project contexts as recognized in both project management and construction management research. For example, the interpretation of projects as a kind of temporary network implies that studies of project business should emphasize characteristics such as uniqueness and complexity, but also discontinuity, which result in a number of important features including a specific and extended transaction process, actor fragmentation and uncertainty (Cova et al, 2002). However, as exemplified by that the characteristic of uniqueness not only indicates whether a given project is unique in a strict sense but also the attributes that are of most interest for a certain study, the choice of characteristics for an empirical study is an important task. In order to conceptually characterize individual projects, it is therefore important to identify aspects that distinguish a given project from other projects. The characteristics of projects mentioned are all of interest in this study. However, while uniqueness and complexity are considered as causes to uncertainty, discontinuity is treated as implicit in the concept of interaction as discussed in Section 2.3.2. Consequently, of the wide range of characteristics emphasized in the literature for projects, uncertainty is considered as the one most suited for this study. A reason for this is to achieve an understanding of the differences between procurement methods.

Winch (1989) suggested that the main uncertainties of relevance for analyzing the construction industry concern the actual construction process and the relations among organizations. Accordingly, the major uncertainties of the industry are not found at the aggregated level since the economic environment, the market or the rate of technological change are not particularly uncertain. Instead, the main uncertainties of the industry concern task uncertainty associated with project uniqueness, natural uncertainty due to weather and geotechnical conditions, and organizational uncertainty following project size and way of contracting (e.g. Kadefors, 1995; Winch, 2002; Flyvbjerg et al, 2003). Accordingly, different procurement methods for construction projects may result in different degrees of uncertainty depending on their frequency and the existence of informal and formal institutions. However, although institutions of the construction sector have been widely discussed in management literature, only a few studies have been devoted to explicitly comparing different procurement methods and the extent to which any of them actually result in particular uncertainty regarding, for example, producing tendering documentation, technical design, achieving a smooth procurement, calculating bids, managing production on site or subsequently.

In this study, two aspects of uncertainty are emphasized of which the first concerns administrative issues and the second technical. In both cases, the uncertainty is considered as general, interpreted by the researcher rather than purely based on the perception of a given actor or relationship. These two aspects of uncertainty are considered to capture differences between procurement methods and may explain other effects such as interaction and knowledge, which are all important for the industry.

Administrative uncertainty

Administration is a term often used to designate information processing and control, which is necessary to facilitate the coordination of behaviour among actors. In general, such activities are often extensive and costly and for this reason improved efficiency by routines represents important knowledge gains. Following the discussion presented in Chapter 1 and at the beginning of this chapter, the following administra-

tive aspects are considered to be among the most interesting to investigate as regards uncertainty.

Number of activities contracted

Construction projects are normally conceptualized as a process constituting a sequence of main phases, e.g. design, construction, maintenance and operations, the duration and order of which depend on the procurement method and contract type used. Intuitively, the more phases and activities included in a given contract, the more skills and knowledge are probably needed to be performed and coordinated. Different procurement methods may also result in differences regarding how synergies between successive activities should be handled, e.g. optimizing trade-offs between investment and maintenance costs, during a contract period. In addition, previous use of a given procurement method also probably affects whether and to what extent actors involved experience uncertainty. In the case of a client, the bundling of responsibilities into a new contract may result in significant unforeseen consequences. A contractor or consultant, on the other hand, may in a similar way resume responsibility for activities not previously performed, which may result in corresponding uncertainty requiring needs of contract clarifications, establishment of complementary agreements, and development of new administrative routines and even sub-organizations. As a consequence, the scope of main activities concerned by a contract is, therefore, considered as one of the main aspects when comparing procurement methods: a contract only involving design or construction activities is considered to result in less uncertainty compared to a contract where both activities are simultaneously involved. In essence, the more activities involved in a given contract, between any two actors, the larger the uncertainty for the actors involved.

Contract length

Contract length represents the second aspect used to characterize uncertainty. Although this aspect of uncertainty is intimately related to the number of activities contracted it is considered to provide additional explanatory power as apparently similar project categories, e.g. unconventional D-B projects, may be subjected to radically different contract lengths. In Sweden, contracts lengths for traditional D-B-B projects, be-

tween a client and contractor, are often 7-8 years including the five years of warranty beyond the essential construction activities. Unconventional projects, on the other hand, may have radically longer contract times as evident from international literature. Although Swedish experiences are scant, international D-B and PPP projects may experience contract periods up to more than 40 years. Following the discussion regarding pros and cons of different procurement methods, the length of the contract is often argued to provide incentives to promote design and construction utilizing materials and production methods resulting in improved performance. A related aspect commonly discussed regarding unconventional procurement methods, especially projects involving maintenance and other post-construction activities, concerns the necessity of devoting more attention to a larger part of the product's life-cycle costs instead of just minimizing investment costs. In essence, the longer the contract, the higher the degree of integration of technical and financial aspects by exposing additional project activities to competition, which results in an optimization of a larger part of the total life-cycle costs of the project. However, with the increased complexity comes increased uncertainty especially due to a higher degree of asset specificity (cf. Williamson, 1985) and costs of monitoring the contribution of different actors to the joint effort (cf. Alchian and Demsetz, 1972). This could certainly be the case if different actors provide resources and the joint effort is evaluated.

Technical uncertainty

Technical aspects are often advocated as one of the main issues of procurement methods. In this study, technical uncertainties are associated with type of requirements and design methodology used.

Type of requirements applied

As indicated in Section 1.2, research on procurement methods has, besides relatively administrative aspects, often also emphasized comparatively pure technical aspects of construction projects. One question subjected to particular debate regarding procurement methods concerns the type of requirements, or specifications, applied in a given contract. As indicated in Figure 1.2, technical requirements can, in principle, be defined on different conceptual levels of which the lowest level consti-

tutes the so-called procedural specifications. These requirements are specific in the sense that they prescribe properties of components in great detail and how they are to be assembled, often without prescribing the physical performance of the final product made from the different components. The underlying procedure has important consequences since procedural specifications can be evaluated early during the contract period, in principle as a facility is still being constructed, which has been considered appropriate by all parties involved, since the potentially tremendous variety of site-specific conditions, materials, equipment and finished structures may result in an unavoidable high degree of complexity and uncertainty (cf. Nam and Tatum, 1988). In the case of the so-called performance specifications, the relationship between characteristics of individual materials and components and performance at an aggregate level is necessary. Furthermore, the evaluation of technical requirements often requires that the evolution of performance parameters can be monitored over longer times, often the entire contract period, in order to ensure that adequate attention has been paid to quality by the supplier. One important question concerns which actor category is responsible for choosing the requirements and who is responsible for the actual performance. In essence, procedural requirements are considered to result in low uncertainty while performance requirements result in a higher degree of uncertainty.

Availability of structural design models

Another important aspect of technical relevance is that constructed facilities are among the most difficult to mechanically characterize (e.g. Nam and Tatum, 1988; Huang, 1993; Winch, 2001). In principle, the essential uncertainty concerns the difficulty of making reliable predictions of technical performance during the comparatively long lifetimes of infrastructure products. The technical uncertainties indicated have often resulted in the selection of a robust design being institutionally entangled as well as manifested by restrictions on design variability (Atkin, 1993; Kadefors, 1995). For example, Stankiewics (2000) argues that engineers are embedded in technological traditions and communities affecting their objective world in terms of so-called design spaces, where design activities are confined by institutions comparable with paradigms. Consequently, actors responsible for technical solutions tend

to think in frames and choose familiar concepts rather than alternative solutions. Hence, in a similar way as institutions guide behaviour, design spaces shape problem-solving processes both by providing theoretical models and other means to legitimize existing technical solutions (cf. Atkin, 1993; Stankiewicz, 2000; Vincenti; 2000). However, in cases where such institutions are not available, significant uncertainty may prevail for any actor responsible for costs of inadequate design due to future change, maintenance, operations or legal advice depending on procurement used. Consequently, the cognitive activity related to methodology used to determine structural build-up including materials and production methods to secure fulfilment of requirements stated in a given project contract may constitute a major uncertainty. In the case of the current study, if design is supported by existing tools or if knowledge regarding materials, structural build-up, production technique and technical requirements and their relations is great, the technical uncertainty is low and vice versa.

2.3 INTERACTION IN PROJECT NETWORKS

The second theoretical area of interest in this study concerns Interaction.

2.3.1 INTERACTION

Interaction represents a concept utilized in some management theories, including the INA (cf. Section 2.1), to emphasize the complexity shown by business activities as opposed to idealizations made in traditional economics.

Interaction as a concept in business studies

According to common dictionaries (cf. Oxford dictionaries), interaction denotes phenomena involving mutual or reciprocal action among at least two actors. In a business context, interaction can be considered to represent the activities actors make and respond to each other in both words and other forms. Hence, interaction should thus be interpreted as significantly more extensive and complex compared to the simple, strictly active or reactive, unidirectional and costless exchange mechanism assumed in traditional economics, in which the actors involved are assumed to possess all necessary knowledge regarding both the product

and the transaction. Instead, the concept of interaction presumes any actor to be affected by the actions of other actors, and, thereby, exhibiting restricted freedom depending on current role and knowledge, which entails that interaction may exhibit many different characteristics over time. This section continues from the network view given in Section 2.1.1 by discussing interaction and how it is modelled for the temporary project networks studied.

As indicated from the presentation of Section 2.1.1, the INA assumes, in line with early economic institutional theory, *the relationship* as a primary subject of analysis in order to understand organizational phenomena. Although it has indeed been difficult to ascribe a distinct definition to the term relationship, it is consistently used within the INA to indicate the interaction process between two actors (Håkansson, 1982; Turnbull and Valla, 1986; Johanson and Mattson, 1987; Hallén et al, 1991; Håkansson and Snehota, 1995; Ford et al, 2010). Since a given network relationship may differ from other relationships the resulting interaction can take a wide range of forms, e.g. depending on whether it concerns the transaction concerning a standardized product or the execution of a unique and complex activity. In order to operationalize the concept of interaction, attention is normally paid to a set of characteristics which are conceived to emphasize the essential features of this relationship.

A model of dyadic interaction

In an associated forerunner of the INA (cf. Section 2.1.1), the so-called *interaction model* (Håkansson, 1982), interaction between two focal actors was characterized using a model comprising four basic elements: (1) *the interaction process*, (2) *the participants*, (3) *the environment* and (4) *the atmosphere*. While the interaction process represents sequential episodes involving products, information, financial and social content in the short term, the longer term recognizes that the relationship in question results in institutionalization as contact patterns are established and adaptations are made. The last term, adaptation, is obviously inherited from evolutionary economics (cf. Nelson and Winter, 1982; Håkansson 1982) and represents a way of characterizing how actors deliberately devote resources to meet the interest of a counterpart in

the long run. Many publications within the INA (cf. Easton, 1992) have in accordance with Berger and Luckmann (1966) emphasized that knowledge obtained by information exchanged between organizations increases control by providing predictability and institutionalization in the form of behavioural norms to a perceived objective reality. For example, the flow of questions and answers calibrates the relationship repeatedly and adjusts activities and capabilities. A long range of researchers, e.g. Cyert and March (1963), Argyris and Schön (1996), Nonaka (1994), Håkansson et al (1999), Dubois and Gadde (2000) and Illeris (2003), argue that social interaction is necessary to eliminate or reduce uncertainty as well as being fundamental to learning, since it provides access to both problems and possible solution in the form of interpretations of experiences, inferences of casual relationships between action and outcomes and analysis of alternative techniques. Consequently, interaction could be considered as an important intermediate link between the characteristics of uncertainty and knowledge gained. The elements environment and atmosphere were originally used within the early interaction approach mentioned to characterize the wider context, including market structure and social system, as well as the degree of stability and routinization of the focal relationship, respectively. Since the early contributions presented in the 1980s, several researchers, such as Johanson and Mattson (1987), Ford and Håkansson (2006), have suggested revisions or complements to the original interaction model. However, although differences among the contributions on interaction exist, there are certain common features among models elaborated within the INA. One such feature is the importance of *time* since interaction is seldom considered as either constant in frequency or content as a given interaction process continuously evolves.

Influence of relationship stage

In order to characterize a given interaction process it has often been possible to identify certain common patterns regarding how interaction among two actors evolves over time (Wilkinson and Young, 1994). Ford (1980) analyzed the development of dyadic relationships between buyers and sellers using five generic episodes where a typical business relationship evolves from a pre-relationship stage to a perceived final stage by successively increasing experience and decreasing uncertainty until

an established and institutionalized relationship materializes. The model indicated has since then been revised (Ford et al, 2003) into a four-stage model comprising (1) *a pre-relationship stage*, (2) *an exploration stage*, (3) *a development stage* and (4) *a mature stage*. In the latter model, the sequential stages are successively achieved by a number of relationship investments as trust, commitment, adaptation and learning.

2.3.2 ASPECTS EMPLOYED TO CHARACTERIZE INTERACTION

Interaction is chosen as a concept in this study to investigate what actually occurs in the cases studied. In this case, the concept provides a way of characterizing the organizational phenomena; the pattern of interaction and the amount exchanged between the actors. The choice was also partly based on interaction providing a means of investigating whether and to what extent uncertainty may contribute to the way knowledge is gained by the actors involved. However, as indicated in Section 2.1.1, interaction in project networks can be characterized in a number of different ways depending on the level of analysis and the phenomenon investigated. In this study, the network lens is employed to observe the organizational phenomena by both characterizing individual projects as temporary networks comprising the three main actors of interest (intra-project interaction), and any resulting dependence among projects using the concept of *inter-project connection*.

Intra-project interaction

As stated in Section 2.3.1, there are a number of ways of characterizing interaction. For example, interaction can be characterized by the number of informal and formal meetings devoted to a problem, search initiatives, the number of iterations and the amount of testing made to reach a final design, and how administrative issues such as cost calculations are handled within a group of contenders. However, due to the inherently complex character, neither all interaction nor all the details can be given. This is certainly the case when it comes to the almost indescribably large volume and aspects involved in the informal interaction during construction works. The main aspects chosen to characterize the degree of intra-project interaction in this study are therefore restricted to frequency, breadth and depth of the relevant content exchanged, primarily in connection to formal meetings between the actors investigated. The

aspects mentioned are assumed to represent both intensity and volume of interaction and is each, in a binary fashion, graded from a low to a high degree. Although a maximum amount of interaction may be conceivable for each of the three aspects mentioned, such an amount may not necessarily mean that uncertainty is reduced or knowledge is gained since a high degree of interaction frequency may be devoted to meaningless information. On the contrary, interaction of great breadth or depth may be so infrequent that it can be questioned if any exchange at all occurred. In any way, a low degree of interaction of the aspects mentioned means that no or limited exchange or interaction occurs, while a high level in all three categories suggest a very high level interaction during a project studied. Since the interaction may change over time, it is for the purpose of the study useful to subdivide a project into phases where the interaction can be characterized in slightly more detail.

Frequency

As indicated in previous sections, the focus of the current investigation is directed towards exchange involving administrative and technical content associated with construction activities. One of the aspects used to characterize the amount of interaction is frequency (Håkansson, 1982; Håkansson and Snehota, 1995). Figure 2.3 gives a conceptual illustration where interaction frequency differs between two relationships (between actors 1 and 2, and actors 3 and 4) with respect to number of meeting (i.e. oscillations) within a given time frame. According to the figure, the relationship between actor 3 and 4 exhibits a higher degree of interaction frequency compared to the relationship between actors 1 and 2. However, in contrast to physics where the number of oscillations may be compared in absolute numbers, interaction frequency with respect to meetings is still considered to exhibit significant complexity since the number of meetings may not only vary with time and the actors involved, but it is also a matter of relative comparison. In this study, interaction frequency is considered as of low degree if it occurs infrequently (< once a month), while a high degree of interaction frequency is considered to prevail if it corresponds to meetings more than once a month. The distinction between high and low degree of frequency is largely based on the general experience that work in-between meetings is often required to be performed until the next meeting,

which also restricts the possible number of meetings held within a certain time-period.

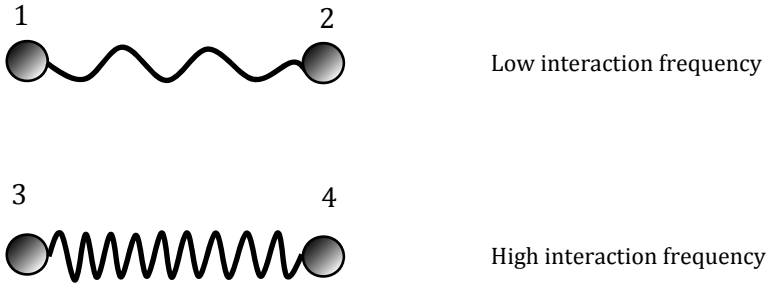

Figure 2.3 Conceptual illustration of relationship between two actors exhibiting low and high degree of interaction frequency.

Breadth

The second aspect of exchange concerns interaction breadth, i.e. whether the exchange involves a limited or relatively great diversity of information topics, e.g. contractual, financial and/or technical issues. Figure 2.4 illustrates a relationship between actor 1 and 2, which in a given episode may involve the exchange of information of one topic (case A) or two topics (case B). Hence, for a given relationship, episode and amount of information exchanged, the type of information exchanged may be characterized by that a single topic or more are involved at once.

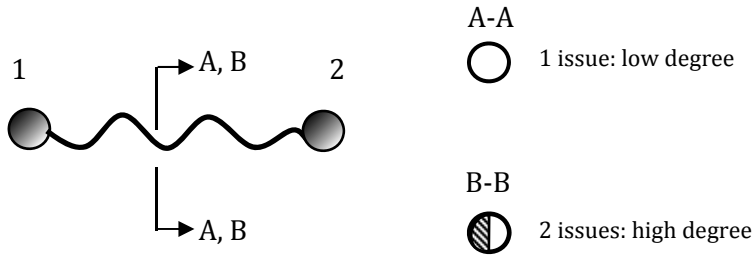

Figure 2.4 Illustration of relationship between actors 1 and 2 exhibiting low (A-A) and high (B-B) degree of interaction breadth, where the former is characterized by a single issue while the latter concerns two issues at the one and same time.

The number of topics concerned by interaction constitutes an important aspect in several models associated with the INA. For example, Cunningham and Homse (1986) used the term breadth to characterize patterns of personal relationships where a broad relationship comprises a high degree of diversity of content or issues dealt within a given relationship. In this case, exchange involving a broad range of issues, e.g. financial and technical matters, is assumed to result in a higher degree of interaction compared to exchange only concerning a single set of aspects. The extent to which interaction is broad within a project can be of interest, for instance, by reference to learning as multidimensional interaction provides access to more diversified, and complementary, information (Håkansson et al, 1999). Consequently, broad interaction may provide the possibility to relate information about a given topic, e.g., technique, to financial issues, and, thereby, the possibility of drawing conclusions regarding the monetary consequences of different technical solutions.

Depth

In a similar vein as the aspects discussed above, interaction depth is classified based on whether the content treated is of low or high degree. In this case, the distinction is based on whether the content is according to established administrative routines or technical standards (low de-

gree) or if it goes beyond and into greater detail, e.g. by investigating non-standardized aspects (high degree). Hence, deep interaction may be represented by non-standard questions requiring extraordinary efforts to investigate technical or monetary consequences. A thorough investigation of a certain technology represents an example of deep interaction. Correspondingly, a low degree of interaction depth is exemplified by questions discussed and solved utilizing existing technical standards or prevailing administrative routines. Figure 2.5 illustrates a conceivable relationship between actors 1 and 2, which may involve the exchange of detailed and non-standardized technical inquiries (case A) and technical knowledge expressed in existing technical descriptions or standards (case B). In the latter case, the information exchanged is considered as more superficial since details, or specific aspects not codified in standards may be articulated.

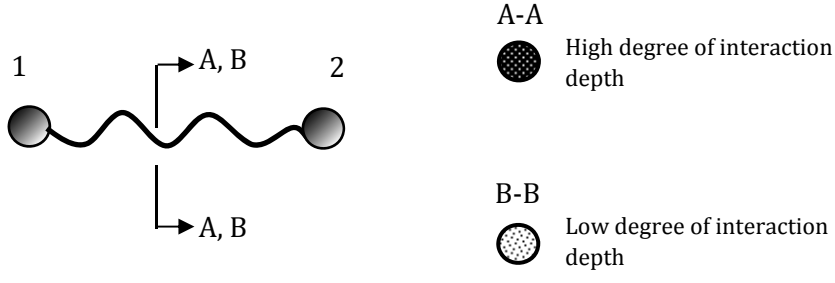

Figure 2.5 Illustration of relationship between two actors exhibiting low and high degree of interaction depth.

This classification is to some extent similar to the distinction of standardized and complex technology (Hadjikhani, 1992), where exchange involving non-standardized content can indicate measures beyond the call of duty due to lack of routines, technical standards and other supporting institutions. The distinction of degree of depth is also an attempt to investigate the extent to which actors act according to existing design spaces (cf. availability of design models, Section 2.2.2) or devote resources to measures beyond.

Inter-project connections

As discussed in Section 2.1.1, the INA emphasizes, in line with evolutionary theory, the hereditary nature of exchange relationships evolving over time as the actors involved mutually and continuously demonstrate their trustworthiness by committing themselves to adaptations in order to reduce perceived uncertainties and meet the specific requirements of a counterpart. An important implication of recognizing the temporary setting of projects is *discontinuity* i.e. the apparent end of exchange and interaction between a buyer and seller after a given project is formally finalized. However, whether an apparent discontinuity actually exists, or whether it is reanimated with time, requires an extended view of projects where relationships are considered as continuous and persistent over time. Since a network view not only provides a means of interpreting individual projects by characterizing interaction within a given project, but also a convenient way of understanding interdependencies among sequential projects, this approach appears as particularly fruitful to capture such project-spanning interaction in the wider organizational context. Consequently, besides interaction within a given focal project characterized by frequency, depth and breadth, any resulting connections from that project to historical and future projects can be characterized as well.

Following the concept of connection formulated within social exchange theory (Cook and Emerson, 1978; 1984), studies within the INA (e.g. Smith and Laage-Hellman, 1992; Anderson et al, 1994) have investigated how dyadic relationships are connected to other relationships, i.e. the extent to which exchange in one relation is contingent upon exchange in other relationships. The concept of connection has also been utilized to characterize more temporary contexts. For example, Håkansson et al (1999) used the notation of connections to illustrate how different hierarchical organizations interacted and learned within a construction setting. Another example is Sjögren-Källkqvist (2002), who discussed dependencies and resulting connections in a multi-project study. Martinsson (2009) identified six types of connections during which knowledge is transferred in project contexts among individuals, temporary organizations, permanent organizations and products. In this case, the term dependence was utilized to indicate effects in individual projects as re-

sulting from sequential execution of activities, common resources in the form of staffs or technical solutions, which all create connections among the individual projects.

By interpreting individual projects as collections of relationships, the concept of connections can be utilized to describe how project procurement characteristics affect actors to establish connections to other projects. According to Engwall (2003), interconnections may concern reuse of technical, e.g. an old technical design, administrative, e.g. documentation systems, or organizational aspects, e.g. personnel, from previous projects. Furthermore, following the notation of sleeping relationships (cf. Hadjikhani, 1996), connections between actors involved in a certain focal project and other subsequent projects provide an interesting type of relationship, especially if knowledge developed in previous projects is reactivated as a consequence of search activities, e.g. by retrieving information stored regarding its performance. Accordingly, establishment of connections can both be considered as exploration as a consequence of search within a given project but also as long-term adaptation in the form of a more permanently established resource tie. Several publications (e.g. Hadjikhani, 1992; Bengtsson and Eriksson, 2002; Engwall, 2003; Maaninen-Olsson, 2007) argue that knowledge from projects of the immediate context is of great importance to the success of new projects. Consequently, the establishment of connections among projects provides an important aspect of evolution in the form of adaptations and network change (cf. Hallén et al, 1991) as well as knowledge transfer (Håkansson et al, 1999). In principle, a given connection may, at least partly, also be the result of investments in physical artifacts such as machinery and equipment, and commitment in human adaptations, e.g. alterations in procedures, routines, recruitment, training and research activities. For example, an investment in a particular equipment, system or organizational structure may provide the possibility or rationale to create a connection from a given project to a historical or future project. Deliberate initiatives to learning may also involve the establishment of new organizations and roles within that organization to spread learning across projects (March, 1994; Leiringer et al, 2009) and thereby result in connections.

Connections established to previous projects

The first aspect of inter-project connection emphasizes explicit connections between the focal project and other, primarily historical projects constituting the organizational environment. This aspect indicates if and to what extent knowledge developed or dwelling in previous projects is utilized in the focal project.

Connections established to future projects

This aspect is used to characterize interaction and what effect it has on subsequent projects. The greater the number of explicit connections from a given focal project to subsequent projects indicates that the focal project has potentially provided more knowledge to future projects.

2.4 KNOWLEDGE AS A FORM OF LEARNING OUTCOME

The third, and last, characteristic investigated in this study concerns knowledge gained by the different actors depending on project procurement method used. Section 2.4.1 begins by presenting common competence-related concepts frequently appearing in the literature including learning and knowledge, and how the concepts are related to each other. In Section 2.4.2, the aspects employed in the current investigation to characterize knowledge gained are presented.

2.4.1 KNOWLEDGE AND COMPETENCE-RELATED CONCEPTS

The term knowledge has, not only been a major research area within economics and management (e.g. Nelson and Winter, 1982; Barney, 1991; Grant, 1996), but also, at least since antiquity, recognized by a long succession of philosophers and other social scientists as an important area for intellectual debates, which has resulted in a comprehensive taxonomy of relevance for contemporary business studies. One of the historically most theoretically explored areas of epistemology, i.e. the philosophy of science, concerns whether and to what extent knowledge can be considered as logical and absolute, or if it is acquired through experience alone. Although there is still no single agreed definition, the term knowledge, which normally applies to statements meeting the three criteria, often attributed to Plato, of justification, truth and belief, has been given a lot of attention regarding its strict interpretation

as well as scientific and practical usefulness (cf. Wittgenstein, 1922; Popper, 1959; Kuhn, 1962; Polanyi, 1966; Lakatos and Musgrave, 1970). However, since the term knowledge has been argued to be too vague to pass a test of necessary and sufficient conditions for objective and universal knowledge, a conclusion that has been supported by a number of constructed examples (e.g. Gettier, 1963), one of the most popular ways of characterizing knowledge is to refer to its hereditary and path-dependent nature[8].

The epistemological fragmentation indicated above is accompanied by an additional number of existing, more practical, definitions of knowledge as well as the term's relation to, more or less, similar terms such as education, information, experience, competence, and innovation (e.g. Levitt and March, 1988; Miner and Mezias, 1996; Fiol and Lyles, 1985; Brown and Duguid, 1991; Von Hippel, 1994; Easterby-Smith, 1997; Gherardi, 1999; Argote et al, 2003) but also comparatively elaborated theoretical framework such as knowledge management (e.g. Alavi and Leidner, 1999), learning organization (Senge, 1990) and organizational learning (Cyert and March, 1963; Argyris and Schön, 1996)[9]. Of the different competence-related terms indicated, experience is often considered to comprise tacit knowledge, i.e. knowledge developed when acting towards certain goals (Polanyi, 1966), while learning usually denotes the process involving who is learning from whom, barriers that prevent learning, what is learned and how it is accomplished. Innova-

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[8] For example, according to Kuhn (1962), scientific discoveries normally start with a realization that nature diverges from what is expected from theoretical predictions.

[9] In Easterby-Smith´s (2003) classification, the concepts organizational learning, knowledge management, learning organization and organizational knowledge represent interrelated theoretical concepts, each focusing on certain peculiarities of learning and knowledge. Organizational learning is often interpreted as the processes within an organization to achieve knowledge acquisition, knowledge sharing, and knowledge utilization (Dibella et al, 1996), while the concept organizational knowledge denotes how actors appropriate knowledge and expand their knowledge repertoires. In addition, organizational learning and organizational knowledge are often considered as academic approaches, while knowledge management and learning organization are considered to represent more normative and practical approaches.

tion, on the other hand, usually stresses the actual result from learning in form of improved efficiency, effectiveness and explicit financial gains (cf. Nelson and Winter, 1977; Curado, 2006). However, although apparently separable, at least in theory, the different terms are inherently interrelated since learning implies the way information and knowledge becomes available to an organization, which influences the level and rate of innovation (Huber, 1998).

Models developed to characterize learning and knowledge

The process by which learning occurs represents one of the most investigated aspects of the competence-related concepts indicated and is far from trivial as suggested by the great number of models and perspectives elaborated (Easterby-Smith, 2003, Pasteur et al, 2006). In principle, besides models based on well-known market (e.g. Davenport and Prusak, 1998) and evolutionary analogies (e.g. Nelson and Winter, 1982; Lindkvist and Söderlund, 2002), three, albeit not mutually exclusive, psychological perspectives have also contributed significantly to the perception of learning: *behaviourism*[10], *cognitivism*[11] and the *social*[12] perspective.

Another important stream of research that has shown pronounced influence on, not only decision-making but also, learning of organizations,

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[10] In principle, behaviourism evolved from the early 20th century until the 1970s, by interpreting learning as primarily an outcome measured by change in behavior according to a trial-and-error process where the behaviour can be predicted using comparatively simple stimuli-response model and environmental factors (Graff, 2008).

[11] Cognitivists interpret learning as an active process of adjustments to a surrounding environment, by which the individual reconstructs own mental frameworks. Piaget (1977) suggested that individuals construct new knowledge from their experiences either by the processes of accommodation, i.e. modifying the existing framework, or by incorporating experience into an already existing framework, without necessarily changing the framework (assimilation).

[12] During the mid-1980s, cognitive learning theories were broadened to incorporate social processes under the heading of social-constructivism (Graff, 2008). This theoretical evolution was partly based on the critique that the cognitive perspective alone tended to overemphasize the cognitive processes and underestimate the social situation in which learning occurs (e.g. Lave and Wenger, 1991; Brown and Duguid, 1991).

and therefore permits special recognition here as well, is the so-called behavioural theory of the firm. This stream of thought was initiated in the mid-twentieth century when researchers at the Carnegie school started to conceptualize organizations as more than merely production functions by transforming existing anecdotal observations regarding learning into a formal theory (e.g. Simon, 1945; March and Simon, 1958, Cyert and March, 1963; Levitt and March, 1988; March, 1994). In addition to the major contribution of bounded rationality (cf. Section 2.2.1), a significant contribution has been within organizational learning as it has been interpreted as an outcome of uncertainty reduction (Cyert and March, 1963). Levinthal and March (1993) proposed that it is possible to design organizations to learn from experience by emphasizing three common problems to learning. First, learning tends to sacrifice the long term for the short term. Second, learning tends to favour effects close to the learner. Finally, organizational learning over-samples success to failure. All three problems mentioned indicate that cognitive limits exist, which makes the matter of routines important in learning.

Common inquiries of knowledge and learning research

The ontological dimension of who actually learns in a given context constitutes a classical topic within learning literature. Although exceptions exist, learning is often conceived as a social phenomenon simultaneously occurring on multiple levels, i.e. both within individuals and organizations, fields and networks (e.g. Huber, 1991; Hohenthal, 2001; Juriado, 2008). Consequently, even though individuals normally are considered the main carriers of knowledge and, therefore, necessary for the development, possession and transfer of knowledge, individuals alone are not sufficient for organizational knowledge (Argyris and Schön, 1996; Nelson and Winter, 1982; Lave and Wenger, 1991; Nonaka, 1994). In this case, several empirical investigations have indicated casual relationships between individual and organizational learning (e.g. March and Olsen, 1975; Argyris and Schön, 1996; Nonaka and Takeuchi, 1995).

A second subject often investigated regarding learning and knowledge is the process during which they occur. The distinction between modifying an existing cognitive frame and developing new frames is a frequent theme in many learning models, e.g. single- and double-loop learning

(Argyris and Schön, 1996), adaptive and generative learning (Senge, 1990), lower-level and higher-level learning (Fiol and Lyles, 1985). March (1994) distinguished between *exploitation*, which refers to the development of learning routines facilitating the refinement of existing products and processes, and *exploration,* which denotes learning routines for the development of new resources by search, experimentation, discovery and innovation. According to March (1994), there are economic motives for organizations to achieve a balance between the two types of learning by optimizing the trade-off between utilizing and refining the existing knowledge base and investments in yet not completely known resources. Despite the apparent logical paradox, many researchers argue that the two basic strategies mentioned are, as in the case of tacit vs. explicit knowledge (cf. Polanyi, 1966), not mutually exclusive but should be utilized simultaneously since they reinforce each other (cf. Curado, 2006). As asserted by Kululanga and McCaffer (2001), when actors rely solely on routines for carrying out work activities, the cognitive capacity to create, acquire and share knowledge is lost. Both knowledge capturing and sharing mechanisms are therefore necessary to learn and implement any knowledge gained. Also, Nelson and Winter (1982), according to their synthesis of evolutionary theory, reused many arguments of earlier evolutionary and institutional theorists to develop a model where organizations are interpreted as collections of routines continuously experiencing the variation-selection-retention cycle. In essence, institutional frameworks facilitate decision-making by constraining and shaping the direction of knowledge acquisition, and, thereby, constitute important furnishers for long-term development by reducing uncertainties and clarifying goals (North, 1990).

Besides the process during which knowledge is gained by different actors, the content of what is learned remains the third important category of learning and knowledge theory. A frequent way of characterizing content is to distinguish among basic topics, e.g. financial, juridical, technical or social knowledge (e.g. Håkansson, 1982; Juriado, 2008). A third example of content classification is to refer to contextual aspects, e.g. whether the knowledge originates from within the organization or from its environment (Ekstedt et al, 1999), is positive or negative for a certain organization in a given situation (Argyris and Schön, 1996) and

for what purpose a given type of knowledge is useful (Inkpen, 2000) with regard to the needs of different parts of a given organization (Nonaka, 1994). Besides the simple classification of content just indicated, it is also possible to define content based on concepts such as know-what, know-how, know-why, and know-who (e.g. Villalba, 2006). Additionally, a wide range of applied research (e.g. Penrose, 1955; Senge, 1990; Kogut and Sander, 1992; Nonaka, 1994) has classified content based on the apparent epistemological distinction between knowledge that is comparably easy to express and knowledge that is not as easy.

Peculiarities of temporary network organizations

This section is intended to reflect on some of the aspects considered of particular interest for projects.

Learning by interaction in networks

As described in the previous sections, learning is often considered as the process during which knowledge is obtained. In principle, such a process can be considered, at least to some extent, as analogous to the process of interaction (cf. Section 2.3.1). In accordance with other network approaches (e.g. Granovetter, 1973; Burt, 1992; Hansen, 1999; Borgatti and Cross, 2003; Knight and Pye, 2005), authors within the INA (cf. Section 2.1.1) argue that network learning is an important characteristic of network activities, either as the actual purpose around which the network is formed or as a by-product from interaction.

Compared to the corresponding situation in hierarchical organizations, learning among different organizations constituting a network often show important informal characteristics that affect knowledge transfer either positively or negatively. Formal organizations normally provide clear communication channels, i.e. with whom to interact, and effective routines, while different organizational belonging often results in both difficulties of developing such routines as well as behavioural reluctance to disclose information to actors of other organizations (Bengtsson and Eriksson, 2002). On the other hand, individuals of different organizations, but similar professions gain knowledge to a higher degree through the process of sharing information and experiences with the group. However, in contrast to conclusions drawn, for example, within the the-

ory of communities of practice (Lave and Wenger, 1991), network theory often emphasizes learning as a result of complementary, rather than shared, characteristics when it comes to products and knowledge exchanged (Granovetter, 1985; Håkansson et al, 1999, Bengtsson and Eriksson, 2002; Gulati et al, 2000, Lavie, 2006). This learning mode is explained by that significant knowledge resides outside organizational boundaries, which makes benchmarking, informal and formal cooperation by visits, joint discussions and tests with external actors important sources of knowledge. Consequently, since heterogeneous constellations comprise members exhibiting different background and experience they are presumably more creative than homogenous groups (e.g. Lant et al, 1992; Lapre and van Wassenhove, 2001) and it becomes easier to acquire valuable knowledge (Håkansson et al, 1999). Another important network characteristic regarding learning and knowledge concerns the influence of number of relationships or connections. One hypothesis investigated by Håkansson et al (1999) was the possibility to learn in a business relationship depending on the number of connections to other relationships. This hypothesis was based on the presumption that the number of interfaces where learning occurs increases with the number of connections. A third important aspect of network relationships is that they change with time (cf. Section 2.3.1), which also affects the degree of learning and knowledge gained. Learning is often considered as of particular importance in the early, uncertain, stages of relationships since the interacting actors are assumed to be engaged in a detailed learning process resulting in actor bonds, resource ties and activity links essential for stability in subsequent stages (cf. Ford et al, 2003). In principle, a final, mature, stage can be achieved where an institutionalized relationship has developed and where connections to other entities have been crystalized. However, as Ford et al (2003) also emphasize, the actors involved in such a mature stage may return to engage in extensive learning activities and, hence, once more in a development stage due to changes in the environment, which both require and provide opportunities for new knowledge.

Influence of the temporary nature of projects

Many researchers suggest that temporary project organizations show several similarities to those of more stable networks regarding learning and transfer of knowledge (e.g. Dougherty, 1992; Håkansson, 1999; Hobday, 2000; Cova et al, 2002). Besides the characteristics of organizational heterogeneity, the number of connections and relationships stage previously discussed for more permanent networks, a frequently addressed aspect associated with learning in project contexts concerns their unique and temporary character (Nobeoka, 1995; DeFillippi, 2001; Bresnen et al, 2005; Prencipe and Tell, 2001; Scarbrough et al, 2004a), which creates barriers to knowledge transfer between individuals and organizations of temporary projects as well as between any project and the permanent setting. Consequently, even though projects as in the case of networks affect the possibility to create and exchange complementary knowledge by interaction (Huber, 1991; Lindkvist and Söderlund, 2002), several additional learning barriers exist, which reduce the flow of knowledge among actors. Martinsson (2009) even argues that it is problematic to reuse knowledge in projects that are very similar to past projects, which stresses the important distinction of knowledge development within projects (intra-project learning) and the subsequent transfer to other parts of the organization including other projects (inter-project learning).

Studies of project-based organizations, i.e. organizations performing their essential business in the form of projects, have shown that they often lack knowledge storage capacity compared to more permanent organizations. For example, due to physical distance and time lags between projects, project-based organizations often have difficulty in analyzing any relation between cause and effect in project goals (Bartezzaghi et al, 1997), a problem which may require substantial investments in physical and human resources to adequately managing discontinuities between past and on-going projects (Hadjikhani, 1992, 1996; Levinthal and March, 1993; Nobeoka, 1995; Kadefors, 1995 Lindkvist, 2004; Ekstedt et al, 1999). According to Nobeoka (1995), and Bengtsson and Eriksson (2002), links between a project and its context, e.g. other projects, are therefore important facilitators of knowledge transfer,

which may require strategic integration of project histories to enhance project learning.

Following the more general theory on the evolution of collective knowledge in organizations promoted by Zollo and Winter (2002), Prencipe and Tell (2001) suggested that it could be utilized for analyzing inter-project learning. In their discussion of learning investments, Zollo and Winter (2002) had characterized the level of learning investment based on whether it concerned *experience accumulation*, *knowledge articulation* or *knowledge codification*. In this case, experience accumulation represents an important behavioural form of learning that is closely related to existing routines and unconscious decision-making (cf. Argyris and Schön, 1996; Nelson and Winter, 1982). Knowledge articulation and codification represent more cognitively demanding processes and requires significantly more commitment by dialogue, e.g. face-to-face meetings, and by written text, e.g. manuals and drawings, reports, respectively. Accordingly, a learning investment is considered as comparatively low when organizations only rely on experience accumulation while knowledge codification represents the highest investment. A conclusion from Prencipe and Tell (2001) was that the possibility to transfer knowledge in project contexts depends on the learning mode. The lower the frequency, the more effective are knowledge articulation and codification compared to the mode of experience accumulation for learning. This conclusion is partly based on the difficulty of retaining sufficient knowledge across projects by other means than comparatively costly articulation and codification.

2.4.2 ASPECTS USED TO CHARACTERIZE KNOWLEDGE GAINED

In this study, the empirical context concerns the extremely large undertakings associated with establishing construction projects from their conceptualization until they enter service, which of necessity means that a great variety of knowledge is both used and gained by the actors involved. Consequently, the question is not whether knowledge per se is gained but rather which type of knowledge and to what degree. However, since all aspects of knowledge cannot be covered within the study, knowledge is considered as the essential outcome for the three actors and case studied as perceived by the researcher. Furthermore,

knowledge gained is categorized based on content using two groups of aspects: whether the knowledge gained is of *administrative* or *technical* content. These two categories are considered to be of utmost interest regarding procurement methods as they may be related to the rationale of utilizing different procurement methods (cf. Chapter 1). The second important aspect of knowledge gained concerns the actual *degree* of knowledge gained. As indicated by the short literature review given in Section 2.4.1, several aspects are conceivable to characterize the degree including the number of contents or the distinction between single-loop vs. double loop or tacit vs. explicit knowledge. In this study, the degree of knowledge gained is to some extent made with reference to the distinction made by March (1994) regarding exploitation and exploration. Without making any further judgment whether any of the two modes is better than the other, exploitation is considered as a comparably simple form of knowledge while exploration is considered as a higher form since it may require additional resources, and commitments. In summary, knowledge is categorized based on whether a client, contractor or consultant has gained it, and the degree of administrative and/or technical issues is characterized by whether it is of lower or higher degree.

Administrative knowledge

In this study, administrative knowledge represents both project-specific, e.g. agreements or financial information associated with capacities and costs of activities and resources of carrying out a given project, and more general aspects, such as development of new contract types and sub-organizations for handling more than one project.

Contractual

Contractual knowledge concerns the more formal way actors do business and is represented by the way administrative and technical inquiries are expressed. For example, reading and adhering to a contract, and developing a contract where financial and/or technical aspects need explanation is considered to result in a low and high degree of contractual knowledge, respectively. One important category of contractual aspects concerns how to establish and interpret technical requirements. Consequently, contractual knowledge may concern how to interpret an

agreement and can be observed both by what is articulated and written in text.

Financial

Financial aspects constitute the second category of administrative knowledge and concern the evaluation of costs and prices of performing activities. Financial aspects may be related to technical aspects as materials, production technique and design methodology used result in costs. In the case that new information of costs associated with an existing production technique is gained by an actor, this knowledge is considered as being of comparatively low degree since it is in accordance with existing knowledge, but not necessarily known to that individual. New framing, e.g. simultaneous evaluation of certain aspects not previously performed, e.g. investment and maintenance costs, or financial and technical content, may represent a new way of interpreting a problem if these topics historically have been resolved by themselves. Consequently, knowledge can be considered as of either lower or higher degree depending on whether it has required a complete level of different interpretation than usual.

Technical knowledge

Technology is a broad term often utilized to characterize the solving of a given problem, whether it concerns aspects of financial, organizational or any other nature. In this study, however, technical knowledge is rather straightforward and used in association with physical materials, production technique and primarily what employees with engineering or natural science background focus on. For the purpose of the current study, technical knowledge is restricted to *material properties*, *production technique* and the more cognitive category of *theoretical structural models*.

Material properties

Knowledge regarding road building materials, e.g. aggregates and asphalt mixtures, is considered relevant in this study since it constitutes one of the important questions for the industry and motives for utilizing unconventional procurement approaches. Knowledge regarding materials can concern their composition and technical quality in term of per-

formance. If materials used essentially are according to existing standards, the degree of knowledge gained may be of lower degree. However, the degree of knowledge gained may be high if new types of materials or variants are tested or implemented.

Production technique
As in the case of materials, the production technique, e.g. what type of technical equipment and how equipment is used within a project, is another relevant issue regarding procurement methods since it is related to the performance of both individual projects and the industry. Also in this case, the degree of knowledge gained may differ depending on the type of production technique used or investigated.

Structural design
Structural design represents the most cognitive of the three technical aspects focused on in this study as it is related to the way the product is conceptualized. Structural design can be made according to a standardized design tool, e.g. a computer-based model, and by developing a new approach which better agrees with the context it is utilized. The former design approach is considered to provide a lower degree of knowledge than the latter.

2.5 SUMMARY OF THE CHAPTER

This chapter presents the theoretical basis of the investigation and started by stating that individual projects studied are considered as a temporary network comprising three main actors: client, contractor and consultant. The project procurement method is characterized based on uncertainty, interaction and knowledge gained. Uncertainty resulting from procurement chosen is characterized using the aspects number of activities contracted, contract length, type of technical requirements and design tool employed. Intra-project-interaction is indicated using the aspects of exchange frequency, depth and breadth, while any connections between projects are characterized by inter-project connections. An important aspect of the study is to investigate whether any of the procurement methods studied results in knowledge for any of the three actor categories studied. In this case, knowledge in the form of administrative and technical aspects is of particular interest during the course

of works. Table 2.1 summarizes the concepts and aspects used in the study.

Table 2.1 Summary of concepts (uncertainty, interaction and knowledge) and aspects emphasized in the study.

Concept	**Aspect**	
Uncertainty	Administrative	No. of activities contracted Contract length
	Technical	Type of requirements Availability of design model
Interaction	Intra-project interaction	Frequency Breadth Depth
	Inter-project connections	Connections to previous projects Connections to future projects
Knowledge gained	Administrative	Contractual Financial
	Technical	Material properties Production technique Structural design

3 METHODOLOGICAL CONSIDERATIONS

This chapter provides a description of the methodical choices made in order to motivate research design, methods of gathering and analyzing the data in order to investigate the purpose given in Section 1.3.

3.1 BACKGROUND AND RESEARCH CONTEXT

Business in construction contexts has since long been of great interest for the author of this thesis, a statement which is important since subjective assumptions of reality may both affect empirical data acquisition and theoretical choices made, and, hence, the actual results from the research. The pre-understanding of the author mainly constitutes specific knowledge regarding the construction sector obtained from practical work at different contractors as well as academic studies carried out at different universities, primarily the Royal institute of technology (KTH), Stockholm University and Luleå Technical University (PhD studies, M.Sc. studies in business administration and civil engineering, respectively). During the last 13 years, I have been formally employed by the contractor NCC, of which the first five years were devoted to PhD studies at KTH (industrial PhD); the current Department for road and railroad engineering. During the last six years, I have, in parallel to PhD studies at Uppsala University, worked as regional laboratory manager for NCC Roads in Sweden. In September 2010, I was awarded the docent title (associate professor) in road and railway engineering at KTH. The academic work has, apart from developing a common language with the different actors working in the industry and projects studied, provided significant interest in constructed-related project business, and, in particular, influence of innovative ways of introducing competition and new technologies to a market exhibiting significant institutional restraints as well as freedom in the form of project-based work.

As mentioned in the introduction of this thesis, project procurement has been a popular topic in construction management research for decades. However, although an early point of departure in the thesis work had been to investigate influence of procurement method on competition among contractors using a more quantitative approach, it successively

became apparent that a more evolutionary approach, where competition was framed by an interaction process and where actors successively gained knowledge, would be much more interesting to investigate. This conclusion was largely based on the lack of such studies and that quantitative research shows significant limitations regarding the possibility of taking the potentially most important characteristic of construction project business, namely the project transaction process, into account. However, the interest of procurement methods was also affected by that the discussion regarding procurement methods became ever more intense within the industry during the middle of the last decade as it was decided by the major client STA to resume unconventional procurement by initiating a larger project close to Stockholm (the project characterized in Chapter 6). Since I was relatively new at NCC at the time, I had the opportunity to observe and notice how more senior coworkers at the company, but also the industry, perceived the situation. Although the current study formally was started after these experiences, the early observations affected some choices made during the current study, in particular regarding the focal projects studied. Based on a literature study in the beginning of the research, I also became aware that only a few studies have been directed to project procurement methods over longer times. Most research presented in the literature on procurement methods has either been devoted to single case studies, usually the procurement and construction phases of single projects, or to statistical analyzes. The lack of in-depth characterization of interaction and knowledge associated with projects and how they are affected by procurement approach was considered as an important research objective, partly since it might provide understanding regarding competition over time. Consequently, during the research it successively became ever more clear that the current study should be carried out using a case study emphasizing the concepts of most interest.

3.2 CASE STUDY

The term case study, often defined as *empirical inquires investigating a contemporary phenomenon within its real-life context* (Yin, 2003). is frequently used as an umbrella word to characterize a series of research methodologies that have in common that they focus on a specific and often complex phenomenon. In most social science fields, including psychology, sociology, political science and management, descriptive case studies are considered as both legitimate research methods, but sometimes also the only approach available to study a given phenomenon (Silverman, 2006). The case study approach is of particular convenience when processes or phenomena are to be studies in detail, and especially, when the boundaries between the phenomenon of interest and the context are not evidently clear (Yin, 2003). For example, case studies are frequently utilized to describe, explore or explain social phenomena in studies within knowledge management and industrial network settings (e.g. Easterby-Smith, 2000; Håkansson and Snehota, 1995) since they provide the possibility of rich and detailed descriptions considered necessary to characterize, e.g. change and learning. Consequently, given the purpose, the complex empirical context and theory utilized in the current study, the case study methodology seems like an obvious choice.

3.2.1 THEORETICAL CONSIDERATIONS

Since models not only provide a framework for understanding a given phenomenon, but also hints how it can be uncovered and explained, the theoretical framework chosen is of central importance when stating the purpose of the study by providing assumptions of reality that can be identified and analyzed (Wieviorka, 2000; Silverman, 2006). Although the theoretical chapter of the thesis described a number of different theories, the main theoretical concepts assumed in the study are those of *projects as networks, uncertainty, interaction* and *knowledge*. As indicated in the previous chapter, neither the process during which the theoretical concepts were chosen nor their internal consistency was straight forward. In the case of consistency, it seems reasonable to argue that none of the concepts mentioned is theoretically unified, which means that each of them comprises a variety of sub-models and interpretations. For example, many publications within the industrial net-

work approach (INA, cf. Section 2.1.1) have characterized interaction using the so-called ARA-model while others have employed an earlier related version called the interaction approach. Furthermore, several publications have emphasized the difference between interaction among organizations in stable networks and interaction occurring in networks of more temporary nature, e.g. projects. In some previous studies, uncertainty and knowledge have been interpreted as more or less parts of the concept of interaction. However, in this study a distinction is made between these concepts in order to investigate each of them more closely. Although, concepts such as network, interaction and project not show any significant contradictions in this thesis, the point is that seemingly coherent theoretical approaches often show significant pluralistic views, which contribute to illustrate important aspects of the perspective, but also that a framework comprising more than a single theoretical perspective shows additional plurality.

Studies as the one indicated implies a number of aspects, which not only pose possibilities but also constraints to the research process (Pettigrew 1997). One of the greatest dangers of qualitative research is to try to report everything (Silverman, 2006). By clearly defining the unit of analysis at the very outset of the enquiry, the study becomes focused and the possibility of obtaining pertinent data improves (Yin, 2003). For example, Halinen and Törnroos (2004) argue that case studies on networks confront at least four difficulties: (1) the problem of network boundaries, (2) the problem of complexity, (3) the issue of time and (4) how to compare different cases. In this study, the boundary of the network was defined by both the project, i.e. the three actors investigated, and by other relevant projects of the organizational context using the approach described in Section 2.1.1. The three other difficulties are considered to be related to the first difficulty and are taken into consideration also by the theoretical concepts used for the study. For example, the high degree of complexity inherent in procurement methods was partly restricted by focusing on a few numbers of uncertainties, aspects of interaction and types of knowledge gained by the three actors investigated. Although not considered to capture all the details, the four aspects of uncertainty finally chosen are, for example, considered to emphasize several of the most important issues thereof. The choice of theoretical

concepts also provided a possibility to compare different procurement methods. The complex issue to characterize the question of time was made partly by restricting the study to a number of years for each case, where both a focal project and projects of the relevant context could be studied, and partly by subdividing the focal projects into three phases. The issues discussed were important as the methodology aims both at developing a conceptual framework for understanding uncertainty, interaction and knowledge gained, and to examine how they are related to project procurement method used.

Parallel to the acquisition of empirical data, theoretical studies were carried out that indicated that knowledge could be analyzed using concepts related to projects, uncertainty and interaction. Explicit focus on innovation and product development was down-played based on findings presented in the literature. In particular, during the investigation it gradually became obvious that much more questions occurred in the unconventional project compared to traditional ones, a circumstance that appeared to be related to degree of uncertainty resulting from lack of institutions.

3.2.2 THE TWO CASES

Based on the aim of the study (cf. Section 1.3), the context of construction project procurement and the information and discussion provided above, it was considered appropriate to choose a longitudinal multi-case study based on two comparatively large infrastructure projects. Multi-case studies often rely on some type of replication logic and, consequently, the cases do not have to be representative of the population as a whole. Rather, the cases are often selected based on the particular characteristics that are under investigation. Consequently, the cases are not representative because of the observed frequency at which the phenomenon of interest occurs; they are representative by pre-established criteria defining them as preferred observations point for the study (Eisenhardt, 1989). Given the importance of institutional framework associated with infrastructure projects, it was decided that the study primarily would constitute two focal projects, one representing a comparatively traditional project and the other an unconventional one. Both projects constituted sub-projects at a large infrastructure project outside Stock-

holm denoted “Norrortsleden”. The two projects chosen were selected partly due to data accessibility, i.e. prior knowledge of them, physical proximity and access to interviews and observations, but also superficial similarity, e.g. concerning the, so-far, successful construction of relatively large road-infrastructure projects procured by one and the same client sharing similar history. The choice of road projects also means that a number of actor categories, resources used and activities performed are similar in the two focal projects.

The first focal project is intended to represent a traditionally procured project, chosen to provide a contemporary picture of a typical construction project as a basis of comparison. The focal project of the second case is intended to represent a polar project to be contrasted with the first, traditional, project. The main reason for choosing the two polar projects indicated was to illustrate potential differences as well as similarities between the two on a relatively detailed level, which also is considered to provide additional robustness, compared to many previous studies on procurement methods. In essence, it was desired to select cases to ensure variation since it provides the possibility to increase the understanding of the phenomenon investigated (cf. Eisenhardt, 1989).

As discussed in previous chapters, an important aspect of interest for the current study concerns interaction and knowledge associated with other projects. In order to investigate whether connections were established from the focal project of each case to other projects constituting the organizational context, each case also included a number of historical and subsequent projects. These projects were to a large extent chosen based on whether they were mentioned during the interviews or whether I by other means knew that they might be of relevance for the study. Also in this case, these projects comprised only larger road infrastructure projects.

The main reason for focusing on road projects is the opinion that the road-related activities of the projects are the activities that are most affected by differences in procurement method. For example, although connection may exist between any focal project studied and other types of projects, e.g. housing projects, they were considered as out of scope

for the current study. Furthermore, roads also show a number of similarities (repetitive projects) that allow ease of generalizability compared to many other types of projects, which may provide interesting analysis and conclusions. Consequently, even though any of the infrastructure projects studied may comprise other activities, e.g. the construction of a bridge, tunnel or advanced ventilation system, such construction elements are of less interest compared to the road-related aspects. Such remaining activities may, however, be brought into the description for reasons of comparison and illustrating interesting aspects of the projects.

Early during the research, it also became apparent that all aspects regarding the actors, their organizational levels and the projects and their phases as well as other projects of the immediate context could not be given space in the study. Accordingly, the study was restricted to cover only client, main contractor and main consultant, on a rather non-specific organizational level, during a conceptualization, procurement and contract phase. Although circumstances occurring prior to the conceptualization phase, including application of work-plans etc., are important for the success of an individual project, such a stage was not considered as important as the phases included in the study.

In addition to the motives given above, the cases were also chosen on more pragmatic reasons. One such reason concerns data accessibility where the two focal projects were procured and constructed at the time of the study, which provided access to data by interviewing key personnel and observations. Furthermore, although road projects sometimes are comparatively well described in detail in public sources, this is particularly true in the case of the current projects. The unconventional project was at the time of the study subject to an inquiry by FIA[13] (FIA, 2005, 2006, 2007, 2008) and widely discussed in the industry, which

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[13] FIA (short for "Förnyelse i Anläggningsbranschen", Renewal in the construction industry) constitutes an industry organization created on the initiative by the general-directors of the national Road and Railroad administrations in December 2003 to reduce perceived problems of the industry (http://www.trafikverket.se/Foretag/Bygga-och-underhalla/Branschsamarbete/Fornyelse-i-anlaggningsbranschen-FIA/Om-FIA/).

also provided an important source of secondary data. In addition, the two projects have been described in Swedish in a book by the STA (SNRA, 2008) and in undergraduate reports (e.g. Bjerneling and Åberg, 2011). As indicated by the other investigations mentioned, the project participants were also willing to provide information in the form of interviews and written material of the projects. However, in contrast to the current research, the investigations indicated above were to a large extent focusing on more general aspects of different project phases, while often neglecting important information of interest for the current study regarding certain detailed administrative and technical aspects. For example, the question of technical design and measures taken to reduce uncertainty were not particularly analyzed. Furthermore, the investigations were essentially devoted to analyze the unconventional project, primarily regarding cost efficiency, cooperation and creativity, largely independent of influence from historical and future events: circumstances which are of particular interest in the current case study.

Limitations

It is of course impossible to cover all aspects of interest within a case study such as this. The choice of cases for the empirical study was mainly based on ability to distinguish between traditional procurement, using procedural specifications and conventional undertakings, and unconventional procurement, which mainly relies on performance requirements and a responsibility covering a comparably wide range of activities including design, construction, maintenance and operations. Hence, although aspects such as contract length, activities contracted, and requirements used important aspects, other aspects such as type of compensation and type of cooperative agreements between the different actors may be important as well.

One limitation associated with the length of the study and, thereby, data collection is that important circumstances occurring before the studies begun, had to be investigated in retrospective. This was particularly the case of the early phases of the focal projects, and in particular the traditional one, as well as the historical projects. Furthermore, in order to limit the study, the time dimension of the research was restricted to five years after the first traditional project had been opened for traffic (until

the year 2012). Consequently, in the empirical part of the study (Chapters 4-6) each focal project is defined to consist of a time-period between design/preparation and four to five years after the main construction activities on site have discontinued. The main reason for dividing each focal project into a sequence of three separate phases is that differences regarding each characteristic instigated may differ during the course of a project. Furthermore, mainly the three actor categories considered as the most relevant: client, main contractor and consultant (cf. Section 4.1) were focused on despite that other actors probably also are of interest for a study.

As described in Section 2.3.2, interaction was distinguished whether it concerned within a given project or among projects by connections. For practical reasons it was not possible to characterize inter-project interaction to the same detail as within each focal projects. The notation of connection was utilized as a simplification as well as an implicit means of indicating interaction with historical projects to the focal project or from the focal project to a project occurring in parallel to it (within the time frame defined for the focal project). Accordingly, the cases illustrated in the current investigation are considered as larger than any individual project despite that the latter may constitute a large part of the former category.

Since construction projects comprise a wide range of versatile activities, the main focus was on certain administrative and technical aspects, in particular aspects related to road construction and pavement design. These comparatively specific topics are partly considered as the main topics of interest with the regard of the problems identified in Chapter 1 but largely ignores other interesting aspects such as those of environment, health and safety. Since both accessibility and relevance to the research question were slightly more restricted in the traditional project, more information was gathered from the unconventional project.

3.2.3 DATA COLLECTION METHODS

Case study methodology not only implies research design but also, more or less specific, techniques for data collection and data analysis. Given the inherent contextual complexity, analysis may be difficult since it

often is performed on a relatively restricted number of empirical data. Hence, a central methodological problem of qualitative research is to achieve sufficient reliability of data collection methods and the representativeness of the sample (Silverman, 2006). Furthermore, a certain data acquisition method may not be suitable for collecting data regarding a certain phenomenon. As a consequence, case–study research normally utilizes several sources of data, typically collected from sources such as documentation, interviews and direct observations. One argument for such a strategy is that multiple sources allow the researcher to gain more insight into the research problem, and, thereby, increase the probability of recognizing aspects that would otherwise not have been observed. Using several methodologies is also considered to increase both the quality and credibility of a study since additional sources may provide support for findings obtained of other sources by triangulation (e.g. Eisenhardt, 1989). For example, data acquisition using observations can be criticized on the basis of subjectivity and unreliable perceptions. However, it can be argued that the use of several methods reduces this risk since the methods mentioned complement each other. In the current investigation, three basic sources of data were used: literature studies, observations and interviews.

Literature studies

The first type of the data collection concerns literature studies, which, in principle, were carried out during the entire research work. Initially, studies were directed towards the empirical setting, i.e. procurement methods and contracts as used in the construction industry as well as the context of the focal projects used in the empirical investigation. An important category of literature reviewed was domestic research on unconventional procurement, in particular historical efforts within the construction sector to apply Design-Build arrangements. In addition, studies had also been devoted to technical requirements and design methodology, which resulted in a pair of review papers. The literature review comprised among others text books, academic journals, technical reports, newspaper articles, case studies and governmental reports. In addition to these sources, specific material regarding the two focal projects was also available. The documentation consisted mainly of publicly available information, including official reports published by the Swe-

dish transport administration (STA) and the National road and railroad research institute (VTI) etc. In addition, procurement material including contracts, administrative documentation and other general publications of the two projects could easily be obtained either by public accessibility or by respondents involved in the projects. Such material was also available and studied regarding a number of historical and subsequent projects. These publications were of particular interest when studying how the client successively changed their procurement methodology with time. Another important source of data was the written communication between the actors during procurement. For example, many questions and answers were communicated in writing within the projects investigated. The main problem of the literature study was not difficulty of accessing material but rather to restrict it given the broad and versified field. Consequently, not all available material could be covered by the study. A second major direction of literature studies concerned the theoretical concepts used in the study, which was partly motivated by the empirical setting but also research questions and purpose of the study.

Observations

A large part of the empirical study was performed by direct observation. In some sense, the observations actually started earlier than the other data collection methods but to some extent also before the formal research actually had begun since I had the opportunity to observe how both focal projects studied were discussed within NCC during bidding in 2004 and 2005. Back then, the two projects constituted a pair of only few projects procured by the STA, and I had the possibility to get some information regarding how the bidding occurred in practice and the opinion individuals had regarding different procurement methods.

When the formal research started the subsequent year, I had even more possibilities to observe what occurred in the projects investigated. Among other, I had the possibility to participate in some internal meetings within NCC and with other actors where comprehensive and relatively detailed issues were discussed. This provided additional understanding of the specific conditions and possibility to make own experiences, and consequently, decreased the potential problem of solely depending on the opinions of others. Observations also provided the pos-

sibility to shift focus as interesting new data becomes available (Platt, 2000; Silverman, 2006). In order to increase the understanding of site-specific conditions, several visits were also made to the project site of each focal project at different stages. During these occasions, informal meetings or discussions were normally held with the personnel on site. The observations were both performed at the construction site and on the site office.

In addition to the observations on site, a total of ten meetings between client-contractor, contractor-consultant and all three actors mentioned, were also attended. The observations during meetings primarily concerned the procurement and construction phases but also during the five years following the essential on-site construction activities. Furthermore, at least one meeting was devoted to each subsequent project indicated in Sections 5.3.3 and 6.3.4. Another type of observations were conducted at a few public industry seminars, which provided the possibility to meet and discuss specific issues with managers and specialists. In two cases, such meetings resulted in that questions also were sent regarding specific issues to two specialists (one of the client STA and one specialist of Sweco). Given the presumed sensitivity of the meetings, tape-recording was, in contrast to the interviews, not attempted during the observations, but primarily by notes and meeting minutes when available.

Interviews

Interviews constitute the most commonly used data collection method in case studies (Silverman, 2006) and represent the third main empirical method of the current study. The strength of qualitative interviews is that the situation during which they occur is similar to an everyday experience and an ordinary conversation. The researcher also has the possibility to control the conversation in order to gather relevant information. However, even though commonly adopted in qualitative case study research, interviews may be associated with significant limitations. One of the main disadvantages of interviews is that the data is mediated, not only by technical means, but also through the respondents, whose statements might be affected by individual experience and attitudes (Silverman, 2006). For example, a given individual might have

reasons not to disclose certain information. In this case, it is important to reflect over the moral realities as well as potential power balance with the interviewees and their interests.

The main bulk of interviews performed in both cases were conducted between June 2008 and October 2012 with employees from relevant actor categories of the two cases. The first formal interview was conducted with a client project leader who had presented aspects of the projects at a number of public seminars. The first contacts with the interviewees were made by e-mail where I described the purpose of the interview and my research as well as the type of issues that I was most interested in. In no case was any potential respondent reluctant to participate. However, three respondents did not want to participate with name or did not want all details discussed during the interview to be public. This was especially the case when individuals, other organizations or other sensitive questions were discussed. Hence, it was decided to promise general anonymity. The interviews were generally conducted at their offices in a peaceful and uninterrupted way.

The interviews were based on an in advanced supplied semi-structured interview guide where a list of topics and questions guided each interview. The common topics comprising the guide were to a large extent based on the purpose and theory (cf. Chapter 2), and partly intended to capture general aspects, e.g. the facts regarding the respondents, the positions and organizations in which they were working including significant projects prior to the focal projects studied. After these facts had been noted, the interviews were directed to the focal project of the study, its history and the role of the respondent during the different project stages. It was among others important to understand the reality of the respondent, e.g. experiences made in the projects. Each interview was also taking the different role of the respondent into account. For example, respondents with more general roles, e.g. procurement specialist or subcontractor, were deliberately asked questions regarding also more general aspects, e.g. regarding appeals within the industry and whether differences exist concerning cooperation with larger contractors, respectively. Given the researcher's knowledge of infrastructure projects, including administrative and technical aspects, a large

part of the interviews were also devoted at how the different actors interpreted and performed activities associated with contractual aspects, bidding, and technical requirements and design. The material obtained during the sessions occurred in interaction where an initial question based on the interview guide often resulted in discussion and an answer, which, in turn, resulted in a new and often more specific question. The semi-structured approach also facilitated the ability of achieving consistent information of all interviewees in certain question. For example, many interviewees expressed similar opinions concerning the industry, its organizations and how projects are procured including available methods. However, although all interviewees were well informed regarding different procurement methods, different opinions sometimes occurred regarding their adequacy depending on personal experiences. The use of open-ended and more specific questions is considered to have provided the possibility to confirm whether the interviewee had a deep and thought through perception of the topics discussed as well as a measure of saturation (cf. Eisenhardt, 1989), i.e. whether the same information was repeated. Furthermore, the information of each interview was compared with information obtained in other interviews or other data collection methods. The main reason for using semi-structured interviews was partly based on the ability to achieve detailed information by asking specific questions, but also to reduce risks of missing interesting information by being too specific. Although the list of topics essentially was the same in all interviews, the questions were changed several times during the process. In many cases, it was considered also appropriate to rearrange the sequence of questions or add additional questions to obtain a deeper understanding regarding a certain issue. This was particularly the case after a number of interviews had been carried out and respondents tended to deliver similar answers but also new refined information. Consequently, the interview guide used in each interview was in most cases unique in one way or another.

The choice of interviewees was based on project participation and identified based on publicly available organization sheets. All respondents chosen were considered as experienced and possessing knowledge regarding not only own responsibilities but also the industry as a whole.

In several cases, the respondents had previous experience of working for other organizations and even in the role of another actor category. In two cases, the respondent was retired, while three held new positions in the same organization. Four respondents had started working for a new employer. The selection criteria for the interviewees were not only based on long experience, knowledge about construction business in general as well as being participating in the execution of the focal projects, but also to achieve a relevant mix of perspectives. The respondents were thereby intended to represent different organizations, e.g. client, contractor and consultant. The different actor categories may serve to provide information regarding the reasons behind certain decisions and actions taken during the investigation. In addition, it was considered as important to achieve representation from middle- to top-level management. In total 22 interviews were conducted with procurement staff, site managers, quantity surveying staff and technical specialists mainly from the three actor categories studied. Most of the interviewees had a background in civil engineering or other technical area with a few exceptions, for example one of the senior managers. In the case of the client, several project leaders directly involved in or associated with the two focal projects were interviewed. In the case of contractors, primarily site managers, area managers and more senior managers of the two companies involved in the projects were contacted. Three interviews were held with consultants working with road-related issues including pavement design. In addition to the categories mentioned, interviews were also held with other actors, e.g., subcontractors and suppliers of important construction materials.

Table 3.1 Interviewees approached during the study.

Actor	***Organization***	***Role***	***Date***
Client	STA	Project leader	2008-06-13
Client	STA	Project leader	2008-08-20
Consultant	Sweco	Technical specialist	2008-09-01
Contractor	Svevia	Business Manager	2009-01-21
Contractor	Svevia	Site manager	2009-02-11
Contractor	NCC	Regional manager	2009-02-13
Client	STA	Procurement specialist	2009-02-23
Contractor	NCC	Technical specialist	2009-03-05
Consultant	Sweco	Manager	2009-04-07
Contractor	NCC	Site manager	2009-06-05
Contractor	Svevia	Quantity surveyor	2009-08-11
Contractor	NCC	Site manager	2009-09-03
Subcontractor	VSM	President, subcontractor	2009-09-08
Contractor	NCC	Supervisor	2009-10-30
Contractor	Svevia	Technical specialist	2009-11-05
Client	STA	Project leader	2009-11-10
Consultant	Grontmij	Manager	2010-02-16
Client	STA	Project leader	2011-02-11
Contractor	Svevia	Technical specialist	2011-04-14
Contractor	NCC	Site manager	2012-08-23
Consultant	Sweco	Technical specialist	2012-10-05
Contractor	Svevia	Division manager	2012-10-08

Each interview was tape-recorded in order to concentrate on the dialog, rather than making notes, and thereafter transcripted. The transcription was carried out word-by-word except in cases where the interviewee would discuss topics of less relevance or issues that essentially were repetitions of previous interviews. In such cases, the discussion was summarized. The use of recording significantly facilitated the possibility to include quotations in the empirical chapters. In general, almost all the

interviews were close to two hours. In most cases, the respondent had brought documentation with them to the interview, e.g. own notes or technical descriptions, to verify issues or circumstances. In some cases, e.g. important dates or other interesting circumstances, where no documentation could be provided at the interview, the author could complement it with own search after the interview. The data collection procedure described often resulted in that the source resulted in new proposals to investigate. For example, in some cases a certain interviewee suggested another person who might possess additional information. With a couple of interviewees, more than one contact was conducted. This was in particular the situation when the interviewee not only participated in one of the focal projects investigated but also in a, later, subsequent projects, or even organizations, of relevance for the study. Another reason for contacting a respondent was to verify specific information, e.g. dates, numbers or other data of certain relevance for the study.

3.2.3 PRESENTING THE CASES AND ANALYZING THE DATA

In this section, the establishment of the two cases and their analysis are described in more detail.

Establishing the cases

Although the studies in some respects appear so, the work was by no means linear since gradually increasing understanding was achieved as knowledge from the data acquisition successively was obtained. Each case was written down several times and in several ways in a separate chapter. However, with time, the two chapters representing the cases became ever more structured, e.g. by sharing the similar sections, headlines etc. Of particular importance during this time was the successively appearing new projects initiated during the time the two focal projects were studied. Which, how many of these projects, and the extent they should be investigated were successively decided largely based on relevance, data availability and the researcher´s work capacity. Since the study was conducted over a relatively long period, not only the scope of the study evolved, the organizations studied also changed. For example, several of the organizations concerned by the study changed by reorganizations, mergers and even by name. When the study started, Svevia,

Grontmij, the STA was called Vägverket Produktion, Carl Bro and the Swedish national road administration (SNRA), respectively. However, although name changes even occurred at a relatively late stage in the study, and older names were used by the organizations for a majority of the study, the current names were consistently used within the thesis.

Capturing the theoretical concepts

One of the more important issues during the study concerned how the theoretical concepts would be obtained from the empirical part. The concepts used to study procurement methods: uncertainty, interaction, knowledge, was each analyzed using the data collection methods presented in this chapter and the aspects given in Table 2.1. However, the concepts and aspects were not directly utilized by the researcher to obtain the data, at least not during the interviews, by any direct question to the respondents. Instead, they were primarily obtained by indirect means such as by asking questions regarding scope of the project, by observing the behavior of the actors in practice but also by interpreting written text. In the case of interaction, questions were, for example, asked regarding the type and number of meetings held with other actors of interest as well as topics covered rather than by asking the respondents explicitly how they interacted. Although some problems occurred, e.g. several respondents used different terminology for meeting categories, the interaction could be determined based on the data obtained. For example, the interaction could be determined from that a respondent indicated that he or she had participated in meetings at a certain frequency and by expressing a subjective view regarding the frequency, e.g. that it was "intense". In the case of knowledge gained, this concept was partly captured by asking the respondents which projects had been initiated and carried out during a certain time-period and whether circumstances of the current project had affected these other projects. Another question during this time was what perspective the different concepts should be perceived. In principle, uncertainty, interaction and knowledge gained could be interpreted from a given actor´s perspective, within the relationship, at a project level or above. In this study it was decided that the concepts generally would be perceived mainly from the researcher's perspective, partly due the experience of the researcher but also for the ease of analysis. In some cases, answers needed to be inter-

preted. For example, in one case a respondent argued that the technical design was not set until the contract phase. However, the experience of the researcher made it possible to nuance the statement: the design was not *formally* set until the contract phase, but was, at the same time, in all essence in accordance with the design used to calculate bids during the earlier procurement phase.

Analyzing the cases

In principle, analytical strategy can be performed using a number of different data analyzing techniques (e.g. Yin, 2003). Using the content indicated in the previous sections, the two cases were analyzed first individually and then by comparing them to each other. This was basically performed by marking each of the three concepts in the written text using different highlighters: red colour for uncertainty, yellow colour for interaction and green colour for knowledge gained. In principle, the analysis followed to some extent the data collection made by reducing the data, refine it, partly by additional literature studies, and draw conclusions.

3.3 EVALUATION OF THE STUDY

In qualitative research, the terms validity and reliability are not obvious since they originally stem from quantitative disciplines (Yin, 2003). In contrast, qualitative case studies involving descriptive data can employ the terms research quality and trustworthiness to indicate whether findings match reality and whether they can be generalized and applied in other situations.

3.3.1 RESEARCH QUALITY AND TRUSTWORTHINESS

Obviously, not everything can be covered within a single study, which may have resulted in important information having been consciously disregarded. The current study was limited to two cases, each constituting a focal project, divided into three comparatively distinct phases, and some previous and subsequent projects. Discrepancies and gaps in the data were checked as much as possible and, in many cases, the interviewees provided feedback on the transcript material and offered additional information. It is important to notice that the way data was collected in the interviews means that the findings to a large extent rely on

the interviewees' perceptions. Hence, the possibilities to capture discrepancies between what the interviewees said and meant about the issues and what was actually done, may differ. This can be of particular relevance in the case that the interviews were made in retrospective since respondents may have difficulties to recall certain issues. However, on the same time, by asking questions to close in time, a respondent may be reluctant to reveal his or her opinion regarding sensitive issues.

By carrying out many interviews, observations and reading many documents, which provide consistent and sequentially related results, I consider so-called triangulation (e.g. Yin, 2003) to have been achieved. Triangulation is generally considered a way of achieving sufficient research quality and can be performed by comparing analysis results obtained using different data collection methods as well as with theory. By performing many interviews with established actors of different background, a coherent view of reality of the phenomena studied has been possible. There are also other methods which have provided support for research quality, including comparing the results with other theory, discussions with fellow researches and that interviewees and personnel involved in the study provides the possibility to confirm what has been written in the thesis. Preliminary results have been discussed not only with individuals at informal occasions but also at conferences (e.g. Transportforum in Linköping) and seminars (with the STA and at KTH). However, even though triangulation is attempted, a complete picture can, in principle, never be achieved but only complementing pictures which result in a better understanding of the phenomena studied (Silverman, 2006).

The research quality also concerns whether it is possible to generalize the results (Silverman, 2006). Although the results may be possible to generalize, which also is indicated by the support provided by theory, several problems also exist. Since only two cases were used in this study to generate results, it is probably difficult to transfer certain findings beyond the current study. For example, the situation back in 2006 regarding the view of procurement methods was probably different than it is in the future due to the radically increased number of unconventional procurements made during the years. Today, it is probably even possi-

ble to suggest that D-B and D-B-M procurement methods are normal, and, hence, no longer "unconventional" to the same degree as during the years of the current study. Furthermore, the mapping of connections among projects may, for example, also be completely different than suggested in this study since they probably increase with the number of projects launched and investments made. However, although difficulties of transferring findings exist, some findings are possible generalize.

3.3.2 CREDIBILITY OF THE RESEARCHER

As to the credibility of the researcher, it can be argued that the capabilities of researchers in generally differ regarding both data collection and analysis. When it comes to data collection, my personal background has provided important insights to both the basic context as well as specific aspects regarding both procurement methods and technical design. Although many technical aspects of road construction and design methodology were known prior to the research, the process during which the study was performed provided new perspectives regarding how different actors perceive their situation. I have during the entire research process tried to remain as open-minded and objective as possible. However, I do recognize that that interpretation and analysis involves, at least, some degree of subjectivity. The fact that I have been employed by a company (sub-contractor) involved in one of the two focal projects, as well as subsequent projects, has to some extent affected the research process. Besides ease to access certain information in the form of individuals and documents in that particular project, e.g. possibilities to participate in meetings or to see documentation constituting the foundation of certain decisions, no significant possibilities is considered to prevail that have affected the main conclusions drawn from the study. Although I served as a coordinator regarding some technical issues early in the project, interviews and visits to the construction sites were mainly conducted within the role as a researcher. In the case of organizational belonging, the main purpose of the current study was to compare procurement methods rather than different organizations. For example, in my opinion the data gathered suggests that both contractors studied approach different procurement methods approximately similar. Consequently, the fact that different contractors were involved in the two

main projects studied is not considered to have affected the findings drawn.

4 CONTEXT

This chapter aims at providing a context for the two cases presented in subsequent chapters. The first section provides a short general description of the main actor categories while the following section presents important aspects of the institutional environment. The third section presents an overall introduction to a large infrastructure project, of which the two cases presented in Chapters 5 and 6 constitute important subprojects.

4.1 MAIN ACTORS

In broad terms, the construction sector comprises, in principle all activities directly contributing to the establishment, change and administration of buildings and constructions. The part of the sector which directly performs construction activities is normally referred to as the construction industry. In Sweden, this industry accounts for approximately 10 percent of GDP and employs around 450,000 persons, including actors such as material producers, equipment manufacturers, contractors, consultants and clients. The construction sector and its basic conditions have changed dramatically during the last 20-30 years, following significant booms, recessions and reorganizations. In 1990, the sector comprised approximately 24,000 contractors, a figure dramatically reduced by approximately 25 percent during subsequent years. The decrease was particularly evident among middle-sized companies. At the same time, the capability of many public organizations to act as professional clients has decreased due to a wave of privatizations in the western world. Besides the actors directly involved in construction activities, additional actors such as local and central government are also considered to be important since they play important roles influencing policies, legislation and tools. However, although many potentially important actors exist, the remaining sections of this chapter are primarily devoted to the three actor categories represented during the rest of this study. The first of these categories is a geographical division of the Swedish Transport Administration (STA). Section 4.1.2 and 4.1.3 provide a short description of important contractors and consultants in the con-

struction industry, respectively, several of which were involved in the two cases presented in subsequent chapters.

4.1.1 THE SWEDISH TRANSPORT ADMINISTRATION

As in most countries, the fundamental responsibility for essential public functions rests with the state, which, within the limits of its constitutional powers, delegates its authority to subordinate agencies and authorities. In this case, the construction sector devoted to civil engineering projects is to a large extent characterized by one large client organization, the Swedish Transport Administration (STA). This agency procures construction services annually for approximately SEK 30 billion, and, thereby, exercises great influence on the sector. Among other things, the STA bears the overall responsibility for the entire road transport system. Of the current total 430,000 km road network, 98,000 km, or 23 percent, belongs to the state and is regulated, administered and operated by the STA. Of the remaining road network, private roads account for approximately 67 percent and approximately 10 percent belongs to municipalities. Even though the other two principal categories mentioned bear the main responsibility for administration and operation of their share of the infrastructure, the roads are normally both regulated and financed, at least partially, by the STA. This responsibility means that the STA assumes a leading role in promoting and supporting the work of other actors within the road sector. In particular, the agency actively endeavours to fulfil the goals contained in the national transport policy, in particular accessibility, transport quality, safety, environmental sustainability, regional development and gender equality in the road transport system. An important task of the STA is to act as client for national construction projects[14] procured on a market comprising the contractors described in Section 4.1.2. In such procurements,

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[14] In principle, the STA has historically distinguished and organized its construction-related activities in three categories, of which the first constitutes investments, i.e. construction of new roads, bridges and tunnels etc. Maintenance, on the other hand, implies significant upgrades such as road surface realignment, while operations involve activities with less sustainable effect, e.g. snow clearance and repair of holes in the surfacing.

a main contract is often established between the client and a main contractor.

The historical background of STA comprises several significant and well-documented events, including its earlier manifestations, nationalization and how its main work tasks have evolved over the years, aspects which all have preceded and affected the current organization (cf. Pettersson, 1988; Liljegren, 2003; Österberg, 2003). Of the many historical events shaping the present organization, one of particular importance occurred in the early 1990s when the Swedish parliament initiated the first step of a major reorganization aiming at separating administrative activities from production-related activities. The first category became the domain of a dedicated road and traffic unit, while the second responsibility was allotted to a newly established production unit. A second step in the reorganization was to gradually expose the production activities of the new production unit to competition from private contractors (cf. Section 4.1.2). The rationale of this exposure to competition was to achieve cost reductions and quality improvements by providing financial incentives. In 1993, the first operations contracts were procured and in 1995 all state investment projects were obtained using competitive tendering procedures. At the time, the present government had far-reaching plans for transforming the production unit in a two-step process into an independent private contractor, plans which were redrawn by the subsequent government. However, in 1996, the production unit was eventually further divided into three independent business units retained within the STA. One of these three business units became the contractor Vägverket Produktion, which was assigned road-related production activities, while a second business unit, Vägverket Konsult, was made responsible for designing activities in competition with private consultants (cf. Section 4.1.3). In 2008, the parliament decided on the major reorganization of the public traffic agencies where the current STA was created by merging the former Swedish national road administration ("Vägverket") and the corresponding railway administration ("Banverket"). During this period, several other mergers took place, including Vägverket Produktion and Vägverket Konsult, which became part of Svevia and Vectura respectively.

During the empirical study, the STA was formally organized in seven comparatively independent geographical regions under a common Director-General of which the Stockholm region represents the client in the projects studied in this thesis. According to STA, productivity and production quality are important measures of projects and procurement methods. In 2012, the strategy was to obtain better value for money by improved productivity, innovativeness and competition.

4.1.2 CONTRACTORS

The second main actor category of the study is contractors, which represent companies performing the comprehensive execution of projects on the basis of the contract documents. In principle, contractors differ from traditional suppliers in the sense that they primarily perform their activities on site rather than delivering the product to other actors at the construction site. The Swedish construction sector is often characterized as a market comprising a few large and middle-sized companies, and many smaller companies with strong local connections. This situation is often conceived as the result of the last 20-30 years of significant booms, recessions and reorganizations (Andersson, 2003). Most large contractors currently operating, including multinational companies such as Skanska, NCC and PEAB, are engaged in a wide range of businesses including civil engineering projects such as roads, bridges, and tunnels, many of which are procured by national transport agencies such as the STA (cf. Section 4.1.1). As well as acting on similar market segments, the large contractors mentioned also show significant similarities when it comes to organizational structure and size. Although changing over time, the above-mentioned organizations have historically been geographically divided into business units for the different main products, e.g. house building and civil engineering. In the case of essential construction materials (e.g. aggregates, asphalt and concrete), they are normally sourced in-house by vertically integrated material suppliers, which in turn purchase auxiliary materials (e.g. cement, bitumen, road signs and surface markings) from external suppliers. In general, since purchased materials and services account for approximately 75 percent of the total costs of contractors (Dubois and Gadde, 2000), economies of scale, predictable prices and low transport costs by geographical acces-

sibility represent essential aspects for competitive advantage (SCA, 2005). A fourth large contractor engaged in infrastructure works was Vägverket Produktion (henthforth Svevia), the fully owned contractor of the then SNRA (cf. Section 4.1.1). Besides the contractors mentioned, or any of their domestic subsidiaries, a number of other comparatively large foreign contractors act on parts of the geographical market including Veidekke, Lemminkäinen, Bilfinger Berger and Oden[15]. According to the Swedish Competition Authority (SCA, 2005), competition among contractors on the infrastructure market depends on the project size and type of undertakings where the large contractors participate in most road investment and maintenance projects as well as operations contracts. In many cases, however, the large contractors employ smaller contractors to perform a great variety of activities as sub-contractors.

4.1.3 CONSULTANTS

Within the construction industry, the term design (or projecting) represents important activities nominally preceding the actual construction-related activities on site. Consequently, a third important actor category of the construction sector is consultants, a broad term denoting experts, including architects and engineers, devoted to investigations, calculations and evaluations, normally on the behalf of a customer, whose identity depends on procurement method chosen (cf. Section 4.2). Each year the STA procures technical consultants for approximately SEK 1 billion for different projects. Among the main consultants procured are the authority's internal business unit, Konsult, and private companies including the comparatively large firms Sweco, Carl Bro[16], Ramböll, WSP and Thyréns. However, although formal contracts are entered into each year between STA and consultants, contractors also continuously purchase consultancy work from the consultant companies mentioned. As in the case of the contractors mentioned in Section 4.1.2, many of the consultant companies present today are the result of significant indus-

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[15] In 2011, Strabag, one of Europe´s largest contractors acquired the majority share of Oden. In 2011, Oden changed name to Strabag.

[16] In 2006, Grontmij, one of Europe´s largest consultants acquired Carl Bro, which in 2007 accordingly changed its name to Grontmij.

try reorganizations and mergers over the years. However, consultants are not always strictly defined, and in some cases, authorities such as VTI[17], SGI[18] and universities perform consulting activities.

4.2 THE REGULATORY CONTEXT

As indicated at the beginning of this thesis, the construction sector is subjected to a wide range of formal institutions of which several concern laws, regulations and procurement policies. Some attention will be given to two of these institutions, namely the Public Procurement Act and the evolution of national procurement policy.

4.2.1 THE PUBLIC PROCUREMENT ACT

One of the most important formal institutions affecting the procurement of construction projects is the Public Procurement Act (SFS 1992:1528). In short, the Act means that products and services procured by public bodies, such as the STA, must be carried out using formal tendering procedures on a market in competition. In order to promote efficiency and objectivity, measures such as uniformity, clarity and standardized specifications are emphasized. The evaluation of tenders is of particular interest in a construction context. In this case, the Act prescribes that procurement should be based on either the tender that is *economically most advantageous*, or the tender exhibiting *the highest tendered value*. In the latter case, the procuring unit is in advance to make an overall evaluation of parameters such as cost, delivery date, running costs, quality, aesthetic values, performance, technical features, service, technical support, environmental impact etc. In practice, however, many procuring units including the STA often choose the former arrangement as a matter of routine. However, it does not necessarily mean that it is impossible for the procuring unit to accept economically favourable tenders under such circumstances, since, according to the Act, it is possible to accept a *variant* execution. In this case, variant implies an alternative bid fulfilling the same function for the end user, with no relevant disad-

[17] *Statens väg- och transportforskningsinstitut (Swedish National Road and Transport Research Institute).*

[18] *The Swedish Geotechnical Institute.*

vantages. The advantage with the variant might be lower price, better quality or additional service compared to the tendering documents. Among other important aspects regulated by the Procurement Act is that it supports three types of invitation procedures above a certain so-called threshold value: *open*, *selective* and *negotiated* procurement, respectively. The main difference among these procedures is in advertising, invitation to bidding and whether negotiations precede the selection of supplier. The choice of method is regulated and in the case of construction products and services, open and selective methods are the normal ones since they are only available in certain cases, e.g. when it can be motivated that it is not possible to specify requirements.

4.2.2 PROCUREMENT POLICY AND METHODS USED

This section is devoted to providing a short description of recent history regarding the policy of the STA and its use of different procurement methods.

First attempt at unconventional procurement

As indicated in Section 4.1.1, the early 1990s were in many respects an important period for the STA and, consequently, the entire construction sector. The economic crisis at that time not only forced politicians to radically reorganize the agency but also to increase public spending, which resulted in a significant increase in the number of infrastructure projects launched at the time. In order to meet the project demand, it was considered important to speed up the design, which in turn made alternative procurement approaches suitable (Grennberg, 1998). Partly based on early work of Grennberg et al (e.g. Grennberg, 1965; 1986; 1987; 1989; 1994) the STA initiated a number of so-called D-B projects[19] utilizing performance requirements (cf. section 1.1.1) in the mid1990s. These D-B projects were to a large extent based on procurement models originally developed for traditional D-B-B projects. The initiative for the new procurement strategy was largely the result of the then Director-General who approved the bearing ideas of the new pro-

[19] The main reason that the projects launched at this time are labelled D-B is the opinion that the responsibility mainly concerned design and construction activities.

curement strategy. However, the initiative was eventually terminated during the second part of the 1990s by his successor. Despite internal disagreement within the agency regarding procurement strategy, the STA decided to put a stop to all unconventional procurement methods indefinitely[20].

Second attempt at unconventional procurement

As a consequence of the problems identified in the construction sector during the last decades (cf. Chapter 1), the STA launched a new procurement strategy in 2003 in cooperation with the Swedish national aviation agency (e.g. Stopp & Belägg, 2003). This strategy aimed at increasing competition among contractors and suppliers, and was partly manifested by joint procurement of important materials such as bitumen and aggregates, which in turn were supplied to contractors awarded individual construction contracts. Another simultaneous measure taken by the STA was to apply so-called combinatory procurement, where small contractors benefitted from being able to submit bids on smaller undertakings while larger contractors at the same time could submit bids on larger parts by adding several smaller parts to a single bid. Some of the measures indicated met significant dissatisfaction from contractors and material suppliers and resulted in open discussions. In particular, large contractors argued that a part of the new strategy meant that STA, their regions and its internal business unit Vägverket Produktion (later Svevia), would become not only a customer and a competitor to the private actors, but also a monopoly supplier of necessary materials. In addition, several large contractors argued that it was no longer meaningful to conduct any own research activities and development work since it would become almost impossible to market any new products given the rigid market structure and inflexible product specifications. Instead, the large contractors argued that the STA should

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[20] The reason for the cancellation of unconventional projects was, besides institutional changes regarding environmental and traffic concerns, to a large extent based on the opinion that the D-B method had been abused by the contractors (Lövmar, 2000). However, although questionable performance had been shown by some early D-B projects, they have often been accused by contractors of actually being D-B-B projects disguised as D-B projects using supplementary performance requirements.

resume the use of alternative procurement methods based on performance specifications and longer contract periods. In the autumn of 2005, the transport administration developed and presented its vision and declared that a major objective was also to significantly increase the number of unconventional procurements once again. More precisely, in 2010, one of three paving and road projects was intended to be procured using design responsibility in one way or another. In addition, the STA desired more cooperative approaches to contract management based on mutual trust, long-term commitment and compatible goals (a.k.a. Partnering[21]). In order to facilitate a positive relational attitude at the industry level, a new industry organization, called FIA (short for "Förnyelse i Anläggningsbranschen" Renewal in the construction industry), was formed as a countermeasure to the problems identified in the sector (cf. Chapter 1). One of the initial tasks of FIA was to monitor and review parts of the procurement and construction phase of the project presented in Chapter 6, which was advertised as a national pilot project.

4.3 THE NORRORTSLEDEN PROJECT – AN INTRODUCTION

Road 265, the so-called Norrortsleden, denotes a 16 km long section of the future road system intended to circle Stockholm (cf. Figure 4.1). The main purpose of this new section is to improve accessibility in the region north of Stockholm. The project is located between the main roads E4 at Häggvik and E18 at Rosenkälla and is planned to be connected to a future north-south passage denoted Bypass Stockholm ("Förbifart Stockholm") which in turn will be connected to the sections already established (cf. Figure 4.1). While some of these sections, including the 5 km long road-stretch denoted the Essinge route, were built as early as the 1960s, other sections are more contemporary. One example is the so-called Southern link; a six km long road, most of which is located in a tunnel. At the last mentioned project, the principal client, STA (cf. Sec-

[21] *During the last couple of decades, the concept of so-called partnering has been globally promoted as a way of improving organizational relations and project performance. However, it should be emphasized that partnering is not a contract form comparable to the approaches given above. Instead, partnering is often characterized as an organization that is formed by implementing a cooperative strategy that modifies and supplements the traditional boundaries between different organizations in the market (Nyström, 2005).*

tion 4.1.1), had cooperated with, in principle, all the large contractors and consultants presented in Sections 4.1.2-3, either in their current organizational form or as a precursor to one of the remaining contractors.

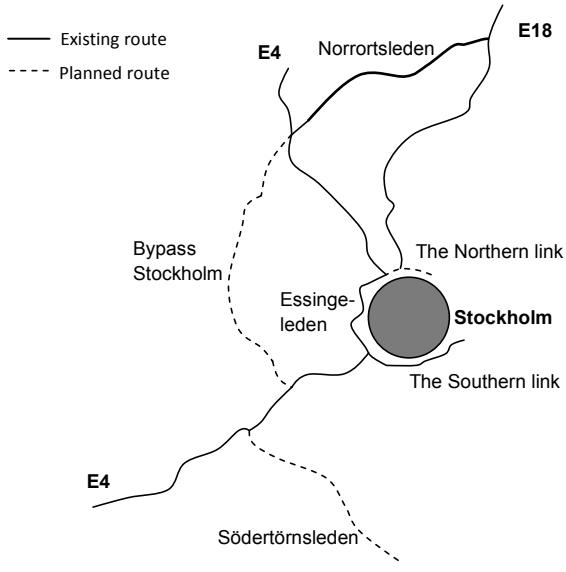

Figure 4.1 Map illustrating projects constituting essential parts of the future road system around Stockholm (2006).

The southern link project is also of interest for the current study for another reason: the project showed several significant problems related to the relationship between the client and several of the main contractors (Johansson and Nilsson, 2002; SNRA, 2008), which also constituted an argument for SNRA to initiate FIA (cf. Section 4.2.2).

4.3.1 BACKGROUND

From a historical perspective, the first time a version of the Norrortsleden project was mentioned in a regional document was in 1958, almost 50 years before it was opened for traffic in the autumn of 2008. Even though the road section in a historical perspective can be said to have celebrated 50 years from initial plans to final inception, it was mainly during the early 1990s that the project received a large boost as the section was presented as an integral part of a large national infra-

structure effort in Stockholm to alleviate the effects of the then recession.

The 1990s – Major design activities are initiated…and stopped!

At the time of the recession in the early 1990s, the STA engaged a number of technical consultants including precursors of the consultant company Sweco (cf. Section 4.1.3) to prepare documentation for future procurements. Among others were detailed plans for the road section developed from the eastern exit from the E4 highway to Täby-Kyrkby, a smaller town located approximately half-way to Rosenkälla (cf. Figure 4.2). It was difficult to find a route that was acceptable to all stakeholders including the County Administrative Board ("Länsstyrelse"), the municipalities concerned and different environmental groups. At the time, this approximately 9 km long section, of the total road length of 16 km, was solely intended to be sub-divided into two comparatively large subprojects. It should be observed that, at this time, the part east of the current traffic intersection Täby-Kyrkby was not an object of particular interest and only manifested as a broad outlined so-called work plan ("arbetsplan").

In 1997, the agreement of the so-called Dennis-package was eventually dissolved by a new government and gradually shut down, mainly due to new commitments and insufficient public financing. Of the entire project planned, only a comparatively short western part was actually constructed during the 1990s. However, planning and design activities continued since a future extension was considered inevitable.

The early 2000s – A new deal

Early on in new millennium, the entire Norrortsleden project once again experienced a revival as the need of a west-east link north of Stockholm had become even more urgent than during the 1990s. However, instead of simply using the plans and documentation established during the latter half of the 1990s, STA decided to upgrade the old plans for a coming Public-Private Partnership (cf. Chapter 1) during 2000 and 2001. This new direction of STA was inspired by foreign experiences and a memorandum presented by the Ministry of Enterprise, Energy and

Communications, in which a number of candidate PPP-projects for Sweden were mentioned, one being Norrortsleden. Accordingly, it was decided by the STA to continue the work as a PPP-scheme using a new organization comprising approximately 30-40 individuals under the supervision of a project manager. The organization indicated, which to a large extent comprised future project leaders of the individual sub-projects, carried out a substantial amount of work during a year and a half to develop procurement-related aspects of the contract. A significant feature of the PPP-scheme was to base the tendering documents on extensive performance requirements (cf. Section 1.1.1). In total, approximately 15-20 internal specialists were devoted to the performance requirements on part time. Most of these were engaged in the tunnel while two focused on the requirements of the road. Since the financial model also became an intrinsic constituent of the intended PPP-scheme, significant efforts were made within STA´s project group to analyze economic benefits compared to traditional financing approaches, e.g. possibilities to optimize capital costs, and investigating whether a conceived payment mechanism could be coupled to perceived costumer-value measured in terms of, for example, road safety. Besides the internal personnel, the work was to some extent followed and discussed by other STA regions as well as large contractors. Another individual who also provided input to the work was the enthusiast and in many respects the initiator of contracts based on performance specifications in Sweden, the former professor of the Division of Construction Management, Luleå University of Technology. In autumn 2001, the work with the PPP-scheme had progressed a long way.

October 2001 – The government bill

In October 2001, STA experienced an unexpected setback when the government bill was presented and nothing was stated about Norrortsleden or any PPP-scheme. Even though the PPP-scheme had been cancelled, the project as such was eventually given the green light to continue. However, instead of a far-reaching and complex PPP-scheme, the new initiative prioritized quick and effective procurement. In order to be able to rapidly start individual sub-projects a number of reconsiderations had to be made. In some cases, existing societal activities had expanded as time had passed and more people had moved to the area.

These changes affected the project since additional road connections were considered necessary. Another problem when restarting the project was related to technical standards, which had been updated during the time it had been put on ice. A third potential problem identified concerned delays due to appeals from different stakeholders. Since the road would pass through an area of significant environmental and cultural interest, it was expected to be sensitive to appeals during the remaining processing period. Hence, a major aim for starting the procurement process was to reduce risks of time-consuming appeals, and achieving a suitable flow of court decisions, by subdividing the previous two comparatively large projects into several smaller sub-projects in such a way that fewer projects did not require mandatory court decisions in order to get started.

4.3.2 THE SUB-PROJECTS AND PROCUREMENT METHODS

The historical evolution indicated in Section 4.3.1 led to the whole Norrortsleden project being subdivided into 11 larger sub-projects[22] under an overall project manager, where each individual project had the explicit aim of emphasizing environmental and working environment issues using external information, internal project meetings and questionnaires as well as social activities (SNRA, 2008). In addition, the project management had worked for a couple of years on identifying a number of concrete measures to encourage collaboration with other actors inspired by Partnering, which was manifested by, for example, joint site camps, common meetings and administrative routines, and conflict solution and profit sharing models. Even though sharing some organizational resources among individual projects, including staff devoted to issues involving administration, environmental issues and inspections, each individual project had an own relatively independent functionally divided organization. The client project leader of each individual project was subordinate to the overall project manager and responsible for the financial situation of the project. In order to manage on site day-to-day operations, each project leader was assisted by an or-

[22] *For the sake of convenience, the 11 sub-projects will in the reminder be referred to as simply projects rather than sub-projects.*

ganization comprising specialists divided on e.g. road, ground works, concrete and bridges and rock, surveying, measuring and controlling the progress of construction activities according to the contract in more detail. The majority of projects were dominated by the traditional design-bid-build (D-B-B) approach. One exception was the last project; the road project between Täby-Kyrkby and Rosenkälla, which was procured using an unconventional Design-Build-Maintain (D-B-M) approach.

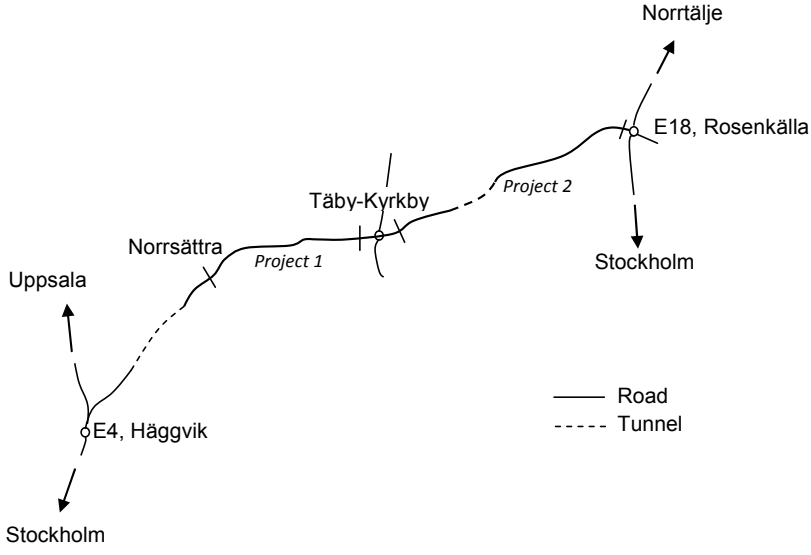

Figure 4.2 Location and distribution of some sub-projects. Project 1 corresponds to the traditional project and project 2 corresponds to the unconventional project.

Of the 11 larger projects constituting Norrortsleden, two are of interest for the reminder of the investigation: the traditional highway project between Norrsättra and Täby Kyrkby (Chapter 5) and the unconventional road and tunnel project between Täby Kyrkby and Rosenkälla (Chapter 6).

5 CASE 1 - THE TRADITIONAL APPROACH

The case described in this chapter primarily concerns one of the 11 larger projects indicated in the previous chapter, which represents a traditional project primarily aiming at establishing a 4.1 km long four-lane highway.

For the purpose of providing a clearer description of the case, Figure 5.1 shows a conceptual time-schedule illustrating the three main phases, design, procurement and contract, encompassed by the focal project (Sections 5.1-5.3). Section 5.4 is devoted to post-construction events until June 2012 when the warranty period of five years ended. In addition to the focal project, the figure also indicates previous and subsequent projects to which the focal project may be related.

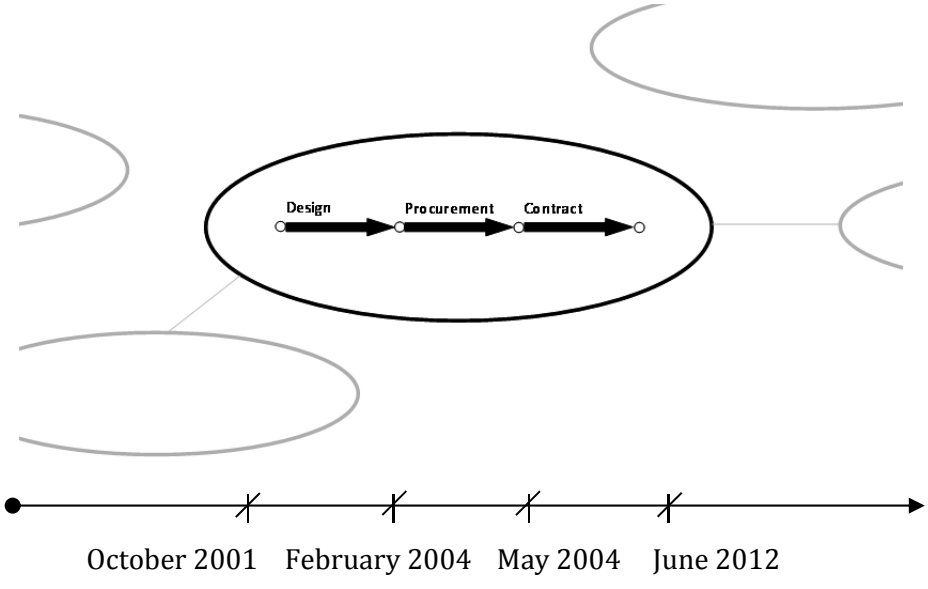

Figure 5.1 Overview of main project phases and activities studied as well as conceivable prior and subsequent projects.

5.1 DESIGN PHASE

In the design phase, the aim of the client was to obtain a conceptualization of the final product in terms of documentation and drawings, which could subsequently be used for procuring construction work (cf. Section 5.2). For the purpose of this study, this phase is divided into *choice of procurement method* and *establishment of tendering documents*.

5.1.1 CHOICE OF PROCUREMENT METHOD

Although the plans for the project had changed dramatically over the years, largely due to new political directives (cf. Section 4.3), the final choice of procurement method was in the end taken by the STA´s overall project manager to constitute a comparatively traditional D-B-B approach. This choice was conceived by the STA as a natural solution for the particular project at the time and not the result of any particular debate or discussion, neither within the client organization nor with any external actors, despite the fact that many clients, academics as well as large contractors, at an industrial level, had for many years spoken in favour of alternative procurement approaches (cf. Section 4.2.2). The decision to utilize the D-B-B approach was largely rationalized by achieving adequate competition among contractors, by extensive project subdivision in order to attract as many bidders as possible, but also to minimize the time to start up and realize the project. The ability to achieve a quick project delivery was facilitated by the circumstance of an already long-progressed design work based on earlier efforts (cf. Section 4.3.1) and the opinion that the D-B-B approach was particularly suited to ensure a smooth and efficient procurement process. Late in 2001, the consultant Sweco[23] started to update the existing design for the procurement due to changes in associated technical descriptions published by the STA during the years following the previous design (cf. Section 4.3.1).

[23] *Of the consultants involved the project, Sweco represents the company responsible for the aspects of most interest within this study.*

5.1.2 *ESTABLISHMENT OF TENDERING DOCUMENTS*

In general, respondents of both the client and consultant characterize the establishment of the tendering documents during this phase as comparatively uncomplicated when it comes to organization, personnel involved as well as the type and number of meetings held. Since the STA did not perform any significant design activities in-house, such activities were procured from Sweco based on a clause in the previous agreement from the 1990s (cf. Section 4.3.1). The two actors mentioned had worked together in a large number of previous projects, both local and nationwide, and, accordingly, many of the individuals involved already knew each other before the project begun. Furthermore, most previous projects showed many similarities with the current project when it came to work procedures, contract arrangement and product requirements. Both the STA and Sweco were located in Stockholm, which also facilitated personal meetings. The work on the tendering documentation was guided by STA´s general model[24], which comprised the essential procurement regulations and contract conditions needed. A general purpose document management system (denoted Chaos), originally developed during an earlier STA project (the Southern link, cf. Section 4.3) and used during all projects on Norrortsleden, was also employed to facilitate presentation of drawings and descriptions. Using this system, individuals of each organization and project phase could search for information needed in their work, publish results and get them reviewed and finally approved by other actors.

Organization of road design works

The road-related design activities were essentially performed in-house at Sweco by 10 consultants organized in four departments: *road and traffic*, *geotechnical engineering*, *rock engineering* and *bridge engineering*. Each of the departments mentioned based much of its work on technical descriptions either developed or sanctioned by the STA. Of the departments mentioned, three consultants worked with road design activities at the road and traffic department, while the remaining con-

[24] *Procurement model 2000 ("Förfrågningsunderlag 2000").*

sultants belonged to any of the remaining departments. In the case of the road and traffic department, the personnel comprised both senior and junior members. According to a respondent at the department, it was considered important to provide opportunities for younger coworkers to work with more experienced persons in order to transfer knowledge regarding formalities, work procedures etc.

> *It was a good opportunity for new employees to get involved in the work and obtain experience by working for more senior consultants (Technical specialist, Sweco).*

Furthermore, the mixing of individuals with long experience and recent formal higher education enabled the department to perform a broad range of design activities while maintaining an adequate level of redundancy. The efficiency of the design work was largely evaluated based on consultancy time to present and incorporate a given standardized solution that fulfilled technical standards.

Main design activities

In principle, the most relevant road-related design activities of the present investigation comprised *investigations*, *geotechnical design* and *pavement design*. Each of the three main design activities mentioned both required to be carried out strictly according to the assignment, prevailing technical standards, but also by taking the two other activities into account. The sequential interdependencies among activities can be exemplified by that a suitable so-called mass balance requires knowledge and coordination of all three individual activities. Although most design work was performed by Sweco, in some cases the STA provided the consultants with the necessary information, e.g. the amount and location of investigations, to perform the design. The outcome from the design activities was successively updated and presented in the client´s database.

The third main design activity mentioned, which also constitutes a main focus of the current study, concerned road design, i.e. analysis and normative suggestions of geographical and typological orientation of the road as well as its structural build-up, including number, type and

thickness of material layers. In principle, road structures constitute a number of bound (asphalt or concrete) and unbound (normally crushed rock) material layers intended to support future traffic and climate loading;, in general, the larger the traffic volume, the greater the need of thicker pavement structure and improved materials. As for the geotechnical design previously indicated, the technical part of the pavement design was not the subject of any particular discussion within either the consultant or the client organization. Based on the technical information communicated by the other departments, the consultants at the road and traffic department established a standard pavement design using a computer program distributed by the STA[25]. Using this software, thicknesses and materials were determined in order to achieve adequate structural integrity during the specified life expectancy. The decision to use the particular pavement type (a so-called rock-bitumen pavement) chosen was also based on the relevant STA technical description, which, among other things, stated that the particular pavement type should normally be used in cases with surplus of adequate rock materials.

> *The STA has an accepted standard for road pavement design. Traffic volume, distribution of vehicle axles, amount of heavy axles, materials in subgrade, and, of course, the life expectancy, which one can have different views on. These parameters constitute input when we use STA´s design tool (Technical specialist, Sweco).*

> *Based on existing norms, rules and regulations, they propose a pavement type. We subsequently review and comment, and, sometimes, make changes (Project manager, STA).*

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[25] The particular pavement design tool constituted a comparatively simple (static multi-layer linear elastic) model, able to determine theoretical life expectancies of a number of standardized pavement structures. In order to do so, the tool does not provide any explicit prediction of pavement performance in terms of cracking, rutting or longitudinal evenness during service, but rather whether or not the design satisfies a more or less fictitious life expectancy of 40 years.

No alternative candidate pavement type, also complying with formal requirements, was ever considered. For example, no alternative to the standard wearing course or base course layers of the pavement was ever considered despite their apparent use in other projects, for example, during maintenance works[26].

> *But we consultants do not actually have any opinion; we do not know what is preferable with respect to the execution and structural stability (Technical specialist, Sweco).*

Neither was any effort made by Sweco to explicitly investigate prior projects regarding technical performance since such aspects were assumed as implicit in the design model provided by the STA. Another topic that was not given any apparent importance by the actors was estimations of future maintenance costs due to the design chosen. For example, the consultants responsible for the road design did not perform any explicit financial investigations regarding different technical solutions. According to several respondents, the situation indicated was common practice in similar contemporary projects. One explanation for the reluctance to consider alternative designs was, besides unwillingness to increase the workload and investment costs, opposition from both internal and external stakeholders, such as local government authorities, which earlier in the process had been promised a certain architectural appearance.

Meetings

Apart from an initial meeting, a total of five different types of formal meetings were held between the STA and Sweco on a regular basis until the spring of 2003. One of the meeting categories indicated constituted five comparatively distinct information meetings with municipalities affected by the project. Of the remaining meeting categories, two basic types of formal standard meetings were held strictly between the client and the consultant. These meeting categories were both mentioned in

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[26] *During the time of the project, several new types of bitumen-bound layers (e.g. thin surfacing and binder courses) had been established in Sweden and used by the STA in other project categories.*

the contract documentation and familiar in practice to most individuals involved in the projects. First, *assignment meetings, or* so-called *A-meetings,* were held on a monthly basis between the project leaders and managers of each organization to discuss comprehensive issues such as the scope of undertakings, production times, work routines, additions and alterations, and financial issues.

The second meeting category, *technical meetings*, varied but was in general held on a monthly basis between individual consultants of a particular department (so-called C-meetings), or departments (so-called B-meetings), and the corresponding specialists at STA to discuss specific technical issues. The purpose of the joint B-meetings, involving more than a single technical area, was to inform other technical areas at Sweco of issues brought up in another technical area. Examples of questions brought up during the meetings concerned personal experiences of certain technical solutions and their perceived efficiency with regard to both technical adequacy and economy. The issues raised were normally discussed on a general and subjective level rather than based on theoretical and otherwise codified material. In some cases, deviant opinions were uttered, but the amount and degree of conflicting opinions were considered as normal for this kind of project. Besides the members of the main departments indicated, additional individuals were sometimes represented in cases when appropriate. For example, in a few cases, individuals working in contemporary projects, taking place in parallel to the current project, were invited with the purpose of mediating potentially important information. However, it was often considered important to restrict the number of participants in order to sustain an effective meeting which, at the same time, resulted in there still being some information gaps.

> *There is a large gap, lack of contact between those who build and those who maintain at the STA. It would be better if we also received the opinions of the latter category. I have never participated in a meeting together with any personnel from the maintenance department (Manager, Sweco).*

The technical C-meetings, involving the road and traffic department of Sweco and the corresponding specialists of the STA, were initially held every fourth week, while later reserved for cases considered necessary. The purpose of these meetings was mainly for Sweco to report the design status and present chosen technical solutions to the corresponding two technical specialists at STA in order to discuss specific technical issues including formal requirements and to what extent they complied with established technical descriptions and standards. In addition, four meetings to review the results were held between the client and consultant.

A fourth, less formal, type of meeting was the internal technical meetings where individuals, or departments, met to discuss and coordinate certain design activities. In the case of Sweco´s road and traffic department, these meetings were initially held every third week, while later in the design work, in case of necessity. The meetings were primarily held in cases when it was considered important to present technical solutions chosen to individuals specializing in other technical areas in order to obtain a common picture of the project. Another purpose was to ensure that there was no duplication of work performed by the different technical areas. In general, formal notice was given of the meeting categories mentioned and they followed a fixed agenda with the intention of clearly coordinating work tasks.

Apart from a formal *start meeting* early in the contract phase (cf. Section 5.3.2), and a few individual participations in meetings to discuss certain technical problems, the design activities were in principle completed after drawings and detailed descriptions had been established and delivered to the client. Consequently, the last part of the design phase constituted of finalizing the procurement documentation and preparing for the next phase.

5.2 PROCUREMENT PHASE

The second main project phase covered in this study concerns procurement and aims at characterizing how the documentation established in the previous phase is used by the STA as a basis for procuring construc-

tion activities from a contractor to realize the project. This phase focuses on the activities of *invitation to tender*, *bidding* and *bid evaluation*.

5.2.1 INVITATION TO TENDER

The procurement process, including the final tender evaluation (cf. Section 5.2.3), was handled by five dedicated employees at the STA constituting a formal project group. Besides a PM where the client announced that a collaborative relationship was desired, any communication with bidding contractors was intended to be coordinated through this group and strictly formal in accordance with current legislation and the procurement method chosen. Based on the drawings and descriptions produced during the design phase (cf. Section 5.1), the tendering documents were provided by the STA on 2nd February 2004 to, in total, 12 potential contractors identified by the client largely from previous projects. The call for tender was submitted in Swedish on CD and included normal procurement materials according to STA's standard procurement model and was among others based on the standard industry contract and a non-priced bill of quantities[27]. Besides tendered price, any bid received from the contractors would also be evaluated (cf. Section 5.2.3) based on so-called soft parameters, e.g. available resources and financial situation.

5.2.2 BIDDING

This section is to a large extent devoted to the client and one of the 12 contractors receiving the tendering documents, Svevia (cf. Section 4.1.2), which both decided to participate in the bidding and ultimately actually was awarded the contract.

Bid organization

As soon as the tendering documentation had been received and a formal decision to start bidding had been taken, the business manager of Svevia established a formal bidding organization comprising two full-time

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[27] The bill of quantities is an important document which expresses the number of activities and resources intended to be performed, e.g. the amount of permanent traffic devices, lighting, bridges and paving works.

quantity surveyors: one for ground and road works and one for concrete works and bridges. The quantity surveyors were mainly appointed based on previous work experience, and in particular, skills regarding estimation of production costs. Besides the two quantity surveyors, the formal bidding organization also comprised a staff member responsible for administration and some planning. In addition to these three employees dedicated to the project for more than two consecutive months, a few purchasing specialists were also supporting the rest of the bid organization part time to investigate certain costs, e.g. regarding materials. Besides the conventional bid organization, similar to most previous projects of the same size, another category involved was a technical specialist responsible for interpreting technical requirements and to propose alternative bids (cf. technical part below).

Main bidding activities

The main internal interaction within the bid organization occurred at a number of semi-formal recurrent meetings during the three-month period when the bidding activities took place in accordance with internal routines for the bidding process. The routines indicated constituted a system where important documents and guidelines for bidding were managed. Besides the meetings indicated, most communication took place at close quarters by either e-mail or by personal contacts since most participants were located at the same office. In the case of external participants, such as potential subcontractors and suppliers, the communication was almost exclusively by e-mail and phone. E-mail was generally considered to be preferable by Svevia to phone contact since it provided the possibility to clearly communicate what had been agreed on as well as a convenient way of documenting it.

The commercial part

Since the project was procured using a traditional D-B-B approach, bids were essentially based on the non-priced bill of quantities, in which activities and physical resources already had been specified in the tendering documents during the design phase. Accordingly, the bid was to be obtained by calculating costs for performing the activities specified in the bill of quantities, and consequently, the principally most important parameters for the quantity surveyors to determine was the time to

perform each activity specified and the associated costs. In this case, the capacity to perform a given activity was largely based on personal experience of previous projects but also information provided by external sources such as subcontractors, material suppliers and equipment manufacturers. For the purpose of efficiency, additional data gathering, calculations and evaluations were in some cases procured from external consultants not being part of the formal bid organization. This was the case when it came to compiling material categories not specified in the bill of quantities. For example, in the case of the bridges, which included some design responsibility, both materials and design activities were needed for cost calculation. Costs of work specified in the call for tenders, e.g. paving works were directly obtained as prices from Svevia´s internal paving department, and costs of blasting and crushing rock material were obtained from external subcontractors by competitive tendering. In general, procurement of subcontractors was performed in a similar way as Svevia´s own client, STA, normally procures contractors, i.e. by sending a call for tenders to a number of potential partners based on a given set of activities defined by the tendering documentation. In general, the prices offered by the potential sub-contractors and suppliers were mainly decisive in each procurement decision, since it would affect the single most important parameter in Svevia´s own bid, the total bid price to the STA.

Besides the main tasks of gathering information regarding capacities, costs and prices to complete the bill of quantities, a significant aspect of bidding concerns appreciation of risks, uncertainties and opportunities. This was one of the few instances where previous projects were discussed among individuals. In general, the current project was considered by Svevia to be comparatively straightforward and not subject to any significant risks and uncertainties. These conclusions were largely based on apparent site conditions described in the tendering documents as well as the nature of undertakings according to previous general experience. An important aspect concerning risks that affected the attitude towards the project was the fact that contractor responsibility was limited by the contract since the D-B-B approach resulted in technical solutions more or less directly chosen by the client.

> *As a contractor, if one produces in accordance with the tendering and contract documents, and gets it right, then you are safe (Quantity surveyor, Svevia).*

Besides establishing the bid on own costs and capacities, competitor analysis was also performed by the quantity surveyors who evaluated previously procured projects by historical bid prices. Such bid prices, including the underlying priced bill of quantities, were obtained from publicly available bid evaluations, a result of the transparency required by the Procurement Act (cf. Section 4.2.1).

The Technical part

In addition to the activities involved in establishing the commercial aspects of the bid, strictly according to the tendering documents, it was also stated in the tendering documents that bidders were allowed to submit alternative bids based on so-called *variants* (cf. Section 4.2.1). However, any variant proposed should be restricted to *alternative constructions* or *different production methods* than those stated in the tendering documents. Variants beyond these measures were strictly rejected as stated in the tendering documents. Furthermore, in order to have an alternative bid at least evaluated by the client, it was up to the individual contractor to show that the variant proposed was acceptable according to STA´s technical descriptions. In other words, the variant should be scrutinized according to theoretical calculations in established standards and not according to actual performance once the product was delivered. In order to provide the quantity surveyors with potential variants of alternative road designs, the technical specialist mentioned earlier participated in response to a direct command from the regional manager.

> *They had technical specialists that perform a lot of research, on thinner bound layers and different sorts of bound layers. It was they who helped us with suggestions. You can do this and so etc. Then we set the price. (Quantity surveyor, Svevia).*

In short, the variants proposed by Svevia´s technical specialist aimed at decreasing the amount of material in the pavement structure, and

thereby the total production costs. The material reduction was partly motivated by calculations using STA´s publicly available design tool but also results obtained from Svevia´s previous laboratory and field tests. In particular, results from a field test in the south of Sweden was utilized for this purpose despite the opinion that the legitimacy of calculations and field test results could be questioned since they, at least to some extent, violated formal texts in STA regulations. The communication between the technical specialist and the rest of the bidding organization comprised of communication by e-mail, telephone and meetings. Potential alternatives were thoroughly discussed at five semi-formal meetings, after which, each potential alternative was cost calculated by the quantity surveyor concerned. Although the number of meetings was considerable, the communication between the technical specialists and the remaining bid organization was in some respects unidirectional.

> *We were only involved in the technical aspects and we had no influence on the financial aspects. We came with a number of potential variants and they [the quantity surveyors: author's remark] calculated the financial consequences. On that basis, they decided behind closed doors what to submit (Technical specialist, Svevia).*

One reason for the limited communication between the production and technical personnel was the perception that the bids were complete in the sense that no discussions regarding either the product or associated risks were necessary. In total, Svevia decided to submit as many as seven variants, developed in parallel to the main bid by members of the technical staff and the quantity surveyor responsible.

Communication with the client

Even though the STA and Svevia historically had carried out many road projects[28] together but also had organizational connections (cf. Section

[28] *For example, Svevia had constructed roads for the STA in a number of projects, either as the main contractor or in a consortium with another major contractor, at road E4 close to Uppsala, Linköping and Norrköping as well as the E18 highway close to Västerås between the years 1994 and 2002.*

4.1.1-2), the communication between the contractor and the client was formal as required by the Procurement Act. The main communication constituted public questions submitted by e-mail. After questions had been received and internally discussed by STA´s specialists, consultants and the coordinating group (cf. Section 5.2.1), the client published both questions and the corresponding answers in so-called supplementary tendering documents. Of the 22 questions asked by Svevia and its competitors, most concerned administrative issues and seven concerned design activities, in particular bridges, for which an awarded contractor would assume some design responsibility. Most of the remaining questions concerned either amounts missing in the bill of quantities or associated production times. Most answers provided complementary information. However, for some questions, the client simply referred to the tendering documents. Although some answers did not provide any additional information to the contractor, it was never the less considered important to ask the question. The way of publicly asking questions and receiving answers meant that it was cumbersome to clarify ambiguities. It was difficult to effectively obtain a complete answer without any remaining ambiguities which required further questions. Furthermore, the formal procedure meant that any clarification resulting in lower production costs would be publicly available, and hence of limited competitive advantage. According to several respondents, there was more than one reason to submit questions during bidding. Besides the obvious reason of clarify ambiguities, it was also considered important to establish equal conditions among contractors by eliminating uncertainties which may be exploited by competitors to achieve lower bids.

> *…sometimes one wants all competitors to have the same prerequisites when cost calculating a bid. It may happen that a competitor discovers obscurities in the tendering documentation and does not say anything, while still calculating for the bid, and consequently, being in an advantageous position so to speak (Quantity surveyor, Svevia).*

The bids were supposed to be received by the client on 19 April 2004, which entailed that each bidder had 2 months and 17 days to finalize its bid. However, during this time, the STA observed that it was not possi-

ble to get access to certain areas needed in time for production. Hence, the bidding time was prolonged by an additional two weeks to 3 May 2004.

5.2.3 TENDER EVALUATION

Of the 12 contractors originally invited for tendering, only four bids were in the end submitted to the STA for evaluation.

The main bids

Each bid was evaluated strictly according to current legislation and based on a tendering sum according to the supplied bill of quantities, whether or not payment in advance was requested and soft parameters. Besides aspects affecting the bid price, a number of formal prerequisites also needed to be met. Table 5.1 shows results from the evaluation of the four bids evaluated by the STA including the monetary effect of the soft parameters. As can be observed, the lowest bid was submitted by the contractor Svevia, while the highest was submitted by the competitor PEAB. Three of the bids were comparatively close in monetary terms, while the winning bid was approximately 18 percent lower compared to the second lowest bid (NCC). After the bids had been opened by the client, discussions were held within STA whether the client really should accept Svevia´s offer since it was initially considered as too low compared to the competing bids as well as the client´s own estimate. The STA was worried that a stressed economy would result in conflict during the contract phase. However, in the end it was decided to accept the lowest bid, partly because no formal reason to reject the bid could be found.

Table 5.1 Compilation of bid prices for construction activities and effect of alternatives on bids (indicated using negative prices).

	Bid prices (SEK million)			
	Svevia	NCC	Skanska	PEAB
Main bid	191	233	246	296
Alternatives	-10,1	-6,6	-6,1	-9,8

The alternatives

In addition to the main bids indicated in Table 5.1, all four bidders submitted a number of alternative bids. The figures in the table with negative signs indicate price reduction associated with the alternative bids compared to each main bid. Consequently, if the client had accepted Svevia´s alternatives, the price would have been nominally decreased from SEK 191million by SEK 10.1million. Three of the bidders proposed, as in the case of Svevia (cf. Section 5.2.2), alternative road designs. In general, the alternatives indicated arguably met the formal requirements stated. However, all alternative bids were rejected by the client based on the formal argument that the variants they were based on would result in a *too optimized design* (sic), which could result in future quality problems. Consequently, the variants proposed by the contractors could, according to the STA, lead to increased maintenance and operations costs compared to the original design specified in the tendering documents.

> *Sure, the results from the calculations using PMS Object show that the original design is over-designed. But the alternatives submitted are exactly on the boundary and the demands regarding required life expectancy, according to the tendering documents during a longer time, are pressing. This statement concerns all alternatives submitted (Internal mail correspondence: from technical specialist, STA).*

However, in addition to the argument presented above, several contractors as well as representatives of the client suggest alternative, more or less, unofficial explanations for rejecting alternative bids. In particular, the inability to provide a watertight justification for accepting a certain variant, which in the case of award might have attracted appeals from competing competitors.

> *Unfortunately, there is a tendency, when we request technical solutions and variants, for the contractors to become very aggressive towards each other and towards us by appealing our decision. They often demand the possibility to provide alternative technical solutions, but when someone else submits a variant, they become sulky (Procurement specialist, STA).*

As indicated, the client was, at least partly, worried that the approval of a variant would provoke competitors, and motivating them to scrutinize the tendering documents for formal errors, inconsistencies, mistakes and even misprints, presumably to achieve a new tender evaluation. The procurement phase ended when the contract was awarded to Svevia in June 2004.

5.3 CONTRACT PHASE

The contract phase presented in this section represents events occurring after the contract has been awarded to the contractor Svevia until the end of the warranty period in 2012. This phase concerns *planning*, *construction* and some important *post-project events*.

5.3.1 PLANNING

As soon as Production and STA had signed the contract in June 2004, both the client and the main contractor continued their preparations for onsite construction activities. Among others, a collaborative agreement was signed between the client and the contractor where it was stated that any cost-savings of innovative technical solutions would be split between the two actors. However, although efforts were made to improve any collaboration within the project by formalizing certain agreements, the respondents indicate that the agreement did not affect the project to any greater extent.

Yes, there is a Partnering agreement, where we went through how we will talk to each other and how cost-savings should be split and so on. Anyway, we have probably not lived up to it, we could have been better in this project. It does not only depend on the contractor but also on us. We are a little too restricted to our documentation and standards (Project leader, STA).

The project organization

As indicated in Section 4.3.2, the entire Norrortsleden project constituted 11 larger projects, subordinate to an overall client project manager. Even though sharing some organizational resources, including staff devoted to activities such as work environment and inspections with two neighbouring projects, the present project had its own relatively independent project organization comprising about seven individuals established in a separate office. In order to manage the extensive on-site day-to-day operations, where individuals of the contractor organizations met phase to phase, the client project leader[29] was assisted by a project organization comprising six specialists surveying, measuring and controlling the progress of construction activities according to the contract.

Although the main design work had been intended to be finalized when the contract between STA and Svevia was signed, certain design works still needed to be performed. More specifically, each time Svevia or any other actor noticed that the existing design did not correspond to field conditions or requirements, Sweco had to revise the drawings and documentation taking the deviations into account. The deviations indicated often resulted in additional construction works, and consequently, additional costs for the client who was responsible in relation to the contractor for the design.

[29] *This particular project had in total three different project leaders during the period of construction.*

There is often some whining when we have done something wrong that results in addition work (Technical specialist, Sweco).

Since the technical consultants did not have any office on the construction site, the main design works were performed after meetings had been held directly with the STA, normally without the participation of any contractors.

The site organization of Svevia comprised the site manager, staff devoted to quality, environment, work environment and economy. Another staff function constituted a dedicated organization of four measurement technicians continuously working with positioning and setting out activities. The production personnel was organizationally divided into five blocks, corresponding to those of the client, with one to two supervisors for each category of ground/road works, rock works, water and sewage, bridges and asphalt paving works (cf. figure 5.2).

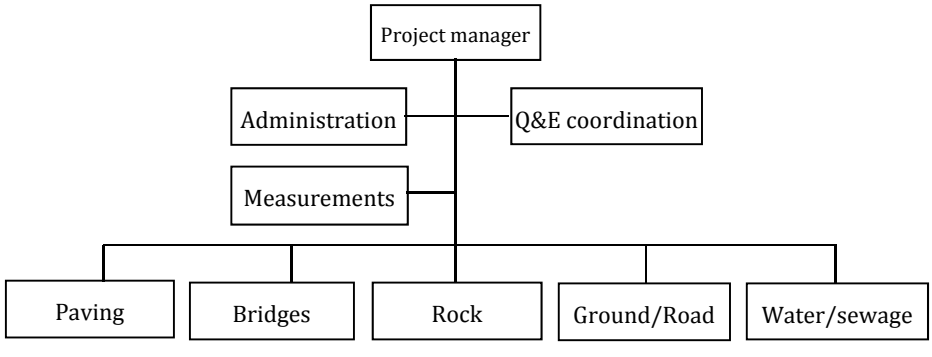

Figure 5.2 Organization of Svevia during contract phase.

Besides the organization indicated in Figure 5.2, a large part of the site organization constituted external suppliers and subcontractors. For example, the main part of the ground and rock works were subcontracted to VSM, a dedicated contractor with which Svevia previously had cooperated in several similar projects. As in the case of most previous projects, VSM, in their turn, used own subcontractors for activities involving excavation and crushing of rock material. For ground stabiliza-

tion works another specialized company, fully own by the competitor NCC, was employed. The reason for using a subsidiary of a competitor was motivated by the fact that Svevia did not possess any stabilization works capacity of its own at the time. A large part of external material needed for the pavement and bridges constituted materials procured from external companies based on skeleton agreements.

Most of the organization indicated, including subcontractors and suppliers, was at least implicitly determined already when the bid was submitted by Svevia (cf. Section 5.2.2). However, some subcontractors had been replaced between the procurement and the contract phase after further negotiations when the contract had been won by Svevia. Any change of subcontractor was largely explained by the practice of Svevia to obtain preliminary prices from potential subcontractors and suppliers, prices which later would be renegotiated when a contract with the STA had eventually been signed.

> *In most cases, when the contract has been awarded, there is a more convenient position to obtain better prices. In this case, it is worthwhile once again to test the market (Site manager, Svevia)*

In principle, only internal business units and departments were in the end guaranteed a contract with Svevia for the contract phase. The rest was subjected to a new round of negotiations.

5.3.2 CONSTRUCTION

After an approximately four-week long planning period, the main construction activities were initiated by the contractors in mid-July 2004.

Main construction activities

According to the respondents, the construction activities on site were in most respects conventional and followed the established design more or less entirely when taking the alterations and additions into account.

> *Of course, even though we only build according to STA´s documents, there are many possibilities to learn a lot by participating in this kind of project depending on your own experi-*

ence. There are always challenges in every new project, e.g. which technical standards to follow, how to document and present circumstances and changes during the project (Site manager, Svevia).

Each contractor was only responsible for the undertakings agreed on according to the individual contract, and consequently, remained on site only as long as it took to perform the construction activities including verifications of the quality by tests or inspections. For example, the production of the road pavement was finalized by Svevia according to the STA´s technical description where procedures of excavation, filling, compaction and control of materials were specified in detail. All materials used and production were monitored by means of laboratory and/or field tests. For example, unbound and asphalt materials were controlled in the contractor´s local laboratory. The results from the testing were later utilized during the final inspections to verify whether or not adequate technical quality had been delivered. According to respondents, a few minor exceptions beyond normal existed with regard to equipment, material and production technique used during the project. In particular, a new type of road compaction equipment was tested and a different type of wall than the one specified in the original contract was used on a part of the section.

Meetings

As in the case of the previous project phases, several different types of intra- and inter-organizational meetings were held. Among others, significant efforts were made by the STA to inform project participants and other stakeholders regarding the project and its progress. According to the STA, a wide range of initiatives was taken and outcomes obtained from the current project of relevance for knowledge development and organizational learning. One example was the ambition of providing opportunities for engineering students to participate on the construction site in practical or theoretical work. These initiatives were made with the purpose of strengthening knowledge and motivation, e.g. by encouraging ideas for technical solutions, which other regions of STA as well as other Nordic road administrations have utilized for their own procurements (SNRA, 2008).

As mentioned in Section 5.1.2, a final formal meeting was held between the STA, Sweco, and Svevia, once the contract between the client and the main contractor had been signed. This meeting was the only one where the majority of consultants responsible for the design met face to face with the contractors responsible for realizing the project. At this meeting the consultants presented their opinion regarding the main difficulties and risks. Apart from this meeting, the consultants of Sweco´s road and traffic department only made sporadic appearances, primarily in relation to the client and its site organization but also in some specific cases with the contractors when swift problem solving was considered necessary. The meeting between Sweco and the STA were held on site, at the client´s office in Solna and sometimes at the consultant´s office in Stockholm.

> *Svevia had very little interaction with consultants during the construction works. Apart from a joint start meeting, the client held all communication with the consultants (Site manager, Svevia).*

The formal meetings strictly between STA and Svevia largely complied with the contract and comprised besides joint risk and work-safety meetings, mainly meetings which focused on production. So-called *Production meetings* were held regularly every other week, where representatives from both STA and the contractors were represented. At these meetings the progress of project activities were discussed. In addition to the production meetings, so-called *project meetings* were held every month, where aggregated issues including information and economy were handled. At these meetings, STA´s project leader responsible for overall project performance participated as well as the area manager of Svevia participated. Most meetings mentioned were preceded by a formal notice of the meeting and notes from the previous meeting if available. As in the case of production meetings, project meetings were largely formal and followed a specified agenda and resulted in minutes that were signed by each party. The procedure indicated was partly supported by formal text in the contract but also rationalized by practical reasons. For example, the many and diverse questions and responsibilities required clear expressions in such a way that both parties had

understood each other. The outcome was later reported to each hierarchical organization. A third meeting category concerned technical so-called *rock meetings*, held once a month to discuss relevant aspects, e.g. blasting operations and associated disturbances. Once a month, a separate meeting was held to discuss and ensure product quality, work-environmental and environmental issues. In the case of the working environment, this was one of the few important aspects that crossed project boundaries since contractors of other sub-projects participated (cf. Section 4.3.2).

Among the most important questions discussed during the meetings concerned the usual amount of alterations and additions, which emerged gradually during the construction works[30]. Although, many costly changes were required during the contract phase, no respondent considered them to be excessive compared to other road projects. Another topic brought up during meetings concerned the variants included in the alternative bids submitted during the procurement phase (cf. Section 5.2.2-3). As previously indicated, no variant was ever accepted during the procurement phase. However, after Svevia had been awarded the contract and started construction activities on site, the question regarding alternative technical solutions was once again raised by the contractor in an effort to reduce construction costs. Although STA expressed interest in discussing alternative technical solutions, in the end none of the attempts succeeded in convincing the client to change the design. Among the reasons for the result was that both parties were to some extent unfamiliar with the procedure as well as too short a time frame.

> *We had some early discussions, especially regarding the pavement structure, but this fell apart because it was difficult*

[30] *In total, over 200 different alterations and additions were identified and subsequently discussed, which corresponded to almost 10 percent of the contract sum. Although many alterations and additions concerned smaller changes to the design, not always resulting in monetary consequences, several of them concerned major measures, e.g. changes to bridges.*

to obtain a decision in time. Soon after, there were a lot of work going on and it was too late (Site manager, Svevia).

Another reason suggested by some respondents was the opinion by Svevia that it would be difficult to convince STA, and its technical specialists, to approve an alternative design suggested by Svevia. The statement given above corresponds with the statement in Section 5.3.1, where the project leader of STA mentioned that they were restricted by their documentation. This opinion resulted in the contractor not devoting any particular resources, such as their own technical specialists, to convince the client.

If the client is not interested, if they have a totally negative attitude, then our own production organization was not susceptible to our arguments. – No way, no one buys that; we will not pay attention to your proposals since our client is not interested (Technical specialist, Svevia).

Accordingly, in the end it was decided to retain the pavement type originally established by the consultants at Sweco during the design phase.

5.3.3 POST-CONSTRUCTION EVENTS

When the construction activities had been finalized in May 2007, well in advance of the original time-schedule, the principal site organization was disbanded and started to work on other projects, and inspections were performed in the summer of 2007 to verify project performance. According to the material presented by the client, the project was successful when it came to project delivery time and total costs so far. Besides inspections on site, including a planned so-called warranty inspection in 2012, the main activities and experiences of the project so far have concerned follow-ups and meetings held among the project participants.

STA

Several respondents argue that the client in general has good experiences from the project, which has been utilized in subsequent projects.

In this project, we have had a rather high level of aspiration to gather experiences. We have had these agreements concerning cooperation with the contractors. We have had follow-up meetings, an open atmosphere...also with design consultants. We also have in our office the department of large projects, for example, the upcoming Northern link, with which we discuss a lot. Then, there is of course more to wish for regarding these issues. At least we have the ambition and we have obtained a lot of experience. We will try to produce a final report, some proper documentation or book which can be used (Project manager STA).

According to a book on the entire Norrortsleden project published in 2008, a wide range of follow-ups were intended to be performed, in particular regarding relational and environmental issues such as impact on wildlife, noise and air quality (SNRA, 2008). According to respondents, investigations of this type are either superficial or rather detailed and therefore suited for specialists who become responsible for transferring the knowledge between different project phases and projects, either by personal experience or by incorporating it into existing administrative or technical routines. However, although several initiatives have been announced, most respondents state that only very few investigations and follow-ups have actually been performed to date, and in each case, the work has been solely internal and mainly concerning administrative, financial and environmental aspects. For example, according to a project leader of the current project, no follow-ups of performance or explicit use of knowledge regarding the design or the road construction developed during the current project were used for any subsequent projects[31] mentioned above.

But I do not have any follow-up regarding the work, what is the status of the road and whether or not we are getting com-

[31] *During the following years 2008-2011, a number of new road projects were started by the STA including projects on road 73 to Nynäshamn, road 288 close to Uppsala and roads 55 and 27 outside Malmköping and Gislaved, respectively, where Svevia was the main contractor.*

plaints. Now, the operations department is responsible for it (Project leader, STA).

In the case of technical aspects, no explicit evidence has been detected for any particular technical innovation or investigation either for the purpose of upgrading any technical description or any explicit use in other projects.

We obtain and bring experiences from different projects as we do revisions. It is fair to say that experiences from a single project does not result in any major revision of the technical rules, but it can happen. On the other hand, a coherent picture obtained from many different projects results in changes (Technical specialist, STA).

As in the case of the general documentation management system *Chaos* (cf. Section 5.1.2) developed prior to the current project, additional efforts have been made by the STA over the course of time to further facilitate administrative activities. One example concerns the upgrade the document management system to incorporate more general documents such as minutes of meetings. Another example concerns the creation of databases for ongoing and finished procurements that store data regarding contract type, the number of bidders and other commercial information. Several of the information systems indicated did not exist during the project described in this chapter and, thereby, represent developments occurring either parallel or subsequent to the project.

Sweco

As in the case of the client, the personnel of Sweco involved in the current project continued working on new projects where experiences gained could be exploited, especially regarding existing work-procedures and technical descriptions. However, only limited explicit experiences from the current project have been utilized in subsequent projects.

No, we have not utilized any explicit experiences from the Norrortsleden project as far as I am aware (Manager, Sweco).

In accordance with respondents, very few investigations have been performed by the consultants regarding the project and its performance. Besides the formal inspections indicated above, the main post-project evaluation constitutes only a few numbers of short visits to the construction site in conjunction with its opening to traffic. No specific evaluation of pavement performance or any other construction element over the years has been detected.

> *No, not by any of us consultants, we do not do that. In such cases, we need to have an assignment since our managers do not want us to spend time on activities we do not get paid for (Technical specialist, Sweco).*

According to a senior technical specialist of Sweco, not participating in the current project but involved in many successive infrastructure projects, the consultants of Sweco only possess very small resources for activities not directly financed by any client.

> *Unfortunately, we have only limited resources for any R&D work. We some have money dedicated to such activities but it is not much. On average, we have enough for 0.5-1 day per year which is almost nothing (Technical specialist, Sweco).*

According to a technical specialist involved in the current project, any evaluation of technical performance is cumbersome, time-consuming and for most future projects irrelevant since the client bears the principal responsibility. The same consultant argues that Sweco mainly obtains experience by directly participating in traditional project work but to some extent also from other sources such as training and education, reading research reports and participating in conferences. However, another source of experience is obtained from participation in projects procured using alternative procurement methods.

> *In design-build projects with performance requirements, we usually do as we do in traditional projects, i.e. we design according to STA´s design model, but this normally takes place in a dialogue with the principal contractor, utilizing their ex-*

perience and with a few variations in the design (Technical specialist, Sweco).

Svevia

As in the case of Sweco and the STA, Svevia participated in a number of projects subsequent to the current one during the time of the study. For example, Svevia obtained contracts between 2006 and 2011 for a number of relevant D-B-B and D-B road projects. However, no significant indication of knowledge developed during the current project appears to have been important for those projects. The main experiences gathered during the current project were mainly limited to general administrative and financial aspects.

> *It is possible to see a connection between Norrortsleden and the E18 highway. Rather many individuals working here did work on Norrortsleden. Many co-workers have the same roles as on Norrortsleden. You should not be afraid of making changes in the projects when you work with the contractor, to change certain technical solutions. The consultants normally produce a design that works but it is seldom the cheapest one. When you have a contractor on site, you can find alternative ways of working, new materials and methods. These conclusions were brought to E18 (Site manager, Svevia).*

> *When the work is done, a final report is written on issues that have been successful and those that have not, e.g. what possibilities there were to make money on purchasing (Site manager, Svevia).*

The lack of follow-ups was, as in the case of the other actors, especially evident regarding the technical experiences of the different construction elements. For example, even though significant laboratory and field tests were carried out to verify technical quality, the resulting data is difficult to utilize in new projects in other ways than controlling production according to existing technical standards. Among the reasons was the fact that it was neither explicitly required by the contract nor motivated by it being able to improve knowledge for the future. A third reason for the

neglect was that no single individual was formally appointed responsible for gathering the information nor had any interest in doing so.

> *No, we have not performed any follow-up. In our opinion, we [technical specialists, authors note] have considered ourselves to be too little involved, so we do not really know what we could receive from it. Furthermore, there are no requirements for it (Technical specialist, Svevia).*

> *Besides personal experiences, future projects are surprisingly little affected by this particular project. Follow-ups regarding performance measurements are inadequate since they require resources and do not result in any competitive advantage in future contracts (Technical specialist, Svevia).*

According to respondents of the contractor as well as client, significant technical innovations were utilized at one of the subsequent projects mentioned. However, no major contribution was inherited from any project on Norrortsleden. Later in 2010 and 2011, Svevia also received a pair of comparably far-reaching D-B projects involving a 10-year long performance contract. However, the current project did not have any particular impact on the design chosen at any of the new projects either.

6 CASE 2 – THE UNCONVENTIONAL APPROACH

The case described in this chapter primarily concerns one of the 11 larger projects indicated in Chapter 4, which represents an unconventional project aiming at establishing a 7 km long road section. Although involving seven bridges, a large tunnel as well as significant installations, the main focus of the study concerns road-related aspects, which were subjected to comparatively far-reaching contractual responsibilities and technical requirements.

For the purpose of providing a clear description of the case, Figure 6.1 shows a conceptual time-schedule illustrating the three main phases, preparation, procurement and contract, encompassed by the focal project (Sections 6.1-6.3). Section 6.3.4 focuses on post-construction events until 2012, four years after the main construction works were finalized in October 2008. In addition to the focal project, the figure also indicates previous and subsequent projects against which the focal project may be connected.

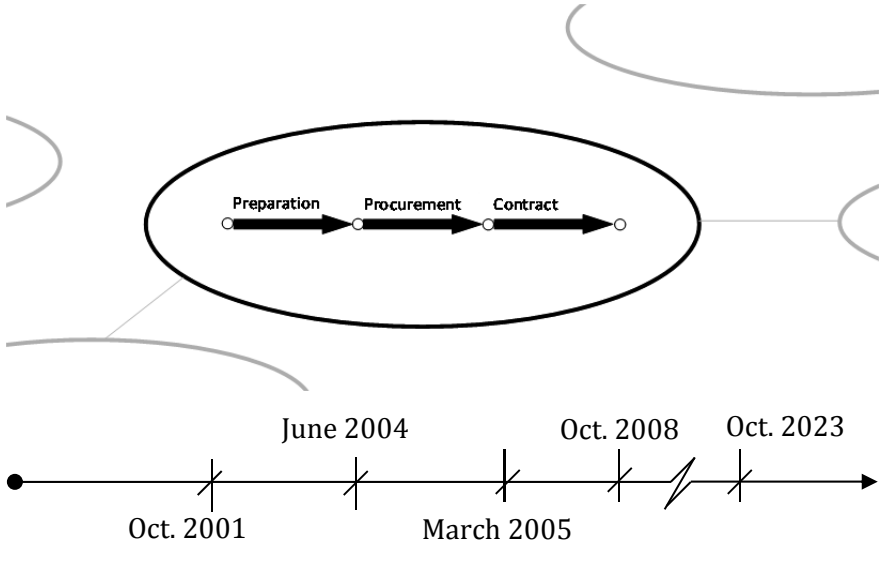

Figure 6.1 Main project phases and activities studied (not according to scale).

6.1 PREPARATION PHASE

This phase concerns the period devoted to the establishment of the tendering documents and is described using two main activities, *choice of procurement method* and *establishment of procurement documents*.

6.1.1 CHOICE OF PROCUREMENT METHOD

In the autumn of 2002, a formal decision was taken by STA´s director to realize the project using a variant of the D-B-M method (cf. Section 4.3.1). The decision was primarily rationalized by two main arguments. First, it was considered important to start and complete the construction works as soon as possible by early procurement of a contractor able to perform the design while at the same time constructing it, more or less, in parallel. The need of a rapid realization was in turn a consequence of the significant time-delay resulting from an appeal by the Swedish Environmental Protection Agency, a significant authority subordinate to the Ministry of the Environment.

Besides the argument of a short time-frame for realizing the project, there was also an interest from the client, and particularly of the project manager, to test an unconventional procurement method. This second argument aimed at counteracting the negative trends observed in the industry (cf. Chapter 1 and Section 4.2) by improving existing procurement methods by applying incentives to short-term goals such as improved work-relationships and quality as well as long-term achievements by providing space for competition and successive cost-reductions based on innovation. Both arguments mentioned evolved around experiences made in previous D-B-B and D-B projects, and were also in line with the opinion of large contractors and made it suitable for the STA to proceed by using parts of the previously developed PPP-scheme (cf. Section 4.2.2 and 4.3.1).

6.1.2 ESTABLISHMENT OF PROCUREMENT DOCUMENTATION

As in the case of the project described in Chapter 5, the tendering documents of the current project had to some extent already been manifest-

ed in drawings and descriptions as well as a report[32] from the endeavour to evaluate unconventional procurement. However, this design was only available in the form of a comparatively rough work-plan (cf. Section 4.3.1). Furthermore, in contrast to most of STA´s previous projects, substantial work had to be devoted to developing the new procurement method since the client wanted to achieve an approach that went beyond the model that had guided previous D-B-B and even D-B projects (cf. 4.2.2). One of most significant characteristics of the up-coming project was that a main contractor would be contracted to assume responsibility for a comparatively large number of main activities. The extended responsibility would not only concern design and construction activities but also to ensure the technical quality during a 15 year long maintenance and operations period. Such a long period had never been contracted for a road project previously in Sweden and since there was no established way of handling the performance requirements and their status during the project, the client had to take a number of measures, e.g. to develop a new database to manage the requirements (cf. SNRA, 2008). The final procurement method would become an advanced form of D-B-M-approach, based on general conditions with as few deviations as possible, due to the broad scope contracted, involving, among other things, performance requirements and an unconventional compensation model based on the fulfilment of the requirements.

Organization of work on tendering documentation

The main part of producing the tendering documents was carried out in-house by a group of STA´s organization, comprising five employees, with help of internal specialists and external consultants (FIA, 2005). The work was supported by an internal reference group, comprising personnel with experience of large projects and unconventional procurement methods, which reviewed and supported the work on the tendering documents. At the many meetings and in correspondence within the group, both general contractual aspects and specifications of the differ-

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[32] *Report for work on tendering documentation ("Modell för utvecklad funktionsentreprenad för Norrortsleden") Underlagsrapport för utarbete av förfrågningsunderlag, Vägverket region Stockholm, (2002).*

ent construction elements were discussed. For each technical area, specialists were engaged to develop appropriate requirements, i.e. the amount, type and scope for each construction elements concerned. In total, as many as 15-20 technical specialists were devoted to the technical requirements of which approximately half were concerned with the tunnel and two belonged to the road and traffic department. Apart from periodic formal meetings, the main communication took place by less formal means, e.g. by phone and e-mail to clarify or verify hypotheses or suggestions. Besides domestic experience, the Finnish road authorities were also contacted to provide experience from their large PPP-projects. In total, it took the STA as much as approximately one year to obtain a draft of the tendering documents. Afterwards, the client arranged four rounds of meetings with potential contractors to discuss important aspects of the procurement method including length of contract period, risk distribution between client and contractor, and how to compensate for certain works.

> *Based on the standpoints we obtained from the market, and from what we ourselves wanted, we established the basis of the tendering documents, what these should comprise, the structure and the main principles (Project leader, STA).*

In the case of the road, the characterization of technical performance was in principle restricted to seven distinct requirements resulting from inquiries and discussions with internal and external actors as well as on experiences of previous projects. In this case, previous D-B projects (cf. Section 4.2.2) were used for benchmarking technical performance. Of the seven requirements indicated, three requirements concerned road surface evenness characterized using an automatic method based on laser technology, according to STA standards, while a fourth was based on a strict theoretical model developed by the VTI (cf. Section 4.1.3). The performance requirements were supposed to reflect both the technical standard each year during the 15 year long warranty period but also so-called *residual value*, i.e. indicate a sufficient technical quality after the end of the contract period. A purpose of including requirements of residual value was to ensure that any contractor contracted would not behave opportunistically and utilize inferior products, notwithstanding

the test of time corresponding to the nominal life expectancy of 40 years of traditional roads. In addition to specified requirements, the tendering documents also stated that the pavement structure should be designed according to certain principles, e.g. for a given traffic volume and by the use of *an established technical description*. The purpose of these statements was to provide opportunities for new technical solutions while at the same time avoiding too radical and untested solutions. As indicated in Section 4.3.1, the original procurement method also comprised parts of an unconventional financing model, which stipulated that any non-compliance with the seven performance requirements indicated would result in a significant fee reduction for the contractor responsible. The compensation model implied was by no means general for all works and, therefore, complemented for certain issues. One example of such deviation from the main model concerned tunnelling works, which were compensated using a particular model developed for the current project following negative experiences from a major earlier project of the Stockholm traffic system: the southern link (cf. Section 4.3).

6.2 PROCUREMENT

This section describes important aspects of the procurement phase including *tendering*, *bidding* and *bid evaluation* activities.

6.2.1 INVITATION TO TENDER

The procurement phase began with a so-called pre-qualification in 2003 where different contractors could formally apply to participate in the upcoming tendering process. As a preparation before the qualification, a PM with clarifying information regarding the project was released by STA. The interest from contractors was initially considered as high by the client who also tried to further increase the interest among contractors by marketing efforts in Europe. In addition, the STA was even willing to contribute to the rather high bidding costs by offering each bidder a total amount of SEK 500 million to submit a bid. In total, 15 potential companies requested the tendering documents but in the end only three main contractors (Skanska, Veidekke and NCC) assigned for the pre-qualification. The tendering documents were only provided in Swedish and submitted to the qualified contractors on the 26 June 2004. Since

the procurement method to a large extent was new to all participants, it was considered important by STA to reduce uncertainties as much as possible by utilizing a *negotiated procedure* according to the Procurement Act (cf. Section 4.2.1) by conducting three individual meetings with each of the three competing contractors. In addition to the planned meetings, the STA also held eight additional meetings with the contractors mentioned regarding certain complex technical issues. Although the meetings referred to were formal in most respects, they were according to several respondents to some extent both informal and unconventional compared to previous STA procurements since it was possible to meet face-to-face with the counterpart. This made it possible to express more in detail important contractual aspects as well as to obtain a more nuanced picture of the client´s expectations.

6.2.2 BIDDING

This section is primarily devoted to one of the three contractors prequalified for bidding, NCC, which was subsequently awarded the contract for the project.

Bid organization

Although participating in the procurement so far, NCC became less interested in the project after receiving the tendering documents in June 2004. One reason for their hesitation was that the project was conceived as different as anticipated from STA´s earlier presentations (cf. Section 6.2.1).

> *To start with we thought there could be many solutions of our own but when we saw the result, it had been reduced to a conventional project. But in the end it was decided to submit a bid (Site manager, NCC).*

Some contractors interviewed had remarks regarding parts of the contract, for example, the client´s intentions with partnering, which was conceived as restrictive compared to NCC´s corresponding interpretation of the concept as well as limitations on technical designs provided by the existing work plan. However, after a couple of weeks, NCC decided to start a formal bidding process, but with a smaller scope than origi-

nally intended. One reason supporting this decision was that the procurement model in many respects was in accordance with NCC´s previous arguments in favour of D-B-M projects (cf. Section 4.2.2). In order to produce the bid, NCC Construction, the business unit responsible for the project, appointed an experienced bidding manager who pooled resources from several internal subsidiaries, business units and departments, e.g. NCC Roads[33] and NCC Teknik, respectively. The intention was to gather the most experienced and formally highest educated personnel available, with the officially stated mission of suggesting competitive technical solutions and avoid traditional standard solutions. Although most individuals possessed any of the two characteristics mentioned, many did not possess experience of alternative procurement approaches of this magnitude.

In addition to internal participants, the bidding organization also included three external consultant companies working under the supervision of NCC Teknik, which possessed both the coordination of consulting activities as well as several own important consulting activities during the bidding. The first consultant company, Midroc, was primarily devoted to installations while the second consultant company, ELU-konsult was devoted to bridges and noise barriers. The third company Grontmij, which also remains the main consultant investigated in this study (cf. Section 4.1.3), was contracted to perform among other things road-related activities. The relationship between NCC and Grontmij was established through a senior member of NCC Teknik, who had previously worked with members of Grontmij. The exclusive contract subsequently drawn up with Grontmij was considered important, partly because it would significantly restrict the ability of competitors to contract any consultant company with the necessary capabilities. The resulting comparatively large formal bidding organization comprised, besides conventional construction-related activities, both maintenance and operations

[33] *NCC Roads represents a business unit responsible for paving operations and supply of aggregates and asphalt mixtures. In the autumn of 2007, NCC Roads acquired the operations activities in Sweden from NCC Construction.*

activities as well as specialists for important technical areas, including tunnels, bridges as well as the road.

Main bidding activities

The bidding of NCC was initiated by a formal start meeting with the intention of informing the different contributors about the project and the procurement method. It was considered necessary to make this meeting as formal as possible due to the fact that most individuals of NCC and Grontmij had limited prior experience of D-B-M arrangements as well as whether and to what extent it could affect the work tasks. The meeting, which included approximately 20 employees, provided an opportunity to let the individuals comprising the bid organization to get to know each other as well as to allocate assignments within the organization.

Technical considerations

Although many activities resembled those performed at traditional projects, for example, in accordance with NCC´s internal formal routines, it quickly became apparent to NCC that more aspects were necessary to take into account when the bid also involved design, maintenance and operations responsibility. For example, it was not obvious how to choose optimal designs, when performance specifications were applicable, since the normal procedure was to develop bids based on existing documentation obtained from the STA. Consequently, the bidding organization needed to establish a way to cooperate internally and to take advantage of the different competences when technical-financial optimizations were to be made. In the case of road design, it was decided by the bidding management that members of NCC Teknik, NCC Construction and NCC Roads would also cooperate with Grontmij. Besides the initial start meeting previously referred to, three formal design meetings were held at Grontmij´s office in Stockholm on the technical issues. The first formal design meeting, was held between 12 participants, 4 from NCC and 8 from Grontmij, and concerned the cooperation itself including a presentation of the formal bidding organization, formalities (times and the evaluation criteria etc.) and Grontmij's fee for executing the design activities. The second and third meetings were held two weeks and four weeks after the first meeting, respectively, and concerned among other things issues such as alternative geotechnical rein-

forcement methods. The meetings between the contractors and the consultants provided opportunities to spread important information to other individuals not normally in contact with such issues. It was clear that the procedure and tasks to be performed were new to many participants and a lot of questions were asked. First, it had been clearly stated by the bidding manager that the bid should be optimized by evaluating several different potential road designs and financially compare them to each other. Second, in order to calculate the costs of each design alternative, not only construction costs but also maintenance and operations costs, and particularly those associated with quality deviations according to compensation model (cf. Section 6.1.2), were necessary to consider. Consequently, it was considered important for the quantity surveyors of each technical area to meet technical specialists, in particular to discuss type, amount and costs of maintenance and operations activities during the comparatively long contract period, which required a number of additional activities, meetings and analyses.

> *The most distinguishing feature of this project was the scope of the undertakings, which resulted in that a number of different technical and financial analyses had to be performed. Among others, risks regarding cost and technical quality, e.g. life-cycle costs, of different potential products must be determined, which is quite unusual in our industry (Technical specialist, NCC).*

In the case of the structural road design, NCC had decided not to use any external consultants but to keep the work in-house. NCC had the opinion that the external consultants were of limited use when it came to aspects not covered in any public available standards. In particular, it was perceived as difficult to get help to predict the future performance, i.e. model pavement deterioration for this specific project by the evolution of parameters concerning performance specifications.

> *A problem with technical consultants is that they solely prescribe materials and methods already established in technical standards. However, if the standardized solution does not say*

anything about the future performance, they [the consultants: author's remark] are of little help (Site manager, NCC).

Of the total of six individuals working on the road design at any time, two had a postgraduate degree in engineering (doctoral studies), while the remaining four possessed long industry experience. Together, this comparatively large constellation of specialists informally and formally discussed suitable pavement types as well as the need for maintenance activities during the contract period. Discussions occurred both regarding the contribution of the different individuals but also which design philosophy that should be used since internal guidelines or other routines to a large extent were missing regarding such aspects. Although significant freedom existed compared to traditional D-B-B contracts, the tendering documents clearly stated that the design should be based on an *established* technical description or standard, although not necessarily one published by the STA. As a consequence, it was judged by NCC that the client could actually accept a standardized foreign method, or materials and methods presented in scientific journals or supported by a reliable research institute such as the VTI (cf. Section 4.1.3). One of the reasons for NCC´s opinion was fear of getting rejected either by the client or indirectly by another contractor during a presumed subsequent appeal. Initially several different pavement designs were considered including non-conventional structures consisting of so-called hydraulic stabilization materials. However, as the bidding activity proceeded such comparatively radical designs were gradually withdrawn, either due to too high uncertainties or difficulties to motivate them based on stated requirements and available models, which in turn might jeopardize not only the quality of the current project but also the future of the entire procurement approach. Since the project was in principle a pilot project, both monitored by the FIA and showing many characteristic advocated by the construction industry (cf. Section 4.2.2), it was not considered as wise to gamble with any radical and untested design. After a number of candidate pavement designs had been proposed in the road group, each was thoroughly cost calculated by quantity surveyors, who in turn provided important feedback to the technical specialists regarding the financial effect and further potential modifications.

Although the internal discussions within NCC resulted in the choice of a comparatively conventional structural design, it was not obvious whether or not the design actually would comply with the performance requirements specified, whether maintenance activities were needed and what the consequences would be for the different subsidiaries if the requirements were not meet during the contract period. Since the performance of the road would be determined by the contribution of at least two different internal units of NCC, it was agreed that the main responsibility for the design would be borne by the largest business unit, NCC Construction. Otherwise, it would be almost impossible to determine which unit that was most responsible for any non-compliance with a particular technical requirement. The main reason for these difficulties was that existing design models are not able to predict performance of a given road but only a general and nominal life expectancy according to predefined and more or less fictive life expectancies (cf. Section 5.1.2). However, the choice of using a conventional design would probably make it easier to appreciate risks since the performance of older projects might be possible to analyze. One measure taken by NCC was to obtain information by a literature survey. Another measure taken was to evaluate the historical performance of previous investment and maintenance projects; in particular the few D-B approaches procured by the STA during the 1990s (cf. Section 4.2.2). During the work, it became obvious that only very few roads historically had been thoroughly analyzed and publicly presented regarding their technical performance. In principle, only a number of previous D-B projects had been sufficiently documented in order to provide reliable data for the current project. Furthermore, it was not practically possible to obtain and analyze performance of previous D-B-B projects, not even those once produced by the NCC themselves, due to difficulties of locating reliable field measurements and documentation. Although a comparatively conventional design was chosen in the end, it was conceived appropriate by NCC to use state-of-the art technology when producing the pavement, including using best available materials and production technique. This was performed partly by evaluating results from a unique comprehensive field test carried out in cooperation with the STA and VTI seven years earlier in 1996. The choice was motivated as an-

other measure to minimize risks in the face of the demanding performance requirements but also as a way of showing the STA that actions actually were taken to utilize new technology in accordance with the client´s expectations. In total, the theoretical work of compiling the experience necessary of previous projects took approximately 8 weeks and required several formal and informal meetings with internal and external specialists at the VTI and STA. Although much work was devoted to these tasks, no communications were ever held with external material suppliers such as cement or bitumen manufacturers, partly due to concerns of disclosing sensitive information but also due to problems of ensuring that any alternative product suggested by the supplier would actually result in improved performance and not only increased costs.

Financial considerations

In principle, the ultimate objective of the bid was to calculate the costs of executing the project in accordance with the tendering documents. A large part of the bidding activities was in many respects similar to conventional bidding where each contractor, subcontractor and supplier calculated the costs of its individual part of the total undertaking. In the case when materials, production methods and their quantities were easily assessable, prices for the different construction parts were gathered and compiled by the quantity surveyors for each technical area according to established routines. As in most conventional projects, the bid organization had to contact sub-contractors and suppliers regarding prices. In this case, formal tendering processes were to a large extent used. Besides establishing the bid based on its own costs and capacities, competitor analysis was also performed by evaluating previous projects.

Communication with the client

Besides the tendering documents supplied early in the procurement phase, in total 10 complementary tendering documents, based on questions and answers exchanged, were sent to the three contractors participating in the bidding.

> *During the upgrade, we had no direct contact with STA. Our questions were sent through NCC (Manager, Grontmij).*

Of the total questions submitted, almost half of them concerned financial aspects, while a large part of the remaining questions concerned technical aspects. Some of the questions raised by the contractors led to changes in the tender documents, as indicated by the numerous complementary documents. Approximately one third of the changes concerned the different specifications and problems related to their interpretation. An example of a particular change concerned the performance requirements of the road, where a contractor had suggested it as being too difficult to practically achieve. This particular question was based on observations of previous road projects, which indicated that the current project was subjected to tough requirements. The procedure of formal questions and answers was essentially the same as in many previous road projects. However, the large number of questions resulted in a significantly greater workload both for the client and the bidding contractors. The bids were originally intended to be submitted on 29 November 2004 but an extension was granted until 3 January 2005 due to the extensive work required to produce the bids. According to several respondents, the work of compiling the bid was significantly more costly compared to traditional bids of the same monetary size.

6.2.3 TENDER EVALUATION

On 4 January 2005, the group responsible for the project (cf. Section 6.1.2) opened the bids received from the three contractors NCC, Skanska and Veidekke. In the case of Veidekke, the contractor Svevia, (cf. Section 4.1.2), was intended as subcontractor for a substantial part of the works. The remaining fourth large domestic contractor, PEAB, had earlier in the procurement process decided not to participate. Each of the three bids received was divided into two parts, one commercial and one technical, which at least in the case of NCC was established in a technical PM enclosed in the bid. Although all three bids were considered to be well executed by the STA, despite no ground breaking radical solution being proposed (FIA, 2005), each bid required clarifications from the contractors regarding both commercial and technical issues. In order to further clarify the different bids, each main bidding contractor, including representatives from important consultants, were given opportunities to present their individual bid for the client. The first round of presentations

took place 2-3 weeks after the bids had been opened and were to a large extent devoted to critical issues such as the tunnel and installations.

Table 6.1 Compilation of bid prices (SEK million).

	NCC	Skanska	Veidekke
Design and construction	575	580	592
Maintenance	95	120	124
Operations	45	92	109
Total	715	792	825

The commercial part revealed that there were only small differences between the three bids concerning design and construction works. The highest bid, SEK 592 million, was only three percent higher than the lowest, which in turn was slightly higher than the so-called shadow bid drawn up by by STA (SEK 573 million). Of the total construction sum of SEK 575 million in NCC´s bid, approximately 1/5 was related to each of the four largest construction elements (e.g. the road, the tunnel, installations and bridges). Even though the bids were relatively close regarding design and construction activities, significant differences existed regarding the more unfamiliar maintenance and operations activities (cf. Table 6.1).

In March 2005, an allowance permit was released by the STA, which favoured NCC for the contract. However, before any contract had been signed by the two parties, the competitor PEAB appealed to the Administrative Court against the appointment of NCC. The formal reason argued was that the STA had violated certain regulations in the Procure-

ment Act[34]. However, according to several respondents, the appeal was largely due to reasons outside the project itself.

> *They [PEAB, editor's note] were sulky and had not even submitted a bid. The appeal was a reaction to an earlier appeal, in another STA region, by NCC Roads which had obtained a paving contract at the expense of PEAB (Project leader, STA).*

Although formally sent to the administrative court, the appeal was soon withdrawn without any judgment after swift so-called negotiations between the STA and PEAB. The contract between STA and NCC was signed on 14 April 2005 after some negotiations.

6.3 CONTRACT PHASE

The third phase comprises the *planning*, *design* and *construction* activities commencing after the contract had been signed between the client STA and the main contractor NCC, until 2012, four years after the traffic opening in the autumn of 2008.

6.3.1 PLANNING

As soon as the contract had been obtained, the preparation for design and construction activities on site was initiated.

The project organization

Since the project would exhibit several important differences compared to other projects, the STA had planned the execution for many years. In June 2005, the client had procured and established the project organization, which constituted relatively few individuals, 9 in all, and whose main purposes were to continue their tasks during the preparation phase (cf. Section 6.1.2) by observing, discussing and verifying the suggestions and actions taken by the contractors. As in the case of the other projects constituting Norrortsleden (cf. Section 4.3), the formal organization was divided into a number of blocks for concrete works, ground

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[34] It was argued by PEAB that STA had significantly changed stated prerequisites, stated during the preceding prequalification stage, which at the time had resulted in PEAB deciding not to participate in the bidding (cf. Section 6.2.1).

and road works, rock works and installations works. The contractor organization, on the other hand, needed more time to materialize and comprised on average 28 individuals. This organization (cf. Figure 6.2) was in essence the one formulated during the procurement phase but grew somewhat in the course of time as the scope of the project became apparent. Each of the four blocks constituting the production part was organized directly under the project organization, which besides the project manager, constituted staff such as administrative personnel and measurement specialists. Of the different organizational parts of NCC, in principle, only personnel from NCC Construction were represented on site for longer times. As in the case of most previously performed projects the remaining organizational parts of NCC, e.g. Hercules, NCC Roads and NCC Teknik, their personnel were still involved in the project, but only part time, and they accordingly essentially remained at their normal workplaces. A significant staff function indicated in Figure 6.2 was purchasing, which constituted a purchaser responsible among others for contracting suppliers and subcontractors not already contracted. The subcontractors and suppliers referred to contributed strictly according to drawings and descriptions established by NCC and its consultants. An important consequence of the procurement method was the need for two additional departments: *verifications* and *design* (cf. Figure 6.2). The first function indicates the extensive work of convincing the client that adequate quality had been delivered. The second department, which also constituted two individuals, was primarily established to administer the work of internal NCC departments and the external consultants.

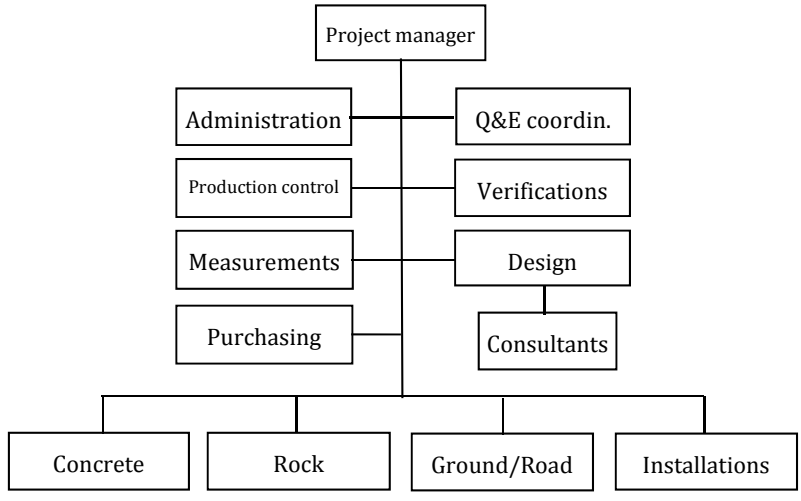

Figure 6.2 Contractor organization during contract phase.

Although not really a direct result of the D-B-M approach, a number of unconventional organizational measures inspired by *Partnering* (Cf. Section 4.2.2) were taken by the STA also in this project. One measure was the establishment of a common workplace at the construction site for the client and contractors. Several respondents, as well as the investigation presented by FIA (2006), confirm that the common workplace facilitated communication, both in quantity and quality, since informal questions could receive quick answers. Another significant administrative and organizational difference also inspired by Partnering was to prevent potential conflicts by establishing guidelines for contract interpretations early on. The guidelines were jointly established by legal specialists of the STA and NCC and manifested in a formal document. When it came to technical issues, including interpretation of the performance requirements, a technical council was formed as well as a dedicated conflict-resolution model. The measures mentioned were not strictly the result of the D-B-M approach but largely a consequence of the STA wanting a more close and cooperative relationship with the contractors than in historical projects. An important consequence of the measures taken

was a need to educate and inform STA´s own project organization of important aspects regarding the new contract including differences from traditional approaches and the way the interaction was intended to take place. The thoughts were articulated at a start-up meeting in June 2005 where the goals of the project and differences compared to other projects were discussed. The meeting attended by approximately 25 individuals of the actors resulted in some revisions to the contract. The internal communication of STA referred to was also primarily performed by holding a number of courses and meetings as well as information by e-mail where the essential features of the approach were communicated. However, in contrast to the client, the contractor side did not perform any corresponding measures (FIA, 2007). Consequently, there was initially a significant information gap between the two organizations, which to some extent affected the working climate negatively. In particular, since both the organization and the tasks of the contractor and client organizations were significantly different compared to conventional projects, initial problems regarding roles and responsibilities occurred.

6.3.2 DESIGN

In the case of design activities, the participation of Grontmij was not guaranteed despite their involvement in the previous project phase.

> *First there was a phase of negotiation, if it really were we who would do the work. It was certainly a business deal. If it was really us that should perform the work. There was nothing written that we would do the design. In particular, regarding what kind of agreement we would have (Manager, Grontmij).*

Each consultant company participating contributed a project leader and a number of consultants depending on the amount and stage of the work. Initially, some discussions were held regarding incentive models for the fee to the consultants, but in the end the relationships were based on a standard contract and a fixed fee (FIA, 2007). An important motive during the contract phase for the participation of Grontmij was expectations from NCC to achieve cost reductions by adapting the design as soon as new prerequisites were discovered on site (so-called

active design). By performing design parallel to the actual construction works, material or production methods could be rapidly changed as demanded by the situation. The design work was initially planned for approximately one year but most consultants would be accessible for the entire construction period.

Main design activities

The design work was divided into four larger groups, of which Grontmij was contracted to carry out the main work regarding the landscape, drainage and the road. The agreement with NCC was by no means different than traditional assignments despite some attempts to establish profit-sharing incentives. A large part of the design work was devoted to conventional activities, i.e. producing drawings and descriptions for construction elements and work on site. This was especially the case when procedural specifications had been specified by the client. However, although the design work in several ways resembled conventional projects, there were a number of significant differences as well. One important difference was the actual goal of the design work. In the present project, the overall aim of the design was to minimize the costs of the contractor within the limits of the performance requirements rather than to choose standardized solutions.

> *When we [STA; author's comment] purchase a given design, the result must be clear in order to perform the procurement without giving special treatment to any specific contractor. On the other hand, when NCC designs, they strongly consider their own production and resources in order to achieve a low production cost. There is a completely different focus and different designs suit different contractors (Project leader, STA).*

Also the consultants of Grontmij experienced that it was different to work directly for a contractor compared to working directly for the STA, as customary.

> *There were quite large differences. This is due to our being more used to establishing tendering documents. But in this case when the contractor already possesses the contract he*

does not need all these drawings and descriptions since he already knows how to perform many activities. Then the design does not have to be so detailed. It was useful for us to learn how a contractor perceives the documentation and what documentation he considers as necessary (Manager, Grontmij).

Although possibilities existed to evaluate several potential, or use unconventional, technical solutions, a large part of the materials and production methods established were simply obtained from STA technical descriptions, a circumstance also observed in other studies (e.g. FIA, 2007). Most measures taken concerned adaptions of technical solutions to fit the production in as an effective way as possible. A reason was the limited time and knowledge available to evaluate new solutions during the project. It was to some extent also unclear regarding the deviations that were conceivable. Another related opinion regarding the difficulty of finding alternative technical solutions was that the consultant was not sufficiently represented on site, which was partly the result of there not having an on-site office. This explanation was further indicated by the fact that many consultants simultaneously worked in other parallel conventional projects, and could thereby easily benchmark standardized solutions in a routine manner.

…they [Grontmij: author's comment] did not only work on a single project. We experienced that some consultants worked for the Northern link and it was difficult to make them understand that STA technical descriptions did not apply to this project. It would have been easier if they had been closer, then they would have understood the consequences of their design work (Site manager, NCC).

In the case of the road, the structural pavement designs had in principle already been established during the procurement phase (cf. Section 6.2.2). Although it had been possible to re-evaluate the design chosen during bidding, since increased knowledge of field conditions successively appeared, no major upgrade was ever made since a suitable design already existed and there were no solid reasons to reconsider it.

Another important consequence of the procurement method was STA´s process of approving and verifying technical solutions proposed by NCC and Grontmij. In contrast to conventional projects, where the solution was already determined during the design phase and later verified by inspections etc., the verification process of a given design during the current project was reviewed by both relevant NCC co-workers, including the design leader, block managers and members of the maintenance and operations unit, and in the end by STA´s technical specialists. The verification process indicated was intended to ensure that appropriate solutions were chosen to meet the specified performance requirements. The technical council (cf. Section 6.3.1) was never utilized to solve any pressing issues besides to act as a counterpart in discussions. In several cases, informal reviews were performed by STA´s technical specialists on designs in progress. In a number of these cases, Grontmij's consultants participated to convince the client of the adequacy of the alternative solutions promoted by NCC. Preliminary permits could then be obtained as well as feedback before the documentation was upgraded to formal work documents. Initially, the STA showed an interest in more closely checking the motives for a particular technical solution. For example, in the case of the pavement structure, technical specialists of the client reproduced in detail the calculations of NCC to verify that the assumptions and calculations made were adequate. However, in the course of time, this standpoint changed and STA passed over to more frequently asking questions instead of scrutinizing the documents in detail. The work procedure described was initially difficult to come to terms with, since few individuals involved had any previous experience of the procurement method and its consequences on work relationships.

> *Many were insecure. There was an open atmosphere and I felt that they listened to us. In this project we consultants had a very good relationship with the STA. We had some technical specialists [at STA, author's comment] that were a little tiresome but I experienced it overall as very educational (Manager, Grontmij).*

> *But at the same time…NCC was sometimes irritated at the STA since they were controlling. They had old codgers that*

required real drawings while NCC did not want to produce them. But I was lucky as one of the specialists handling the road soon retired. We avoided the main part of the fuss and got another one that was very benevolent (Consultant, Grontmij).

The problem was that the procurement method was new for the client as well. Instead of as usually referring to technical descriptions, they had established a list containing a large number of stated requirements. However, initially the different technical specialists had difficulties in accepting that standardized solutions were not always necessary. I would not say that any conflict started but sometimes the project leader of the STA had to direct their technical specialist (Manager, Grontmij).

As described in the next section, there were some uncertainties when interpreting the performance specifications. In order to facilitate the interpretation, possibilities to discuss each requirement were arranged by the STA at common meetings among the actors. The discrepancies revealed were discussed in detail and a number of improvements were suggested by both NCC and the STA. The solutions agreed on regarding performance requirements were to a large extent motivated by the intention that they would constitute requirements in future contracts. In cases when the two parties expressed contrary opinions, the disagreement was solved by discussions. The technical council (cf. Section 6.3.1) was to the knowledge of the author never used to solve any disagreement.

Meetings

The type and number of standardized meetings between Grontmij and NCC were essentially the same as in the conventional projects where STA is client.

This is how it is done with STA in normal projects, initially we have meetings every second week and later, approximately once a month. There is no difference (Manager, Grontmij).

One of the first meetings involving the consultants was a joint risk seminar comprising representatives from NCC, STA and Grontmij. As for conventional projects, both smaller formal meetings, comprising personnel from one technical area (C-meetings), and common formal design meetings (A- and B-meetings) were held to discuss design and technical solutions. The meetings were initially held at NCC´s office in Solna but after the summer of 2005, the meetings were moved to the newly established office at the construction site. Although the meetings sometimes included production personnel of NCC, the participants were generally limited to Grontmij's consultants, NCC´s and STA´s technical specialists. The number of meetings varied depending on the areas concerned. When it came to C-meetings for the technical area concerning the road, a pair of consultants from Grontmij met the corresponding technical specialist of the STA on a couple of occasions to discuss road-related issues under the supervision of NCC´s technical coordinator.

> *It was the case that NN [NCC´s technical coordinator, author's comment] would participate in all meetings with the STA. Possibly, I talked with MM [STA´s counterpart, author's comment] on the phone without NN being around, but he was always at the meetings (Manager, Grontmij).*

In the case of C-meetings regarding the road design, only a few meetings were held.

> *Not very often. There were occasions at the beginning when we asked some questions. We also had a couple of meetings where we were supposed to present the road profile since they wanted to approve it before we could continue (Manager, Grontmij).*

When it came to the more comprehensive B-meetings, they were more periodically held during the entire phase, approximately every two weeks. They were initially held in relatively large groups. However, after a while, it was considered necessary to separate certain technical areas in order to make the meetings more effective. Even though direct contacts sometimes occurred between the STA and Grontmij, the main contacts occurred through the one at NCC responsible for the design. In

some cases, it was difficult to maintain a direct dialogue, albeit urged by NCC, between certain consultants and STA´s technical specialists since the actors tended to act according to their traditional roles in D-B-B approaches.

> *It was difficult for them to understand that STA´s normal rules did not apply in this project; that we were their principal client. In their thoughts, they would be working as usual for the STA (Site manager, NCC).*

In several cases, deviant opinions were uttered, but conflicting opinions were considered as normal for this kind of project. According to a couple of respondents of the STA, organizational parts of the contractor NCC did not fully cooperate regarding both technical and administrative issues. The contractor should also have better informed its subcontractors regarding the procurement method. An example of a potential dispute concerning technical inquiries was how the performance requirements of the road should be interpreted. NCC considered the contract as rather unclear regarding some details. Accordingly, during a series of meetings held in 2007 and 2008 between managers and technical representatives of the STA and NCC, it was decided that some aspects of the contract should be altered if they were based on the recommendations of FIA (cf. Section 3.2.2). As indicated, the purpose of the discussions was not only to clarify practical aspects of the current project, but also to establish a practice for testing and evaluation, which could serve as a general model for future projects. Besides clarifying, and even changing, a few of the seven functional requirements, the discussions highlighted critical aspects of the performance requirements and how they should be interpreted, which resulted in that additional quality control was ordered by NCC to ensure their fulfilment.

6.3.3 CONSTRUCTION

According to most respondents, the construction activities on site were in many respects conventional and complied with the design successively established. Each contractor was in principle only responsible for the undertakings agreed on according to the individual contract, and consequently, remained on site only as long as it took to perform the construction activities including verifications of the quality by tests or inspections. When it came to the construction of the road, which was a construction element subjected to the most extensive performance requirements, several measures beyond normal were taken by NCC in the field to ensure the high quality of the road, as determined during the procurement phase. For example, additional efforts at ground stabilization, compaction of unbound materials and additional checks of road surface and bridge/road interfaces were made in order to reduce risks of technical problems during the contract period.

> *Well, if you read the contract, too uneven joints are not allowed and must be corrected. Based on experiences and the extra measurements made on this project, we did not think we could manage without additional milling activities (Site manager, NCC).*

> *An important feature of this project is that the penalties for not reaching stated quality goals are much higher compared to conventional projects (Site manager, NCC).*

Although important sub-contractors were informed of the project and the performance requirements, NCC did not want to delegate the performance requirements entirely to them. Instead, NCC performed additional measures to be on the safe side. The decision to resume the final quality assurance was partly motivated by that NCC considered it to constitute a core competence, which could not be delegated to an external subcontractor. As in the case of all road projects, significant work was devoted to laboratory testing of the unbound and asphalt materials used to build the pavement structure. However, during this project the testing was customized by making it less frequent in some areas while more extensive in other compared to STA standards. The choice of alter-

ing test frequency and scope was based on the possibility of actually doing that, according to the contract, and that it was deemed better to control certain aspects which were considered of interest also in the long run many years after a traditional contract would have expired.

In general, the respondents of each actor investigated describe their participation as both positive and stimulating. The project has also by most participants been considered as successful regarding delivery time and costs[35], compared to most projects of a similar scope and scale, despite a number of additions occurring during the course of the project. However, in contrast to many other projects, the most significant changes to the original plans concerned additions rather than alterations. One significant example was the decision to add a new traffic junction. The realization of this particular change required cooperation between the consultants, the contractor and client.

Meetings

In contrast to the parallel design activities, the early stage of the construction was not characterized by close contact between the two parties, STA and NCC. However, the number of *production* and *project* meetings successively increased as the project evolved. Most of these meetings were formal, with a fixed agenda, and held in accordance with the contract. For example, both production and project meetings concerning the progress of project activities were held on a continuous basis. The two meeting categories mentioned showed several similarities to the corresponding meetings of conventional projects. However, the meetings also displayed some differences since they mainly concerned exchanging information rather than a massive number of negotiations of changes and additions.

> *At these meetings, mainly information regarding the status of works was mediated, i.e. how far we had come. In that way, it*

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[35] According to an estimate made by the STA, approximately 5 % of the construction costs was saved by utilizing the D-B-M approach compared to the traditional D-B-B approach (DN, 2008).

was a little awkward since the meetings are normally used to solve contractual issues (Supervisor, NCC).

Besides the two conventional meeting categories mentioned, a number of less formal meetings were also held. These meetings were primarily held to communicate and discuss opinions regarding how the interaction between the two parties should progress as well as certain technical aspects. An example of the latter category was weekly so-called *good-advice* meetings. So-called *snake*-meetings, constituted another meeting category, and were held approximately every second month, with purpose of inspiring with new advice and minimizing the number of problems concealed in the project (FIA, 2006).

6.3.4 POST-CONSTRUCTION EVENTS

After the construction activities had been finalized and inspected in October 2008, most actors involved in the project, including the site organization, left the construction site and resumed working on new projects. The inspections differed to some extent from traditional projects in that the requirement could both concern the design and the actual performance. Thereafter, the operations department of NCC resumed responsibility for the project with the aid of a number of subcontractors, among others an organizational unit of the main contractor Svevia (cf. Section 4.1.2 and Chapter 5). In contrast to the construction activities where the actors were co-located, the contacts between the STA and NCC occurred mainly at short but periodic meetings held every second month. During these meetings 3-4 individuals participated of which 1-2 belonged to NCC, mainly the site manager responsible for operations, and the remaining two constituted a project leader of the STA and one external consultant hired by him. A large part of the content discussed during the meetings between 2008 and 2012 concerned technical aspects related to the tunnel and its installations. Although NCC fulfilled the agreement with the client, STA was still dissatisfied with the performance of certain installations and how such discrepancies were contractually regulated. In the case of the road, very little was discussed. The results from the performance measurements of the road were dis-

closed once every year but, so far, always without any comment from the STA[36].

Many of the different actors devoted to the current project became involved in activities of other large infrastructure projects in the Stockholm region, e.g. the Northern link and bypass Stockholm (cf. Figure 4.1). Although much knowledge developed in the current project was similar to conventional projects, in particular regarding financial issues such as material costs and production capacities, a significant amount of unique knowledge has been gained and used in subsequent projects, as will be exemplified below. Since the current project represented a national reference project under the surveillance by industry representatives, a number of experiences could be identified and implemented in the subsequent projects, e.g. Roads 34[37] and 50[38], procured by the STA.

Grontmij

When it came to the consultant, several respondents suggest that significant experiences have been obtained from the project, in particular regarding the work relationship that has been useful in new assignments. Several of the technical specialists at Grontmij argued that working directly for a contractor is significantly different than working for the STA.

> *For me personally, it is the way of thinking. That is what I have learned most about (Manager, Grontmij).*

The experiences were brought to new projects in which Grontmij was involved in to either establish procurement documentation or directly as consultants for contractors in D-B projects. However,

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[36] Since the technical quality of the project is to be evaluated during 15 successive years, no definitive answer regarding its performance either compared to the contract or with other projects can be made at this time.

[37] Road 34 denotes a major D-B project contracted to NCC in 2009 for SEK 240 million, which was opened for traffic in 2010.

[38] Road 50 denotes a major D-B-M project contracted to NCC in 2010 for SEK 1.3 billion, which is intended to be opened for traffic in the autumn of 2013.

although much individual tacit knowledge was probably obtained during the current project, only limited experiences were related to technical aspects, which is partly a result of lack of involvement in investigations and follow-ups regarding performance of historical projects.

> *Well, we do not do any particular follow-ups, e.g. what it is like several years after we designed it (Manager, Grontmij).*

The lack of follow-ups and evaluations has provided some problems regarding the ability to serve clients in future projects, in particular when providing normative suggestions for unconventional projects. For instance, when a contractor formally responsible for design in a given D-B project not necessarily requested that a particular standard should be followed, but that the total costs should be minimized, it has shown to be difficult to convince consultants that alternative design methodology and materials actually can be used but also that the consultants should commit themselves to consider such methods solutions.

> *It is probably that we are rather poor in making such assessments and we do not have any research for that (Manager, Grontmij).*

Several respondents verify this view and motivate the standpoint by that both competence and clear responsibility towards the remaining actors contribute to this behaviour.

STA

Many of the experiences obtained during the current project were publicly communicated by the STA at a number of national meetings comprising a wide range of contractors, consultants and clients. The project has also, as indicated in this chapter been published in form of a number of general industry reports, a book as well as within more academic research. According to the last publications, the STA have not performed any thorough evaluation of the project after the construction activities ended in 2008. However, the project has still resulted in significant learning regarding procurement for the client representatives involved in the project, knowledge that was brought with them into new projects,

primarily in tacit but also in explicit form. In the latter case, the current project showed significant impact on several subsequently procured projects regarding how to improve procurement and administrative routines. In 2008, a large series of new road projects were launched in Sweden, partly as an effort to counteract the expected worldwide recession, which utilized information from the current project regarding administrative, juridical and technical aspects. Consequently, the STA have used some experiences to develop a concept to procure D-B and D-B-M projects[39], comparable to a type of standard. Of the many road projects procured during 2008-2012, several were D-B projects subjected to 8-10 years of warranty, while two projects hitherto constituted D-B-M arrangements subjected to 20 years of maintenance responsibility, and based on performance requirements. One example of administrative-juridical knowledge gained during the current project was to carefully consider how to request technical information from the bidding contractors during the procurement phase, since such material is sensitive to appeals as obvious from Section 6.2.3. Some of these questions were resolved during the course of the current project in dialogue with the two other main actor categories. There were also a great number of lessons learned regarding technical details that were utilized in subsequent projects. Among other examples are what performance measures and acceptance levels to prescribe and how they should be verified and presented for the client during the entire contract period. Certain performance requirements used in the current contract were considered as inadequate, due either to their being considered as unclear or without any distinct evaluation criterion or default consequence, so that they were not used in subsequent projects. In other cases, the STA devoted resources to improve contracts and specifications, e.g. by developing clear procedures for measuring, levels for the performance requirements and financial penalties for not meeting the requirements. In this case, the current project provided important experiences for subsequent projects.

[39] *Denoted TEiP ("Totalentreprenader i praktiken", Design-build contracts in practice).*

> *At the procurement of the new Road 50, we have gathered experiences from Norrortsleden [i.e. the current project; author's comment], and, of course, we hope that the financial result will be as good as well (Project leader, STA).*

In some cases where significant limitations with the current requirements were known or detected, research efforts were triggered. One example of such an endeavour is a research project performed by the VTI on the behalf of among others the STA through FIA (SBUF, 2010). The STA also initiated general discussions with consultants and contractors regarding performance requirements as well as general aspects of the contracts.

> *It is impossible to write a complete contract where all contingencies are eliminated. We therefore need to incorporate clarifications, changes and other improvements over the years (Project leader, STA).*

The evolution between the current project and subsequent projects could among other things be observed by comparing texts in procurement documentation and written communication during bidding in the current project and subsequent projects.

NCC

Although many measures taken by the contractor during the present project may be considered as small, several respondents argue that the current project has resulted in several activities for developing new knowledge that has been possible to utilize in new projects. For example, knowledge has been materialized in monthly written production reports, seminars during public seminars and internal project kick-offs, at which representatives from the current project´s site organization have been invited. For example, during bidding of one of the larger D-B-M projects previously mentioned (Road 50), the project manager of the current project was invited to present her general view on risks and opportunities in unconventional projects. As a consequence, NCC decided to devote additional resources to large infrastructure projects and, in

particular, systematic information gathering regarding production costs as well as technical solutions in order to do future business.

> *This particular project is alive in a kind of way since we still possess the responsibility of the performance. We document our experiences informally and we have to live with the choices we made, if we choose appropriate surfacing and if we committed ourselves to the right installations etc. (Regional manager, NCC).*

The experiences from the current project also affected NCC´s subsequent involvement in D-B and D-B-M projects procured during the years 2006-2012. As a consequence of the extensive reliance on performance requirements, long contract time and commitments from the STA towards D-B and D-B-M methods, several types of commitments were made by NCC to improve technical quality, not only in the current project, but also in subsequent projects performed during the years defined for the current project (until 2012). Among these commitments were direct investments during 2010 in certain special equipment, e.g. two so-called material transfer vehicles (MTV) and a road scanning vehicle useful for improving paving operations and measuring road performance, respectively. It was among other things decided by NCC to perform continuous follow-ups of relevant projects to investigate their performance. One example of a project investigated in this effort concerned a certain project located close to the present project, namely the project presented in Chapter 5 which constituted one of many D-B-B projects also evaluated. Using these measures, not only uncertainties were intended to be quantified and managed, improved production control could also be achieved by measuring during production as well as illustrating the results to production personnel, and thereby improve individual dedication in daily work.

> *The annual follow-ups make it possible for us to identify good and bad projects and discuss the causes so that we learn to future projects (Technical specialist, NCC).*

Furthermore, NCC utilized and further refined simple theoretical models developed during the current project as well as results obtained from the performance measurements carried out the years after traffic-

opening, partly obtained using the road scanning vehicle mentioned above. These models were used during bidding to predict technical performance and thereby compensating for the limitations of traditional design methodology (cf. Section 5.1.2 and 6.2.2). In some cases, when the models indicated that the STA had demanded too tough requirements, compared to the opinion of the contractor, the results and motives were discussed with the client, who sometimes changed the initial requirements during procurement. A fourth example of development concerns the cooperation between the different organizational parts of NCC. As mentioned in Section 6.3.2, it was reported that discussions occurred between the two large business units of NCC when it came to distribution of product responsibility. In the current project the responsibility of road performance was essentially one-sided where NCC Construction assumed the main responsibility of performance despite the fact that another business unit, NCC Roads, show large impact whether the product meet stated requirements. It successively became obvious that NCC´s organization was probably not optimal for handling very long contracts during which significant maintenance and operations activities are planned. This conclusion led among others to the recruitment of additional employees in relevant areas. In 2009, the need of a more structured way of working together with new road projects was manifested in a formal joint quasi-organization denoted *the road platform*. Although largely a result of a significant increase in project supply by the STA during the years 2008-2010, the common platform highlighted important aspects discussed and agreed on in the current project. This was considered as particularly important since storage and retrieval of the knowledge gained during successive projects could be lost due to personnel turnover.

Among other initiatives made by NCC during the time after the completion of the current project was to devote attention to dedicated R&D projects. In 2010, it was decided that a cement-stabilization technique would be tested on a significant part on the D-B-M projects previously referred to (Road 50). The rationale of using this radical new technique was partly due to pressure from the client for innovations, cost competition and confidence built up by experiences from previous projects, such as the current one, as well as theoretical support gained by research.

Another initiative during this project was the use of advanced polymer-modified binder for producing the asphalt. The measures indicated were partly rationalized based on knowledge developed in earlier projects, e.g. the main project studied in this chapter.

7 ANALYSIS

The purpose of this chapter is to analyze the empirical material described in Chapters 4-6. Sections 7.1 and 7.2 are devoted to individually analyzing the two cases, while Section 7.3 presents the main comparative analysis.

7.1 CASE I – THE TRADITIONAL APPROACH

In accordance with Table 2.1 in Section 2.5, the analysis is based on the three concepts of uncertainty, interaction and knowledge gained.

7.1.1 UNCERTAINTY

Several circumstances indicate that the focal project of this case exhibits a low degree of uncertainty. This conclusion is largely based on the essential product, the actors involved, the activities performed and the resources used in almost all aspects being conventional, well-known and established in existing legislation, administrative routines and technical standards. Among other things, the scope of the product is considered as conventional since the client has historically procured several projects of similar scope and size. The project organization, including the client, the contractor and the consultant, already knew each other well from work in previous projects. In the case of the actual procurement method, the procedure preceding its choice and its execution is considered as standard for the client´s historical projects (cf. Section 4.2.2).

Degree of administrative uncertainty

This section analyzes the degree of uncertainty based on the number of activities contracted and contract length according to their chronological appearance in the case.

Number of activities contracted

As in most previous projects procured by the client, design and construction was each procured separately from different actors: the essential design activities were obtained from a consultant during the design phase, while construction works were procured from a main contractor utilizing the documentation developed in the previous project phase. No subsequent maintenance and operations works were included in the

project but procured separately outside the scope of the current investigation. Since the contractor and the consultant did not participate to any greater extent during the design and procurement phase, respectively, these actors are not considered to have been exposed to any corresponding uncertainties at this particular project phase. The design work exhibited mainly ordinary routine tasks and both the work performed and product delivered were formally accepted and taken over by the client at the end of the design phase, implying that the consultant did not bear any significant responsibility for future product performance, or maintenance costs as the design satisfied existing technical standards either directly developed or indirectly sanctioned by the client. In the case of the procurement and construction phases, the contractor assumed, in a corresponding way as the consultant, the responsibility that future works would be conducted according to the details of drawings and descriptions provided by the client from the design phase. Consequently, the procurement method chosen resulted in that the client remains the actor assuming the largest share of uncertainties. However, the procurement method chosen is still considered to reduce client uncertainty by achieving a freestanding project during the different project phases (cf. Section 7.1.2). By strictly relying on dyadic relationships, the emphasis on formal communication structures as well as established routines and practices, the actual choice of the D-B-B approach can be considered a means for the client to reduce uncertainty, for example, regarding competition, project cost and delivery time (cf. Cyert and March, 1963; Nelson and Winter, 1982; Cova et al, 2002). In particular, the exclusion of third-party actors, e.g. contractors, from the design appears as a deliberate measure by the client to reduce uncertainty by planned isolation that might otherwise jeopardize the project goals (cf. Lundin and Söderholm, 1995).

Contract length

The second aspect of administrative uncertainty concerns the contract length, i.e. the time any of the three actors had an agreement with another actor. Contract length is also related to the time that project goals such as costs and quality are evaluated and regulated. The length of the agreement between the client and consultant for the current project is not considered as long since the essential work mainly concerned the

design phase, despite some work in the contract phase, and the work was evaluated more or less instantaneously once the documentation produced had been approved by the client. As indicated in the previous section, an important aspect of uncertainty during the design phase concerned the distribution of burdens between the two actors involved. In principle, the client not only assumed most uncertainties regarding the product, but also the time of the design and costs associated with changes in the design as they were formally handled during that additional consulting time. Consequently, the consultant experienced comparatively low uncertainty in these administrative aspects partly due to the relatively limited agreement with the client.

In the case of the procurement phase, the firm reliance on existing and known routines during the three-month period for bidding, indicates that no particular market or transaction uncertainty prevailed neither for the client nor for the bidding contractors. The principal uncertainties for contractors during this phase concern the appreciation of their own material- and production-costs as well as the market price of which the contractor probably had great experience. Any default costs of not meeting stated project goals, e.g. completion time and quality, were clearly stated in the documentation. The few administrative questions asked by the contractors to the client during the Q&A procedure also indicate low uncertainty. The third activity of this phase, tender evaluation, was in almost all aspects uncontroversial with its strong focus on formality and price. Although several alternative bids were submitted by the bidding contractors, none were ever accepted. Since an alternative bid does not conform exactly to the client´s request, given the strong confining pressure of the technical standards, it is not clear which deviations are allowed and how they ought to be motivated for approval by the client. To the knowledge of the author, it is very uncommon that alternatives are even evaluated, and even less accepted, by any public client, which suggests that the administrative uncertainty with variants is perceived by the client as rather high.

The construction works were in most respects in accordance with the design, despite the occurrence of alterations and deviations, which means that they could be managed within the current contract and the

contractor obtained compensation for a significant part of these changes. Also, neither the client nor the contractor regarded them as extraordinary but approximately of the same amount as in other projects. Traditional road projects, including the one described in Chapter 5, are normally restricted to a contract length covering the few years of on-site construction and a subsequently following five year long warranty period, which indicates comparatively low uncertainty for the contractor. Since the client had contracts with both the consultant and contractor, the client experienced a higher degree of uncertainty than those actors. However, since the overall contract time is considered as comparatively short, the resulting uncertainty is still considered as moderate.

In summary, the client contracted the consultant to perform design activities and the contractor to perform construction activities, which means that the client exhibited a higher degree of uncertainty than the two other actor categories. However, although a relatively large responsibility was assumed by the client, it was still to moderated by firm reliance on existing routines and standards.

Technical uncertainty

This section analyzes the degree of uncertainty based on the type of requirements and design methodology employed according to their chronological appearance in the case.

Type of requirements

In the case of the design phase, the consultants produced the design using well-known procedural specifications either established or sanctioned by the client. Although several updates were actually needed during the design, the resulting work activities of the consultant were still guided by formal institutions. Consequently, no development of new technical knowledge regarding materials characteristics, production technique or design principles were ever required in association with the focal project, which indicates that the technical uncertainties for both the client and consultant in this respect are also considered as relatively low (cf. Shenhar and Dvir, 1996; Winch, 1989).

In the case of the procurement phase, the contractor was not subjected to any particular technical uncertainties given that the project was to be carried out using the design established during the previous project phase. The technical requirements had been utilized in previous projects and were familiar to the bidding contractors. Furthermore, although some of the 22 questions asked by the different bidders during the procurement phase concerned other aspects than contractual and financial, no significant technical questions regarding the road were ever treated. The limited use of technical specialists by both the client and contractor during this phase also suggests low uncertainty in the form of interpreting the exact nature of materials, production technique and design models. This circumstance also indicates that the few technical uncertainties perceived did not need any clarification. Although some alternative technical solutions were suggested, neither new technology nor development of such was actually needed.

When the construction activities on site started, a number of deviations between design and field conditions were observed. However, any resulting changes were taken into account by the distribution of burdens agreed on in the contract, which means that the client assumed most uncertainty in this regard. The essential technical quality was evaluated shortly after the on-site construction activities ended by means of tests or inspections referred to in the contract documentation. Given the distribution of burdens (cf. previous sections on administrative uncertainty) and that the final inspection was successfully passed in 2008, the contractor is considered to experience relatively few uncertainties thereafter. However, since the client has sanctioned the technical design, including the technical descriptions on which it was based, this actor also experienced higher uncertainty than the other two actors regarding any future performance. However, given the experience on which the technical standards are based and the extensive portfolio of projects permitting variation in individual project performance, the risk of poor technical performance for this particular project is still considered as a moderate uncertainty for the client.

Structural design methodology
Since the structural design was carried out by the consultant during the design phase using the client´s dedicated tool, which in turn represents an analytical manifestation of the latter actor´s technical descriptions, no uncertainty concerning whether the design would fulfil the requirements (cf. previous section) existed neither for the consultant nor the client.

Although the contractors during the procurement phase apparently developed alternative technical solutions, the variants themselves are considered as relatively conventional, limited in scope, and largely based on established design methodology. However, since the alternative bids were rejected by the client, no real technical uncertainty persisted for any contractor. As in the case of technical requirements, the client represents the actor subjected to most design uncertainties since that design tool only states whether a given design is according to a certain technical standard rather than actual technical performance.

In conclusion, the use of a design tool based on procedural specifications resulted in that the consultant as well as the contractor was only subjected to limited technical uncertainty, while the client was subjected to moderate uncertainty due to responsibility that the specifications result in adequate future performance, as well as any future costs of insufficient quality and maintenance.

7.1.2 INTERACTION
As discussed in Section 2.3.2, interaction is separated into two categories depending on whether interaction occurs internally within the project (intra-project interaction) or whether it concerns connections established between the focal project and other projects.

Intra-project interaction
Intra-project interaction is distinguished by interaction frequency, breadth and depth.

Frequency

During the first project phase, intra-project interaction occurred bilaterally between the client and the consultant. Although some interaction occurred between the client and contractors at an industry level, concerning among other things procurement methods in general, it neither explicitly concerned nor affected the decision of the client to utilize the D-B-B approach for the current project. The relationship between the client and consultant is considered as mature, established and long-term as indicated by previous engagements, a circumstance that facilitated both exchange of information and coordination due to existing administrative routines as well as technical standards (cf. Håkansson and Snehota, 1995; Ford et al, 2003). Although a substantial part of the interaction between the two actors occurred by artifacts, such as telephones, e-mail and documentation management systems, meetings constituted the principal mode of interaction. Apart from a few meetings with external stakeholders, the main interaction between the client and consultant occurred at four different types of formal and standardized meetings devoted to administrative and technical discussions. The interaction frequency is considered as comparatively intense during this project phase, especially regarding technical issues, and is largely in accordance with the prevailing agreement between the actors as well as compared to other D-B-B projects of similar scope and size.

During the procurement phase, the actors involved comprised mainly the client and the contractors competing for the contract, while the consultant involved in the previous project phase played an essentially smaller part. The interaction between the client and the bidding contractors was strictly limited to arm´s length relationships. In particular, the interaction was characterized by formality, rather than by dialogue and cooperation, as requested by the Procurement Act. The bidding activities of the contractor studied involved relatively few individuals each following established internal routines. Only a few internal meetings were held, largely of comparatively low formality, and the work is not considered to have been associated with any particular uncertainties. Consequently, interaction frequency during this phase between the client and contractor is considered as relatively low.

During the contract phase, the character of interaction changed once again to become more frequent, multifaceted and relational compared to the extreme arm´s length type during the previous phase. Besides the enormous amount of interpersonal interaction at the construction site, the main mode of interaction of interest for this study occurred in the form of formal meetings. The interaction showed, as in the case of the design phase, significant dyadic tendencies, despite some involvement from the consultant, and was facilitated by the interacting organizations comprising similar organizational configurations and frequent informal contacts. In essence, four different types of regular meetings were held between the client and contractor once or twice a month. The number and type of meetings were in many respects in accordance with the contract as well as being comparable to other projects of similar size and scope. Besides the standard type of meetings held between the two actors mentioned, some initiatives were also promoted by the client to provide learning. The interaction frequency between the client and contractor is considered as relatively high, while the interaction between the client and the consultant is considered as of lower frequency due to its less frequent and responsive character to solve pressing issues.

Breadth

The interaction during the design phase is largely characterized by the client providing information regarding needs and data while the consultants performed the essential design activities and communicated the results back to the client. No obvious conflicting interests existed and both actors shared a common view in achieving an objectively adequate design as determined by existing institutions including the joint contract specifying project time-schedule and fee. However, the main categories of meetings between the two actors were either administrative or technical in their content, which suggests limited interaction breadth. Although some breadth was achieved by the more general technical meetings relatively low breadth is still generally considered to have prevailed due to lack of joint analyses e.g. regarding alternative designs or evaluation of life-cycle costs. Even though the essential dyadic interaction probably affected the questions treated during meetings, the seemingly limited breadth is mainly explained by the assumingly deliberate distinct division of technical and administrative aspects.

Even though the procurement phase exhibited relatively low interaction frequency, the information exchange between the client and contractor can be considered as comparatively broad since it involved many different topics, e.g. both technical and economic aspects. However, since many important issues, for example, technical aspects, in principle, had already been predetermined, there was no need to treat such questions in the same forum as economic matters. In addition, as indicated by the division of work among individuals of the contractor, administrative and technical issues were often treated separately. There were, for example, few needs to make any evaluation of costs due to design changes or whether a certain design would result in other life-cycle costs compared to another solution. Furthermore, the client did not even properly evaluate technical solutions in alternative bids either internally or with the aid of consultants, which also is considered to have negatively affected the breadth of interaction between the client and contractor.

As in the previous phases, the main administrative and technical aspects of relevance for the progress of the project were normally discussed separately at the series of periodic meetings held between the client and the other actors. Consequently, since the three actors almost never met altogether to discuss any topics, there were few opportunities to jointly evaluate a problem or situation towards alternative solutions and effects on costs. Although examples of efforts made to increase interaction breadth, e.g. seminars among project participants, the interaction is still considered as restricted regarding breadth.

Depth

Although the meetings during the design phase only comprised representatives from the client and the consultant, some differences among meetings categories with regard to knowledge articulation could be noticed. For example, the topics covered during the more general meetings suggest that a significant purpose of this meeting category was to provide general administrative information and to inform other meeting participants of the project status (establish a common picture and avoid duplication of work), respectively, rather than developing or transferring new knowledge. In contrast, the few more technically oriented C-meetings, comprising more homogenous participants, i.e. of similar

practice (cf. Brown and Duguid, 1991), exhibited more detailed discussions regarding concrete technical solutions. However, although seemingly technical, this meeting category primarily involved coordination and articulation of solutions in existing standards. Consequently, the depth concerning both administrative and technical issues is considered as of relatively low degree since neither explicit results, investigations of previous projects nor research constituted any significant part of the discussions.

Since the interaction between the client and contractors during the procurement phase was essentially based on existing institutions, including established routines and technical standards, it is generally considered as of low depth. Even though technical aspects were discussed in some detail during the procurement phase, in particular in connection with alternative bids within the contractor and client organization, the interaction depth is not considered as of high degree. This conclusion is based on the view that materials, production technique and design methodology utilized and solutions proposed in most respects were according to standards. Hence, although non-standardized aspects were involved to some extent, they are not considered as sufficient for the technical depth to be classified as being of high degree. In contrast to the two first main activities of the procurement phase, the bid evaluation did not show any inter-organizational interaction but only among individuals of the client organization. The fact that alternative bids were in principle allowed could indicate that some resource commitments from the client towards bidding contractors. In a similar way as the contractors devoted resources to develop the bids, it might have required additional resources from the client to evaluate the bids. However, this commitment was neither directed towards any particular actor nor credible as indicated by later client statements (cf. Section 5.2.3). A conclusion from this result is that it is difficult to obtain business using alternative bids in D-B-B contexts due to institutional barriers. In summary, the choice of the client to stick with the original design, rather than switching to an alternative, may be considered a result of reducing uncertainty. Consequently, during the procurement phase, the interaction depth is essentially considered as being of relatively low degree with the possible exception of the contractor´s alternative bid.

The depth of interaction during the contract phase was comparatively low, and as in the case of the two previous phases covered, largely due to the firm reliance of the actors on existing routines and standards. The relatively low degree of interaction depth between the client and the contractor was probable a result as well as a cause of the comparatively standardized and conventional aspects of the project, which neither required nor permitted unconventional technical solutions or extraordinary evaluations of financial consequences but mainly revisions or complements of existing documentation of previous project phases. Consequently, as in the case of the design phase, technical discussions and inquiries (quality testing, field trials etc.) were limited to existing solutions codified in technical standards and were therefore also of low depth. Both contractors and consultants verify that they are too little involved in other activities and phases apart from their main assignments. Consequently, it was difficult to use arguments from technical specialists at this late stage since they were neither invited nor committed to participate in the project. As in the case of the dyadic interaction, and resulting limited breadth, the adherence to technical standards can be considered a deliberate measure by the client to reduce technical uncertainties.

Inter-project connections

Inter-project connections are indicated using number of connections from the focal project to previous projects and future projects.

Number of connections to previous projects

The perhaps most obvious connections between the current project and previous projects concern other projects associated with Norrortsleden (cf. Section 4.3). For example, the use of common administrative functions among the different projects at Norrortsleden constitutes an important example of connections between the current project and other Norrortsleden projects. Connections are also exemplified by the fact that the consultant of the current project obtained the design assignment based on previous interaction with the client. A third example is that potential contractors during the procurement phase were identified from participation in previous projects. A fourth example of inter-project connection was the contractor's transfer of knowledge regarding

costs, prices and capacities from previous projects to calculate bids during the procurement phase. However, although experiences and knowledge certainly were transferred from historical projects to the current one, few examples of explicit connections exist where circumstances in a specific historical project significantly affected the current project. This is particularly evident in the case of technical aspects as, in principle, only a single connection could be found in this study. No actor investigated utilized any greater amount of codified knowledge obtained from explicit previous projects to design or otherwise made decisions of technical importance. The only exception was the contractor who utilized results of a previous project in order to develop an alternative bid. Consequently, essentially all technical inquiries were incorporated in the project via technical standards prescribed in the client´s technical descriptions.

Connections to future projects

As indicated in Section 5.3.3, a number of, for this study, relevant projects were initiated between 2007 and 2012. The main connections between the current project and such subsequent projects are related to individuals participating in both categories. The consultant has in principle not devoted any attention at all to the current project once it passed the final inspection. The contractor, on the other hand, seems to have devoted some attention, at least to administrative issues involving purchasing. However, no other explicit influence on subsequent projects has been observed during the study. This is particularly the case concerning technical aspects. It was possible to obtain information that the current project has affected subsequent projects in that administrative routines have been adapted in other projects close to Stockholm. Consequently, several important aspects regarding safety, the working environment and risk management were brought in written form from the current project into the design phase of other subsequent projects by the client. However, it is still considered that the current project has only shown limited effect on future projects due to relatively few connections. For example, no evidence suggests that the current project has resulted in any revision of national administrative routines or technical descriptions published by the client.

7.1.3 KNOWLEDGE GAINED

This section addresses knowledge outcomes for the three main actors studied and is divided by administrative and technical content and in accordance with project phase studied.

Administrative knowledge

Administrative knowledge gained by the three actors studied is categorized based on whether it concerns contractual or financial aspects.

Contractual aspects

The extensive scope of the project investigated suggests that the actors involved had many possibilities to gain knowledge. However, since administrative aspects associated with contractual aspects in almost all respects were familiar in the sense that they already existed at some level, but were not necessarily known to all participants, the degree of knowledge gained by the client and consultant is thereby considered as relatively low for both actors. This finding is considered as a consequence of the relatively low degree of interaction breadth but also depth during the phase studied.

Following the extremely limited interaction between the client and contractor involved, very little knowledge is considered to have been gained by any actors besides what was codified in the tendering documentation and the formal procedure during which it was conducted. The circumstances evolving around the reluctance of the client to consider any alternative bid or variant suggests that the actors gained some knowledge regarding the contractual complexity in which the project was embedded but also that it is questionable to devote resources at all to develop such bids given the procurement chosen. Later projects seem to verify this assumption since no road-related alternative bid to the client, to the knowledge of the author, has ever passed bid evaluation.

As in the case of the two previous project phases, the contract phase only provided a few examples where any higher degree of knowledge was gained by the three actors. Although some initiatives were taken by the client to encourage knowledge development and organizational learning, it has been difficult to find any solid evidence of effects for the

three actors investigated during this project. An explanation for this is that much that was articulated during the meetings held resembled knowledge from everyday experiences, i.e. showed only a low degree of interaction depth and breadth. One exception is the collaborative agreement regarding cost-savings from any technical solutions. The current project also only shows a few examples where the actors involved actually developed knowledge that later has been utilized in subsequent projects. For example, this particular project did not result in any revisions of either technical description or procurement documentation utilized for subsequent projects.

Financial

The relatively high interaction frequency during the design phase among the client and consultant provided several opportunities to articulate information and gain financial knowledge. However, since the interaction between the actors was already institutionalized, while no evidence of specific commitments was detected by any actors that went beyond normal work routines, the degree of financial knowledge gained is considered as being low. This was among others indicated by the lack of financial evaluations of alternative technical designs.

A somewhat similar situation as the one described for the first phase is considered to have prevailed for the client and contractor of the second phase due to the extreme arm´s length interaction. Although some knowledge of higher degree was gained by the contractor while discussing technical solutions that deviated from traditional ones, and that apparently resulted in lower costs (cf. Table 5.1), the knowledge gained can overall be considered as being of low degree for both the client and contractor due to lack of any analyses beyond the actual investment costs for the assignment described in the procurement documentation.

Following the change in interaction from the previous phase, the amount of knowledge gained has also changed. The relatively high interaction frequency between the client and contractor, in particular during production and project meetings resulted in financial knowledge for both actors. This was certainly the case regarding additions and alterations. However, since the knowledge gained to a large extent concerned

actual production data and purchasing costs, which could be analyzed in comparison with the corresponding data from the procurement phase, the actual knowledge gained is still considered as being of relatively low degree. In a corresponding way, the knowledge gained by the consultant is also considered as limited when it comes to financial aspects. The low degree of knowledge gained is not only due to the fact that the interaction was based on already existing institutions but is also due to limited interaction with the contractor. Hence, not being able to interact directly with the third party provided knowledge barriers for both the contractors and the consultant by low interaction breadth.

Technical knowledge

Technical knowledge gained by the actors is classified by reference to material, production and design.

Material properties

Since technical issues to a large extent were determined by the client based on existing codified material, no knowledge of a higher degree is considered to have been gained by either the client or consultant during the design phase. The corresponding situation is also considered to have existed during the subsequent phases for the client and contractor with the exception when the contractor developed alternative bids. The situation described is probably that none of the actors involved had either motive or possibility to promote or thoroughly investigate alternative materials during the project. However, since the contractor devoted at least some resources to evaluating and internally articulating alternative bids during the procurement phase, this actor gained some technical knowledge regarding material behaviour from previous efforts. However, the overall limited focus on material properties, besides verifications of technical quality by the contractor and subsequent approval after inspection, provided a low degree of technical knowledge for all actors involved.

Production technique

As in the case of technical knowledge regarding materials, only limited technical knowledge is considered to have been gained by any actor involved in this project regarding production technique. For example,

even though the contractor utilized some new technology the lack of thorough investigation or evaluation of effects resulted in it being difficult to utilize any knowledge obtained in subsequent projects. In almost all other aspects, the production technique was in accordance with existing standards, and the degree of knowledge gained is accordingly considered as being low.

Structural design

The main contributor to the structural design activity in this project was the consultant, and, consequently, also the main actor that used knowledge regarding this aspect. The need to update the design, during the first project phase, due to changing standards, suggests that some knowledge was gained by both the client and the consultant. However, as exemplified by the fact that the main technical knowledge was gained by junior consultants while interacting with more senior ones, this knowledge may be considered as being of lower degree since it was in accordance with standards. The contractor devoted some effort using a conventional design methodology to develop alternative bids, which is considered to have provided some technical knowledge that can be categorized as being of higher degree. The corresponding check of the contractor´s calculations by the client is also considered to have resulted in some knowledge. However, since the efforts referred to were primarily based on existing technical standards and design tools, any degree of technical knowledge gained by the actors is considered as low.

In summary, the main actors gaining knowledge during the first project phase were the client and the consultant, while the contractor is not considered to have gained any particular knowledge due to limited interaction. Correspondingly, the main actors that gained knowledge during the second project phase were the client and the contractor. In the third contract phase, all three actors are considered to have gained some knowledge. A large part of the knowledge gained by the three actors can be considered as tacit and individual, emphasizing the experience accumulation utilizing existing institutions as an important mode of learning. The degree of both administrative and technical knowledge gained by the actors is considered as low due to low degree of interaction. One reason for the limited knowledge gained was among others the

lack of breadth in the interaction where deeper financial consequences of technical aspects could be evaluated. Figure 7.1 summarizes the findings during the three phases studied regarding uncertainty, interaction and knowledge gained for the three actors investigated.

Table 7.1 Summary of findings for the traditional project procurement method.

Characteristic	Indicator	Phase I	Phase II	Phase III
Uncertainty	Administrative Technical	*Generally low uncertainty due to few activities contracted, short contract times and procedural requirements supported by an established design tool for the consultant and contractor, while moderate for the client due to larger responsibility including routines and standards.*		
Interaction	Intra-project interaction	*Relatively high frequency but low degree of breadth and depth between client and consultant.*	*Relatively low degree of frequency, breadth and depth between client and contractor.*	*High frequency while low breadth and depth between client and contractor. Generally low between client and consultant.*
	Inter-project connections	*Few explicit connections established by the three actors to previous and future projects, in particular regarding technical aspects where only a single connection to a historical project was found.*		
Knowledge gained	Administrative	*The client and consultant gained low degree of contractual and financial knowledge.*	*Low degree of financial but also contractual knowledge for both the client and the contractor.*	*All three actor categories studied gained a low degree of contractual and financial knowledge.*
	Technical	*In general low degree of knowledge gained regarding material, production and design by all three actors studied.*		

7.2 CASE II - THE UNCONVENTIONAL APPROACH

In accordance with Table 2.1 in Section 2.5, the analysis is based on the three concepts of uncertainty, interaction and knowledge gained.

7.2.1 UNCERTAINTY

Several circumstances indicate that the current project exhibits comparatively high uncertainty in a number of, for this study, relevant areas despite the apparent conventional nature of the actual constructed facility, reliance on previous relationships, routines as well as technical standards.

Degree of administrative uncertainty

This section analyzes the degree of uncertainty based on the number of activities contracted and contract length according to their chronological appearance in the case.

Number of activities contracted

In contrast to most previous Swedish infrastructure projects, the procurement method of the current project stated that a supplier should assume an extended responsibility beyond previous project responsibilities including the establishment of the design and subsequent execution including maintenance and operations activities. Even though several unconventional D-B projects have historically been carried out in Sweden, the current project was larger, both in scale and scope, compared to those. The decision taken by the client to choose the unconventional D-B-M approach thereby resulted in the project showing significant need, market and transaction uncertainties (cf. Håkansson et al, 1976). An important part of the client´s uncertainty can be related to the fact that an external contractor would be responsible for activities normally controlled either directly by the client or indirectly by reference to the client´s routines or technical descriptions. A major need uncertainty during the preparation phase was whether the tendering documents produced actually would express what was requested by the client (cf. Håkansson, 1982; Cova et al, 2002). Another important question for the client during this phase concerned whether the result from the preparation phase would result in adequate market competition compared to

other projects of the same size during the following procurement phase. A potential transaction uncertainty for both the client and bidding contractors concerned how the actual procurement should be carried out in practice, e.g. the time frame needed for bidding and whether or not physical meetings were necessary between the actors. This particular uncertainty is partly related to the comparatively large amount of information needed for preparing the project and its complex procurement procedure, which both indicate high uncertainty (cf. Håkansson, 1982; Cova et al, 2002; Gransberg and Molenaar, 2004; Gruneberg et al, 2007). However, although the project in many respects showed significant administrative uncertainty, the development of the procurement method exhibited many deliberate measures by the client to counteract too high uncertainty (cf. Section 7.2.2). Even though much effort was devoted to make the procurement model as clear and indisputable as possible, the fact the procurement was eventually appealed against by a competing contractor (cf. Section 6.2.3) shows that such uncertainties cannot be completely eliminated.

Since the D-B-M approach employed was not only new to the client, but also any competing contractor and assigned consultants as well, several potential uncertainties existed for these two actors during the subsequent procurement. This concerned, among other things, difficulties in determining costs, or at least the causal relationship to a given technical solution, for some activities, e.g. maintenance costs as dependent on the design and construction method utilized. An important uncertainty for the contractor concerned whether and to what extent any design works should be delegated to external consultants. In the end, the contractor decided to assign a well-known consultant based on a previous relationship. However, as indicated in subsequent sections, the contractor decided to retain significant parts of the technical aspects, especially those associated with the performance of the road, in-house and the two actors were therefore subjected to a different magnitude of uncertainty in this respect: the contractor was subjected to greater uncertainty than the consultant. A delivery-related uncertainty, also of technical relevance, for the contractor concerns the question whether a proposed technical solution and associated design would actually be formally ac-

cepted by the client, a question that could not be finally resolved during bidding but during the subsequent activity of bid evaluation.

As in the case of previous project phases, the procurement method applied also resulted in uncertainties regarding roles, responsibilities and procedures during the contract phase. The project organizations of the client and the main contractor were in some respects unique due to the number of actors involved and distribution of responsibilities and the need for coordination. Even though the organization of construction activities was in most respects conventional and divided into technical areas, the share size as well as number of consultants and technical specialists devoted to the project during this phase is considered as unique. The size may be explained by the fact that the two actors were uncertain whether sufficient resources had been committed. Although both the type and number of construction activities are considered as neither large nor small compared to many other road investment projects procured by the client, the process during which the main design was carried out in parallel to construction is considered as uncommon for road projects in Sweden, which suggests that significant uncertainties existed.

In conclusion, the extensive scope of the contract including design, construction as well as maintenance and operations, resulted in a number of significant uncertainties for both the client and the contractor. Since the consultant only had a contract with the contractor for design activities, the corresponding uncertainty is also considered as being of lower degree.

Contract length

In the case of the second aspect of administrative uncertainty, contract length, the long contract time between the client and contractor is considered to have resulted in significant uncertainty for both actors. Also compared to previously procured D-B projects, the nominally 18-year long contract period of the current project is considered as unique in Sweden. Also, compared to subsequent unconventional projects procured by the client until 2012, only two projects exhibited as far-reaching responsibility as the project described in Chapter 6. Since the

contract between the two actors extended 15 years beyond the actual construction works, during which, among other things, maintenance and operations works needed to be performed and reported, the administrative uncertainty is considered as being rather high. Furthermore, since the contract was new, none of the actors could be sure of details regarding future assignments, e.g. how disclosure of performance should be done or which life-expectancy certain installations would actually have. Consequently, the long contract period, combined with complex administrative arrangements, resulted in the two actors being subjected to comparatively high uncertainty but from rather different standpoints: the client experienced uncertainty regarding whether objectives were contractually coherent and expressed the actual needs, while the contractor primarily confronted uncertainty regarding the complex execution.

One important aspect of administrative uncertainty, which is also associated with technical aspects, concerns the possibility of determining the contribution of a single actor in a joint effort (cf. Alchian and Demsetz, 1972). Since the consultant was not only subjected to a limited scope of activities but also to an agreement with the contractor implying that their contribution would be evaluated almost instantaneously, the corresponding uncertainty is also considered as being low in these respects. Consequently, the contractor assumed most uncertainties regarding the product, time of the design and costs, as the work was formally handled by additional consulting time being needed to ensure harmony between the design and technical descriptions. The fee was successively evaluated as the design work progressed. In summary, the consultant experienced comparatively low uncertainty due to short contract time, while the contractor assumed a higher degree of uncertainty due to the longer contract time with the client.

Technical uncertainty

This section analyzes the degree of uncertainty based on the two aspects of type of requirements and design methodology employed according to their chronological appearance in the case.

Type of requirements

One important question for the client concerned whether the result from the preparation phase would result in adequate technical quality. Although many technical uncertainties, such as ambiguities regarding geotechnical conditions and climate, are considered as comparatively small given the physical nature of the project, several other aspects are considered as major uncertainties. The most important technical uncertainty during this phase concerned what type and number of technical requirements to utilize. Another important question was what acceptance levels to require and what penalties any non-fulfilment should result in. Although the client may be exposed to relatively high uncertainty, by allowing a supplier to choose materials and production technique, the performance requirements chosen are considered as relatively established and relatively well-known, which suggests that the client only faced moderate uncertainty in this respect.

In the case of the relationship between the contractor and consultant, the utilization of performance requirements as the essential requirement type resulted in significant uncertainty. This was partly manifested in whether it was possible to achieve the stated requirements at all and to what degree any technical solution would perform better than another one. In other words, how would the requirements be interpreted by the actors and how would the actors approach the uncertainty, e.g. by choosing materials and production technique, and how would risks be determined? Since the performance requirements were expressed on a construction where more than the actor in principle could contribute, e.g. by design and construction, or construction and maintenance, could there be any strict division of responsibility? Consequently, the agreement between the contractor and consultant resulted in the latter actor assuming lower uncertainty while the former assumed a higher degree.

Structural design methodology

One important aspect of uncertainty, which is also associated with type of requirements and contract length, is what was required from the contractor regarding design methodology. The client required that an established design approach should be applied to design the pavement structure. However, since no strict demand on design tool or model existed,

the uncertainty for the client may at first glance be considered as high. However, since the quality in the end would be determined by performance requirements during a comparatively long contract time, the question of design methodology is essentially an uncertainty for the contractor. This is particularly true in the case that no established design tool or model existed to reliably predict the technical performance of any pavement type or materials proposed (cf. Section 6.3.2). Hence, the resulting difficulty of not being able to reliably predict performance represents a major technical uncertainty, in principle, for both the contractor and the consultant. However, as previously indicated and discussed in more detail below, the two actors mentioned acted in rather different ways regarding this uncertainty, which ultimately led to the contractor assuming the main responsibility. In essence, the contractor was subjected to high uncertainty concerning design methodology while the client and consultant only assumed low uncertainty.

7.2.2 INTERACTION

As discussed in Section 2.3.2, interaction is separated into two categories depending on whether interaction occurs internally within the project (intra-project interaction) or whether it concerns interaction between the focal project and other projects in the form of connections established.

Intra-project interaction

Intra-project interaction is distinguished by the aspects frequency, breadth and depth.

Frequency

The intra-project interaction during the preparation phase occurred mainly within the client organization but to some extent also with external consultants, contractors and other client organizations. Although the interaction frequency is considered as low between the client and the other two actors of the study, the degree of interaction within the client organization is considered as being high. The high degree of interaction frequency is manifested by the amount of work and meetings on developing the procurement method, and is probably a reflection of the uncertainty involved while making project goals clear and robust for

subsequent project phases regarding, for example, market competition and the transaction.

Although the type of interaction observed during the unusually long procurement phase to a large extent was governed by economics logic, formal legislation and routine work, it was in many respects unique compared to other projects previously procured by the client. The nominal time-frame of six months for bidding is considered as long and costly compared to other road projects procured by the client and the fact that it was extended suggests that even more time could have been required to complete the bids. The high interaction frequency is particularly emphasized by the negotiated procedure, the number of physical meetings as well as the great number of questions asked by the contractors and the number of answers given by the client. The interaction shows some triadic tendencies (the interaction may be characterized by two sets of dyads; one comprising the client and contractors, and the other one comprising the main contractor studied and its consultant). However, in some aspects, the three actors interacted at the one and same time. Following the uncertainty of the project, and its possible negative effect on the number of potential domestic bidders, the client tried to further attract foreign bidders to reduce market uncertainty (cf. Nilsson et al, 2005). The perceived transaction uncertainty is indicated by the large numbers of client contacts with potential bidders prior to contract signing as well as the focus on delivery questions (Håkansson et al, 1976). The final number of bidding contractors, in all three bidders, suggests that they did not consider the overall uncertainties as too high. When it comes to the formal part of the interaction between the contractor-consultant dyad and the client, the procedure also showed some relational characteristics although it was based on a public tendering procedure. One measure by the contractor and its consultant to reduce uncertainty was to send numerous questions, which were subsequently clarified by the client. The interaction during the question and answer procedure was comparatively intense despite its formal character. For example, the large number of questions asked and answers given concerning administrative and technical content not only suggest extraordinary frequency but also that the messages communicated had been subjected to significant discussions within each camp. Although

the bidding activities of the contractor to a large extent complied with established internal routines utilizing financial knowledge, the administrative uncertainty inherent in the new procurement method also resulted in a number of measures having to be taken by the contractor to mobilize internal and external specialists and consultants. This is evident from the relatively large bidding organization (cf. Section 6.2.2) and the number of meetings between these two actors. Consequently, the interaction frequency between the client and contractor and contractor and consultant is considered as being high.

In principle, the contract phase was to some extent overlapping with the previous procurement phase where the main actors continued to interact. This phase showed several examples of triadic interaction, where all three main actors investigated participated in the same meetings. The interaction between the client and the contractor was facilitated by the fact that both organizations comprised similar organizational configurations, were co-located with daily informal contacts and periodic formal meetings. The prevailing administrative uncertainties regarding both roles and tasks to be performed resulted in a number of additional measures beyond normal regarding organization, information and cooperation. The decision to establish a joint contractor and client workplace, project-specific training and education, guidelines and a conflict resolution model indicate commitments and intensive interaction beyond normal. The high interaction frequency between the consultant and the other actors is also considered as high as indicated by the number of meetings and other means of communication.

Breadth

Although the relationships between client and the other actors are considered as both established and long-term, the unique tasks of the current project were to a large extent performed with a different scope compared to previous projects. During the development of procurement documentation, the client organized significant manpower and knowledge regarding the needs while both internal and external actors provided additional breadth by important feedback regarding both administrative and technical aspects. The great many inquiries needed, e.g. contract length and technical inquiries, suggest that the interaction in

general was broad despite interaction frequency with other actors being low.

Although measures were taken by the client during the first project phase to reduce uncertainty, the project goal of minimizing costs during the entire contract time by taking the wide range of activities and types of requirements into account meant that the contractors and consultants confronted new challenges, which could not be totally eliminated. The perhaps most significant measures during bidding was to establish a basis for cooperation and to find potential technical solutions by simultaneously taking both financial and technical aspects into account. Since the consultants formally both worked for the contractor and, hence, could affect the overall production costs, it was considered important by the contractor that the consultants took an active part in the recurrent meetings and discussions. Hence, the interaction concerned, in addition to purely technical tasks, both administrative tasks such as defining responsibilities and the establishment of effective communication structure by periodic inter-organizational meetings. The contractor utilized experiences from its maintenance and operations department to evaluate costs associated with different construction methods. However, as indicated by the comparatively large differences among maintenance and operations work for the three different bids (cf. Table 6.1), significant uncertainties probably still existed. Although each of the three first uncertainty aspects emphasized; activities contracted, contract length and type of requirements, each resulted in uncertainty, the main uncertainty for the actors seems to be their combination and joint effect. These measures indicate broad interaction taking more than just technical aspects into account. However, as indicated by the apparent different ways for the contractor and consultant to approach technical uncertainties, full cooperation between the two actors cannot be claimed. This is partly indicated by the difference in contract length of the contractor towards the client and the corresponding agreement between the contractor and consultant. In the case of the design of the road, the uncertainty inherent in the inadequacy of the established design model to predict technical performance (cf. Sections 5.1.2 and 6.2.2) provided incentives primarily for the contractor to reconsider existing design methodology, especially as non-standardized materials and production

methods were considered. The consultant did plausibly both deliberately, and due to the act of the contractor, played an essentially more restricted role regarding unconventional technical solutions, which also can be considered as a means of avoiding uncertainty. Furthermore, the benefits of providing the financial consequences of the different alternatives to technical experts was seen since the current project could be one in a series of subsequent projects where financial and technical content needed joint evaluation. Consequently, both the interaction breadth between client and contractor and between contractor and consultant was broad.

The contract phase also showed several examples of broad interaction between all the three actors. The additional functions of the contractor, e.g. verification and design, provided opportunities for interaction among the actors. The focus of minimizing production and maintenance costs also resulted in a relatively broad interaction between the consultant and contractor despite the relationship still suffering from the physical distance, i.e. from not having an office at the site, and the latter actor´s involvement with other projects as well as extensive firm reliance on standard solutions. In order to decrease uncertainties associated with the new procurement approach, the client had internal meetings and training regarding the procurement method. The establishment of a joint workplace and wide range of meeting categories facilitated communication and, therefore, also provided a means of decreasing uncertainty. In addition, guidelines were established and joint interpretations of the contract occurred between the three actors to discuss and explain certain issues. Hence, the resulting high degree of interaction breadth is also indicated by the opinion that it was desirable to reduce the number of participants at certain meetings given the already high interaction frequency.

Depth

The first phase showed several examples of deep interaction mainly within the client organization. Several deliberate and non-conventional measures were undertaken by the client to balance perceived uncertainties with potential gains. In particular, a number of efforts were made on details regarding the procurement method itself and the procedure ac-

cording to which it would be carried out during subsequent phases. When it comes to doubts regarding overall project costs, the client made its own cost calculation based on previous experiences. One measure by the client to reduce technical uncertainty during the first phase, e.g. regarding geotechnical conditions, was to supplement large parts of the original documentation developed for a previous version of the project. The requirement by the client that the pavement design should be based on an established design methodology (cf. Section 6.2.2) probably reduced the client´s uncertainties related to technical quality and future maintenance costs. Although no explicit empirical data was found that the client ever considered the technical uncertainties associated with inability of general design tools to predict performance for the other two actors, the conclusion of deep interaction during the preparation phase is supported by the degree of detail given to both administrative and technical content, e.g. type and levels of requirements.

The negotiated procedure (cf. Section 6.2) comprising physical meetings between the client and contractor provided significant possibilities to both clarify and discuss the intent and the content of the procurement approach in comparatively great detail, which is considered to have positively affected the degree of market and transaction uncertainty. Another important aspect of interaction during this phase was the cooperation between the contractor and consultant during bidding. Although both organizations due to previous experiences were well aware of the difficulties of achieving effective coordination, efforts were made to improve intra-organizational interaction efficiency. Not only were broad financial and technical evaluations considered necessary, their evaluation is also considered as non-standard since it went beyond existing routines, standards and models. A third example of similar commitment concerns the collaboration between the contractor and consultant to develop competitive technical solutions by utilizing complementary experiences. In order to reduce some of these uncertainties, standardized solutions (according to prevailing STA technical descriptions) were often employed by both the contractor and its consultant despite that other solutions were conceivable. However, in some cases, at least the contractor confronted these uncertainties by efforts to reconsider the design philosophy, conduct a literature study and to appreciate the per-

formance of materials and production technique using experience as well as more explicit research results rather than strictly following established technical standards. Consequently, the interaction between the client and contractor can be considered as relatively deep, while the interaction between the contractor and consultant was deep regarding administrative issues but not regarding certain important technical ones.

Although most construction activities on site were rather conventional, a number of non-conventional measures were taken by the client and contractor to reduce uncertainties realized during the course of works. For example, the client emphasized the new procurement approach by education. The two actors also formalized contractual aspects in written form. In order to minimize negative surprises regarding the actual technical performance of the road, additional quality efforts and checks were made by the contractor. The technical verification process (cf. Section 6.3.2) where all three main actors participated also represents an important example of unconventional interaction of great depth. Another interesting example of deep interaction is given by the special meetings where client and contractor representatives revised and clarified certain aspects of the contract (cf. Section 6.3.2). The interaction between the consultant and any other actor was essentially based on routines and standards. Consequently, the interaction depth between the client and contractor is considered as of great depth while the interaction with the consultant is regarded as of lower depth.

Inter-project connections

Inter-project connections are indicated using a number of connections from the current project to previous and future projects.

Number of connections to previous projects

The case studied showed many examples of connections from the focal project studied to previous and subsequent projects. The main connections established during the preparation phase were rationalized by the desire to obtain administrative and technical information to reduce need, market and transaction uncertainty in order to develop the procurement method. Of the connections identified, several were to the

other Norrortsleden project, and previous unconventional projects, including the draft PPP (cf. Section 4.3.1). Connections to previous traditional projects were also identified, e.g. the development of the compensation model from experiences from the Southern link (cf. Section 6.1.2). The final decision to utilize a contract period including 15 years of maintenance responsibility indicates that experiences of previous projects were taken into account.

In the subsequent phase, the client once again utilized experience from previous projects by connections to procure the contractor using a negotiated procedure. In the case of the contractor, not only experiences of construction works was utilized, but also maintenance and operations costs were obtained from connections to previous maintenance and operations contracts, respectively. Another important type of connections concerned the urgent need of the contractor to reduce technical uncertainties during the procurement phase by comparing the technical performance of historical projects with the requirements of the current project. Consequently, not only financial and production-related data of previous projects were used by the contractor to calculate bids but also technical data to determine risks regarding investment and maintenance activities during the comparatively long contract time. Another conceivable connection between the current project and previous projects concerns the appeal by a competitor during the tendering evaluation (cf. Section 6.2.3). As indicated in Section, 6.2, the contractor argued that the consultant only suggested standard technical solutions while expecting customized and innovative solutions. Besides reasons associated with distribution of burdens and the way of minimizing uncertainty, another source of the technical solution chosen might be that the consultant in question incorporated the particular technical solution from a parallel project where it was used. In summary, the current project showed several examples of connections established by the client and contractor to historical projects regarding both administrative and technical aspects.

Number of connections to future projects

In addition to connections established to historical projects, the focal project studied also exhibited many connections to future projects as

well. One example of connection is indicated by the decision of the contractor to participate in bidding despite dissatisfaction with the final approach chosen by the client. The final decision of that contractor to reconsider the participation was based on the general fit of the project with earlier expressed desires, which indicates that adaptation occurred from both sides to meet the counterpart. The commitments were partly motivated by the belief and will that the work not only would result in a contract, but also that the goals of the client regarding the success of the procurement model would be fulfilled, which could lead to additional unconventional projects in the future. During the time-frame investigated, several significant investments were also made by both the client and the contractor of relevance for future connections. The client committed resources to further develop the procurement approach by gathering information from the project to utilize in subsequent unconventional procurements during the years 2008-2012. A number of R&D projects were also initiated by the client as a result of experiences made in the current project. The contractor, on the other hand, made investments in certain specialized equipment, internal capabilities in the form of new organizational arrangements and external relationships to authorities and universities. These investments meant that the contractor could increase information gathering and analysis capacity of project performance including projects executed prior to the current one. In conclusion, the number of connections from the current project to subsequent projects is considered as high with regard to both administrative and technical aspects and most connections were made by the client and contractor.

7.2.3 KNOWLEDGE GAINED

This section addresses knowledge outcomes for the three main actors studied and is divided by administrative and technical content and in accordance with project phase studied

Administrative knowledge

Administrative knowledge gained by the three actors studied is categorized based on whether it concerns contractual or financial aspects.

Contractual

Certainly, a significant part of the knowledge gained during the preparation phase, and the other phases, concerns individual tacit knowledge related to everyday experiences. However, although experience accumulation constituted an important mode of learning, articulation and codification of knowledge (cf. Zollo and Winter, 2002) also played important parts. The emphasis on developing a new procurement approach where design, construction, maintenance and operations activities were bundled, while technical quality was determined by physical performance, rather than procedural specifications and technical standards, resulted in the client developing a high degree of new knowledge regarding a broad set of issues. The extensive interaction within the client organization, in particular breadth and depth, during the preparation phase suggests that significant amounts of knowledge were gained, and often with the purpose of reducing associated uncertainties. Although not primarily considered as technical, the contractual knowledge gained in association with the requirements is to some extent related to technical aspects. The manifestation of the result in codified form suggests that the knowledge gained was substantial as indicated by the number of connections from the current project to subsequent projects.

The second project phase showed significant knowledge outcomes for all the three actors involved, which is also considered a result of the high degree of intra-project interaction. All three actors appear to have gained a high degree of knowledge regarding the new procurement method during the negotiated procedure as indicated by the high interaction breadth and depth and the type of detailed questions asked and responded on. The establishment of an agreement between the contractor and the consultant shows that additional contractual knowledge was gained. The fact that the bidding phase was extended and requirements actually were changed, following internal evaluation by the client, due to questions by the two other actors suggests that a rather high degree of knowledge was gained. In particular, the need by the contractor and consultant to have certain questions answered is considered to have provided knowledge for all actors. The possibility to achieve a dialogue suggests that comparatively deep knowledge was gained since knowledge was articulated rather than solely gained by experience ac-

cumulation (cf. Zollo and Winter, 2002). The cooperation between the contractor and consultant also seems to have resulted in administrative knowledge regarding each other's limitations and the important work procedures to be improved. The question of internal distribution of responsibilities regarding technical performance and associated costs between business units during the long contract period suggests that a high degree of knowledge was both articulated and codified within the contractor organization. However, the deliberate choice of the contractor to keep certain information strictly internal indicates that certain knowledge did not reach the consultant. The realization that performance requirements on a final product render it difficult to determine the contribution of a certain actor or subunit in the joint effort, and that this difficulty should be carefully thought through, and in the case of shared responsibility ensure agreements regarding responsibilities over organizational interfaces, constitutes an important realization for the contractor. However, in any case, the procurement phase resulted in that all three actors gained a comparatively high degree of knowledge regarding contractual issues.

The continuation from the previous project phase provided possibilities for the three actors to maintain as well as to further obtain a high degree of knowledge. The unique site organization of both the client and contractor during the contract phase resulted in a number of experiences being made regarding new tasks and their effect on work relations. For example, the contractors' responsibility for verification and design activities provided opportunities to gain administrative knowledge including the needs and demands of the client regarding an adequate process and product. The establishment of a cost-saving agreement also indicates that some new contractual knowledge was gained. In the case of working directly for the contractor, not only during the procurement phase but also during the contract phase, the consultants became aware of the institutionalized relationship in relation to the client, where adequate standardized solutions should rapidly be produced. In contrast, the work for a contractor meant that evaluations of non-standard alternatives and their rationalization were encouraged, while the consultant had to manage any resulting uncertainty either technically or contractually (in this case, the contractual path was taken). Another important

aspect of knowledge concerns the relatively large emphasis on knowledge codification. Of the three main actors studied, mainly the client and the main contractor devoted recourses to codify knowledge developed during the project to be used in subsequent projects. In the case of the client, a number of management, environmental and financial aspects have been codified (cf. FIA, 2006; 2007; 2008 and STA, 2008), which made it possible to bring aspects regarding safety, environmental, working environment and risk management from the current project into the design phase of other subsequent projects. Of particular importance is the development of the standardized procurement approach used in subsequent D-B and D-B-M projects. Even though, to the knowledge to the author, no knowledge obtained during this particular project resulted in any revisions of any STA technical descriptions, the utilization of knowledge gained in the current project in a number of subsequent D-B and D-B-M project suggests that a high degree of knowledge was gained by the client. The investment in time to discuss technical requirements with the contractor also provided knowledge to refine performance measures, acceptance levels and how the results should be disclosed by the contractor and checked by the client in future projects. When studying the development of procurement documentation over several successive unconventional projects, a development from the approach used to procure early D-B projects in the 1990s to the development of the method used to procure the current D-B-M project and to the documents used to procure subsequent unconventional projects in 2008-2012 seems to exist. This successive development of connections indicates evolution and that the procurement approach used for the D-B-M project was not institutionalized at the time of its inception (cf. Ford et al, 2003). Such contractual evolution has been observed in other studies as well (e.g. Juriado, 2008) and has been used as an indicator of organizational learning. The contractor, on the other hand, not only realized that the way of organizing in a market characterized by a large volume of unconventional projects, devoted much attention to develop routines to manage future projects by formalizing internal procedures and systematically gathering and evaluating information on past and running projects, i.e. extending the scope of traditional pro-

ject management (cf. Engwall, 2003). Parts of the codified material for the current project were utilized by the contractor in future projects.

Financial

As in the case of contractual aspects, the client gained a high degree of financial knowledge during the first project phase. This was partly indicated by effort in form of time and costs to actually develop the procurement approach but also the work devoted to developing compensation models.

Although the bidding activities of the contractors partly followed established internal routines, explicit information of previous projects were necessary to calculate bids as more than a single alternative was needed as costs, production capacities and technical quality of both new activities, e.g. maintenance and operations, and their combination were needed. Consequently, the resulting broad and deep interaction provided additional knowledge to the contractor. The internal interaction between quantity surveyors, technical experts and consultants resulted in the actors accumulating experiences of each other's work situation, needs and problems. For examples, technical experts obtained knowledge regarding the financial consequences of a particular design, while production personnel obtained knowledge regarding potential technical solutions. Consequently, the contractor is considered to have obtained a high degree knowledge regarding financial aspects. Although the consultant and client gained knowledge, the degree is considered as lower due to the limited interaction, in particular depth and breadth, regarding financial aspects.

During the contract phase, the focus of minimizing production and maintenance costs indicates that the client and contractor also during this phase obtained knowledge regarding these issues. However, the administrative content of what was learnt mainly concerned the client and contractor organizations since these two actors interacted to a higher degree and devoted more resources to knowledge codification. The administrative knowledge gained by the consultant is considered as being lower due to the limited interaction and firm reliance on institutions compared to the other two actors.

Technical

Technical knowledge gained by the actors is classified by reference to material, production and design.

Material properties

As previously indicated, the first phase studied was mainly considered to have resulted in contractual knowledge for the client despite the fact that at least a significant part of this knowledge was associated with technical issues such as requirements. Apart from such aspects, no particular technical knowledge is considered to have been gained by any actor.

Since technical issues to a large extent were subjected to performance specifications, the contractor used the possibility to use knowledge already developed regarding its own materials in the procurement phase. The verification process where the client interacted both deeply and broadly with the contractor, but also the consultant, by formally and informally controlling technical solutions provided technical knowledge to all three actors. However, since the contractor represents the only actor devoting resources to evaluating and internally articulating technical solutions, in particular during the procurement phase, this actor is considered as the one that gained a high degree of technical knowledge regarding material behaviour. Furthermore, explicit documentation of technical performance during the production of the current project as well as in the form of annual performance measurements of the road have been used to determine the performance of the materials and production methods chosen for this project. As the contractor gained knowledge regarding the technical performance of products utilized in the current project, codified knowledge could be used in future unconventional projects.

Production technique

As in the case of technical knowledge regarding materials, some evidence where knowledge of a higher degree was gained by the contractor could be found in the project. For example, the internal demands for a high degree of compaction resulted in it being possible to utilize any knowledge obtained from this in subsequent projects. Extensive meas-

urements during production also provided some knowledge regarding the possibilities of the production method to fulfil stated requirements. As a consequence, the contractor developed knowledge regarding the production method as well as steps towards a model to interpret their effect on performance. Since the knowledge indicated was utilized in subsequent projects, this suggests that the knowledge gained was important, not only from an internal contractual perspective (cf. contractual aspects above), but also technically to achieve defined requirements. Since none of the two other actors contributed to the choice or analysis of production technology, they are considered to have gained a lower degree of knowledge.

Structural design

As indicated in Section 7.2.2, although the interaction was often extensive, the main work of the client and consultant was devoted to requesting adequate design and activities producing drawings and descriptions, respectively. Even though the client required an accepted design model for the project, no evidence that the client gained any particular knowledge from this could be found. Since the technical design of the road and pavement structure to a large extent had already been decided in the previous phase, low technical knowledge is considered to have been obtained by the consultant. Instead, the contractor appears to be the actor that gained a high degree of knowledge regarding both design models, e.g. how alternative materials can be modelled, in existing design tools, but primarily the different focus of design: structural design in unconventional projects subjected to performance requirements over long contract periods should be utilized based on a risk-management perspective using empirical data of previous projects. The follow-ups meant that material and production technique could be evaluated, which suggests that a high degree of knowledge was gained for the contractor.

In summary, the only actor gaining knowledge during the first project phase was the client. As in the case of the preparation phase, knowledge gained during the procurement phase also differed among the actor categories studied with regard to content. All three actors gained a high degree of contractual knowledge during the second project phase, while

the contractor also gained regarding financial aspects. In the third contract phase, all three actors are considered to have gained some knowledge, in particular the client and contractor who scored high levels in both contractual and financial issues. In the case of technical knowledge, the contractor stands out as the actor gaining most knowledge, while the client and consultant gained only lower degrees.

Table 7.2 Summary of findings for the unconventional project procurement method.

Characteristic	Indicator	Phase I	Phase II	Phase III
Uncertainty	Administrative Technical	*Generally high uncertainty for the contractor, but also for the client, especially administrative, while low for the consultant regarding most aspects studied.*		
Interaction	Intra-project interaction	*Low degree of interaction between the client and the other actors. Broad and deep interaction of high frequency within client organization.*	*Interaction of high frequency, breadth and depth between client and contractor. Similar interaction between contractor and consultant but lower depth regarding technical aspects.*	*Interaction of high frequency, breadth and depth between client and contractor. Similar interaction between contractor and consultant but lower depth regarding technical aspects.*
	Inter-project connections	*Several explicit connections established by client and contractor to previous and future projects, in particular regarding contractual and aspects associated with tech. performance requirements.*		
Knowledge gained	Administrative	*The client gained a high degree of contractual and financial knowledge.*	*All actors gained a high degree of contractual knowledge. The contractor gained a high degree of financial knowledge.*	All actors gained a high degree of contractual knowledge. Client & contractor gained high degree of financial knowledge.
	Technical	*No particular.*	*Contractor gained high degree of knowledge. the client and consultant gained lower degree.*	

7.3 COMPARATIVE ANALYSIS

This section provides the comparative analysis in order to explain similarities and differences between the two procurement approaches investigated.

7.3.1 UNCERTAINTY

Despite the respective label of the two cases presented in this study, the two focal projects investigated were in many respects not particularly different. For example, the number and type of main actors involved, resources used and activities performed were in several respects similar and well-known by the other actors from previous work. Both projects concerned the establishment of road infrastructure and involved essentially one and the same main client. The size in both physical and monetary terms is also comparable to each other as well as being considered as normal for Swedish infrastructure projects. The number and type of bidders during the procurement phase were in both projects considered as normal: 4 and 3 for the traditional and unconventional, respectively. In the case of competition, three bidders are generally considered an important indicator of adequate competition (RR, 2012). Although the utilization of parts of the concept of Partnering in the current projects has not been emphasized as a significant feature of the investigation or a way of distinguishing the projects from each other, this concept might have affected the degree of uncertainty in a positive way. Consequently, many of the characteristics often used to indicate project uniqueness suggest that both projects studied showed many examples of similarity (cf. Nam and Tatum, 1988; Cova et al, 2002). However, besides such general characteristics, the aspects chosen to characterize uncertainty in this study suggest that significant differences between the projects still existed.

Administrative uncertainty

This section analyzes the degree of uncertainty based on the two aspects of the number of activities contracted and the contract length in the two cases.

Activities contracted

In the case of procurement method chosen for each project it is evident that the traditional project did not exhibit any particular uncertainty regarding activities contracted for either the contractor or the consultant but mainly for the client. In particular, the design was procured separately from the consultant and the actual production on site was procured from a main contractor, who in turn subcontracted significant parts of the works based on existing technical standards and administrative routines. The D-B-M project, on the other hand, was in many respects unique in the sense that the client had to develop significant parts of the procurement method instead of relying on existing institutions. Although unconventional road projects had already been procured by the client, no previous project of this size had ever involved construction, maintenance and operations activities in the same contract. In this case, both the client and the contractor became subjected to higher uncertainty compared to the traditional project, while the consultant was still subjected to approximately the same low uncertainty as in the traditional project.

Contract length

While the short contract length of traditional D-B-B project in almost all respects can be considered as common, the contract length of the unconventional D-B-M project is unique compared to historical road projects. Since the client contracted the contractor for a much longer period in the unconventional project than in the traditional one, both actors exhibited a higher degree of uncertainty compared to in the traditional project. Since the consultant was only contracted for a comparatively short period, their degree of uncertainty is considered as lower and at approximately the same level as the traditional project.

Technical uncertainty

This section analyzes the degree of uncertainty based on the two aspects of type of requirements and contract length for the two cases.

Type of requirements

The firm reliance on technical standards and the client´s responsibility for the technical functionality of the product in the traditional D-B-B

project resulted in low uncertainty for the contractor and consultant. The unconventional D-B-M project, on the other hand, relied to a great extent on performance specifications, which means that the contractor assumed higher uncertainty compared to in the traditional project. Although the client delegated much of the responsibility to the contractor in the D-B-M project, the client is still considered to exhibit comparably high uncertainty. However, since this uncertainty to a large extent is of contractual character, the remaining and actual technical uncertainty is considered as being relatively low. In the case of distribution of responsibilities between the contractor and assigned consultant, the two actors mentioned used different tactics regarding the uncertainty of the unconventional project. The use of company-specific materials and production technique, and theoretical models to predict technical performance against stated performance requirements suggest that the contractor assumed comparatively high uncertainty in the D-B-M project (cf. Shenhar and Dvir, 1996). Since the consultant worked in a similar situation in both projects, this actor is regarded to experience similar low amount of uncertainty. According to Gruneberg et al (2007) the extent to which actors recognize uncertainties and risks, including methods of dealing with them, vary considerably. For example, it is seldom clear for a client whether or not the technical performance requirements of unconventional procurement approaches actually would be enough to secure the same quality as provided by the large amount of requirement utilized in traditional projects (cf. Gruneberg et al, 2007).

Structural design methodology

As indicated in Sections 7.1 and 7.2, two aspects are of interest regarding structural design methodology. First, the main responsibility for the design methodology in the traditional project was the client, while the contractor represents the main actor responsible in the unconventional project. Second, not only are different actors responsible for the design methodology in each project, the uncertainty is also considered as being at a different level as the traditional project only showed moderate uncertainty while the unconventional one exhibited a high degree of uncertainty since the former project was designed in relation to a general standard, while the latter project should exhibit a particular performance.

In essence, the traditional project represents a deliberate attempt to minimize certain types of uncertainty for all actors involved by means of dividing the project into phases of essentially dyadic interaction (cf. Section 7.1.2), the unconventional project represents a deliberate attempt by the client to increase the freedom of the other two actors, and thereby also certain types of uncertainty for all three actors. The institutionalized procurement method employed in the traditional D-B-B project resulted in low to moderate uncertainty for all three actors investigated mainly due to availability of institutions, while the unconventional project exhibited a higher degree of uncertainty, in particular regarding administrative aspects for the client and technical for the contractor.

7.3.2 INTERACTION

In this section the projects are analyzed by emphasizing the interaction occurring among actors involved in each project and connections established to other projects.

Intra-project interaction

As indicated in Sections 7.1.1-7.1.2 significant differences exist between the two cases studied with regard to interaction frequency, breadth and depth.

Frequency

Given the comparatively large difference in scope of the first phase of the two focal projects studied, it is not easy to determine whether any of the projects overall showed higher interaction frequency compared to the other one. During the first phase, the traditional project is considered to show a high degree of interaction frequency between client and consultant as guided by existing institutions. In the unconventional project, interaction occurred to a large extent by less formal means, involving internal and external actors but fewer numbers of standardized types of meetings between the different actors investigated.

In the case of procurement, the comparatively large differences in project scope resulted in a number of differences in interaction frequency being able to be observed between the two projects. The unconventional project showed several examples of higher interaction frequency com-

pared to the traditional project. The perhaps most evident example concerns the negotiated procedure, with physical meetings and intense written communication between the client and contractors, which stands in stark contrast to the corresponding arm´s length interaction of the D-B-B project.

The contract phase also showed a number of differences in interaction frequency between the two projects. Although the traditional project experienced a nominally high interaction frequency, given the great many individuals working at the site and the number of formal meetings held, only a few aspects can be considered as extraordinary compared to both previous projects and the unconventional project. The D-B-M project, on the other hand, provided an additional number of meeting categories beyond normal, a joint workplace for client and contractors as well as extensive communication between the production personnel and technical experts. Consequently, the unconventional project is considered to exhibit even higher interaction frequency than the traditional project during the last phase studied.

Breadth

In contrast to the established procurement approach of the D-B-B project, the unique situation involved in the conceptualization phase of the D-B-M approach provided incentives for the client to gather both internal and external expertise by network access (cf. Håkansson and Snehota, 1995; Håkansson et al, 1999; Borgatti and Cross, 2003) to reduce both administrative and technical uncertainties. Consequently, while the traditional project showed a comparatively limited breadth of subjects discussed by the client and consultants, the unconventional project involved more multidisciplinary interaction and different actors as well.

In the case of the procurement phase, there were also significant differences between the two projects regarding breadth of interaction. The traditional project showed strictly arm's length exchange between the client and bidding contractors with no particular attempts to involve any third party or questions, while the comparably relational procurement process of the D-B-M project showed more evidence of involvement of a larger number of internal administrative and technical spe-

cialists as well as external consultants who both needed to establish cooperation and solve complex problems. The resulting difference in interaction breadth between the projects investigated is probably that the problems of the traditional project were distributed according to discipline and solved separately by different actor categories, while the problems of the unconventional project required that different competences and disciplines cooperated and solved them jointly. For example, a possible explanation of the higher interest of both internal and external technical assistance in the D-B-M approach is that management, including the quantity surveyors, could fit the technical knowledge available to the actual financial problem faced (cf. Håkansson and Snehota, 1995; Menon and Pfeffer, 2003; Davenport and Prusak 1998; Borgatti and Cross, 2003). Another possible, and related, reason for the limited participation of technical specialists in the traditional project is that individuals are unlikely to transfer knowledge from other parts of the organization if they are not rewarded, e.g. by social recognition for utilizing internal knowledge (Winch, 2002; Menon and Pfeffer, 2003).

As in the two previous project phases, several differences also occurred in the last phase of the two projects investigated with regard to breadth of interaction. In the traditional project, the main interaction occurred in accordance with both formal and informal institutions where the three actors almost never met in person. The unconventional project, on the other hand, exhibited more interaction including additional meeting categories where all three actors studied participated to a higher degree compared to the other project regarding joint aspects such as administrative and technical, and contractual and financial aspects within the same forum. Again, the difference in interaction breadth was partly due to the relatively higher uncertainty regarding roles and tasks and the need to incorporate a broader range of questions to solve the problem at hand.

Depth

Both projects studied showed interaction to a large extent based on previous work and the utilization of existing routines and technical standards, all within the institutional context of respective procurement method chosen. However, it is obvious that the actors involved in the traditional D-B-B projects to a higher degree adhered to existing institutions than the actors of the unconventional project, which affected the depth of interaction. In the first phase studied, the primary goal of the traditional project was to produce tendering documentation according to prevailing institutions. Consequently, no obvious benefit from providing the financial consequences of any technical alternatives were ever seen since the current project was mainly considered a discrete, one-off, project where short-term financial content prevailed. In the unconventional D-B-M project, the corresponding phase showed a completely different scope as it aimed at developing a procurement approach rather than simply exploiting an existing one, which required significantly deeper interaction among the actors involved (cf. March, 1994; Ford et al, 2003). Not only did the work incorporate the establishment of an adequate work procedure that went beyond normal work routines, the content also involved both non-standardized administrative and technical aspects.

Also the procurement phase showed differences concerning the depth of content exchanged. While the traditional D-B-B project showed only limited depth regarding both administrative and technical aspects due to the adherence to routines and standards, the negotiated procedure of the D-B-M project, involving a large amount of specific questions and physical meetings, suggests that both administrative and technical aspects covered exhibited great depth. The examples related to pavement design indicate that existing institutions showed significant effect on actor behaviour irrespective of projects studied. Since neither any established form of working nor technical standards, such as the ones normally used in traditional projects, had to be complied with to the same extent in the unconventional D-B-M approach, an institutional vacuum appeared where new knowledge was needed. This is exemplified by the consultant´s possibly deliberate strategy, or ambition with the relationship, of adhering to technical standards and not taking any responsibil-

ity for technical performance in relation to the other actors. Such conduct is in accordance with general observations (e.g. Gidado, 1996; Nam and Tatum, 1988) suggesting that construction design is very conservative regarding materials and production methods by not relying on trial and error procedures. However, the contractor acted in another way. In particular, the uncertainties regarding how to choose technical design and how it affected investment and maintenance costs resulted in discussions, which articulated uncertainties, potential solutions and measures by the contractor to gain knowledge and reduce such uncertainties not only based on existing routines but also by explicitly referring to theoretical models and empirical results of historical projects. This finding is according to results presented in previous investigations (e.g. Maaninen-Olsson, 2007). Also the early and expressed ambition from management of the contractor to come up with new technical solutions is considered to have increased the emphasis on not relying entirely on established technical solutions. This conclusion is similar to that of Leiringer (2003), who emphasized the importance of early commitment and sufficient resources to achieve innovative behaviour, but at the same time, at least to some extent, contrary to the conclusion that technical solutions chosen are according to existing standards to avoid risks. In order to motivate the technical solution, it was even considered necessary by the contractor to re-evaluate the ontological assumptions regarding existing design models. It became obvious for the technical experts of the main contractor of the unconventional project that a new design regime was needed since no available model existed that could reliably predict behaviour in terms of expressed performance. The evaluation of results from empirical inquiries of previous projects provided the contractor with knowledge and, consequently, support for choosing a particular solution. In essence, while designers of traditional projects work according to professional responsibility when choosing a certain design, the corresponding responsibility in unconventional approaches has been considered to occur according to a sense of risk management (Fahmy and Jergeas, 2004). An interesting aspect related to the attempts related to reduce technical uncertainties is the empirical character of the search. Instead of primarily attempting to investigate theoretically advanced design models promoted, e.g. as found in scientific journals,

the work was largely basic and devoted to understanding the fit between the client´s new requirements and technical performance of historical projects. In principle, the conclusion follows the analysis of e.g. Cyert and March (1963), Kahneman and Tversky (1979a,b), March (1994) and Flyvbjerg (2006), where organizations deliberately attempt to reduce uncertainties by actions in form of adaptations to specific goals as well as establishment of simple search rules.

The characteristics indicated in the previous phase were also observed during the contract phase. In particular, the trend where the actors of the D-B-B project mainly worked according to existing administrative routines and technical standards was evident. Although not as evident as during the procurement phase, the unconventional project showed several examples where the actors did not act on the basis of existing routines but sequentially tried to adapt to the situation. This was partly illustrated by the discussions between the client and contractor within new meeting categories, and even changes made to the technical requirements and partly by additional commitments to certain construction elements, e.g. by increased testing and evaluation.

In essence, the interaction of the traditional D-B-B project was to a large extent dyadic and sequential (cf. Thompson, 1967) over the three phases defined where all inter-organizational interaction occurred directly between the client and either the consultant or contractor, while the last two actors mentioned seldom interacted directly with each other. The resulting almost strictly bi-dyadic interaction can in some respects be considered as the result of sequential planned isolation (cf. Lundin and Söderholm, 1995) to reduce administrative uncertainty. The unconventional D-B-M project, on the other hand, exhibited more triadic and reciprocal (cf. Thompson, 1967) interaction during interdependent project phases where more actors were involved and a wider range of questions were treated at one and the same time. Although the individual projects showed periods of lower and higher interaction frequency both with regard to actors and phases studied (cf. Bengtsson and Eriksson, 2002; Ford and Håkansson, 2006), it is evident that a higher degree of interaction occurred in the unconventional project compared to the traditional project, primarily regarding interaction breadth and depth. The

higher degree of interaction of the D-B-M project is also considered to have resulted in significant differences regarding the knowledge flow across the project. In particular, the unconventional project allowed individuals of different perspectives (e.g. consultant and contractor) to exchange information compared to the traditional project. The interaction of the D-B-M project was to a larger extent informal, driven by personal commitments to solve perceived uncertainties ensuing from the uniqueness of the project, rather than confirming to formal institutions as in the case of the traditional D-B-B project. In the D-B-M project individuals of the contractor also voluntarily searched and reached common understanding by coordinating actions in the form of mutual adaptation and cooperation (cf. Brown and Duguid, 1991; Håkansson and Snehota, 1995; Szulanski, 1996; Cannon-Bowers and Salas, 2001). The lack of explicit knowledge of D-B-B projects is probably also the result of limited demands by management of all three actors for follow-ups, which further decreased motivations from project participants to perform investigations (cf. Lindkvist, 2001). This resulted not only in high interaction breadth compared to the traditional project but also increased depth. The findings indicated verify some of the arguments presented in the literature, e.g. the argument often promoted by contractors that D-B approach favours continuity between designers and contractors (e.g. Fahmy and Jergeas, 2004). However, since parts of the structural design were kept in-house by the contractor, the counterargument of design consultants that the role they play in D-B projects is limited also seems relevant as well. A similar conclusion can be drawn by the limited involvement of subcontractors and suppliers, which in contrast to contractor argumentation (cf. Fahmy and Jergeas, 2004) still resulted in arm's length relations during the D-B-M project. The reason for this was probably that their work was expected by the contractor to be performed according to existing technical descriptions and comparatively separated from other work, which may have been partly motivated by efficiency and ease of evaluation as well as ability to switch supplier from project to project while at the same time keeping certain information in-house.

Inter-project connections

As in the case of intra-project interaction, the number of connections from each focal project to historical and future projects also differed in the two cases.

Number of connections to previous projects

Both focal projects studied shared important historical events, which affected the choice of procurement method. Such interdependencies among projects not only make it difficult to actually define a distinct beginning of a given project but that projects may be interpreted as links in long chain of interdependencies between the actors although the resource exchange at times significantly decreased (cf. Hadjikhani, 1996; Engwall, 2003). However, despite similarities, there were significant differences between the two projects studied regarding connections to historical projects. In the case of the traditional project, limited specific knowledge from previous projects was needed due to few uncertainties. This conclusion is a result of that decision-making within the traditional project is primarily based on existing institutions. In the case of the unconventional project, the client searched and used knowledge of historical projects to a greater extent compared to the traditional project in order to develop the procurement method, and, thereby, reduced perceived uncertainties. The contractor, on the other hand, utilized information obtained from previous projects to predict performance of technical solutions and associated risks. The need to establish knowledge regarding the technical requirements was to a large extent the result of internal demands on effective risk management and the absence of an appropriate design methodology within which the evolution of performance parameters during the comparatively long contract period could be determined.

Number of connections to previous projects

When comparing amount of connections made of each case studied, it is again suggested that the unconventional project resulted in more connections than the traditional one. In accordance with e.g. Gann (2000) and Engwall (2003), this study suggests that construction projects are normally characterized by market-based and short-term interaction where limited attention is paid to aspects beyond the project at hand.

However, the analysis of the unconventional D-B-M project also suggests that there may be a different interpretation. Figure 7.1 illustrates a conceptual one-dimensional time-scheme where the two focal projects investigated are shown (focal projects confined within a dotted square) from the contractor´s perspective regarding technical aspects. The traditional D-B-B project is indicated in white (No. 8) while the unconventional D-B-M project is indicated in black (No. 9). In addition, a number of previous projects are also shown to the left of the focal projects of which two (No. 3 and 7) represent the few early D-B projects referred to by the main contractor of the unconventional project as sources of *technical knowledge* during bidding of the current project (cf. Section 6.2.2). Traditional projects (No. 1, 2, 4-6) represent historical D-B-B road projects procured and constructed, between 1994 and 1999. As indicated in the figure, there is an apparent difference between traditional D-B-B and the unconventional D-B(-M) projects with respect to connections as suggested by the number of lines between the unconventional projects at this stage in time. The main difference between the project types is that the projects procured using unconventional procurement methods tend to both provide commitments to deep interaction, in order to gather and analyze explicit experiences from other projects and thereby form connections, due to sufficient and necessary uncertainty as well as possibilities to actually do that by imposing performance measurement: demands on measurements actually provide such data, in *codified* form, for the future since this constitutes the essential quality data required by the client. While the traditional D-B-B approach, as represented by the project of Chapter 5, only provided knowledge manifested in technical standards by procedural specifications, limited explicit connections to previous projects were ever established by the contractor (cf. Figure 7.1). Hence, partly due to technical requirement and design uncertainty but also to the long contract time, the unconventional focal project (No. 9) provided reasons to investigate the performance of relevant previous projects.

An interesting observation in Figure 7.1, concerns the apparent increase in number of connections with the number of unconventional projects launched. As indicated in Section 6.3.4, the contractor used knowledge codified during the current project for new projects (Nr. 12 and 14) pro-

cured in 2006-2012. A possible reason for the lack of explicit connections between the traditional focal project and other traditional projects is probably a consequence that no actor actually needed information from this project in their daily work since all knowledge, in principle, existed in formal institutions such as design models and technical standards. In this way, the formal institutions of traditional projects provided important artifacts to transfer knowledge (Lindkvist, 2001) but at the same time that significant learning barriers existed in those projects where knowledge largely remained either in formal standards or in tacit form (Carlile, 2004). The connections between subsequent project no. 16 and the traditional projects 5, 8 and 10 are a result of the contractor´s investments in specialized equipment (cf. Section 6.3.4), which is further discussed in Chapter 8. Although the illustration of Figure 7.1 concerns technical aspects as interpreted by a contractor, the empirical findings also suggest that similar patterns could be obtained for the client regarding administrative aspects associated with the development of the procurement approach: experiences made during the successive unconventional projects were successively manifested in a general concept for procuring such projects (cf. Section 6.3.4). However, the limited uncertainty indicated by limited number of activities contracted, short contract time and reliance on standard solutions did not provide sufficient incentives for the consultant to embark on a similar search effort. The few connections noticed in the traditional case are considered to be related to business opportunities and knowledge regarding costs, capacities and market price.

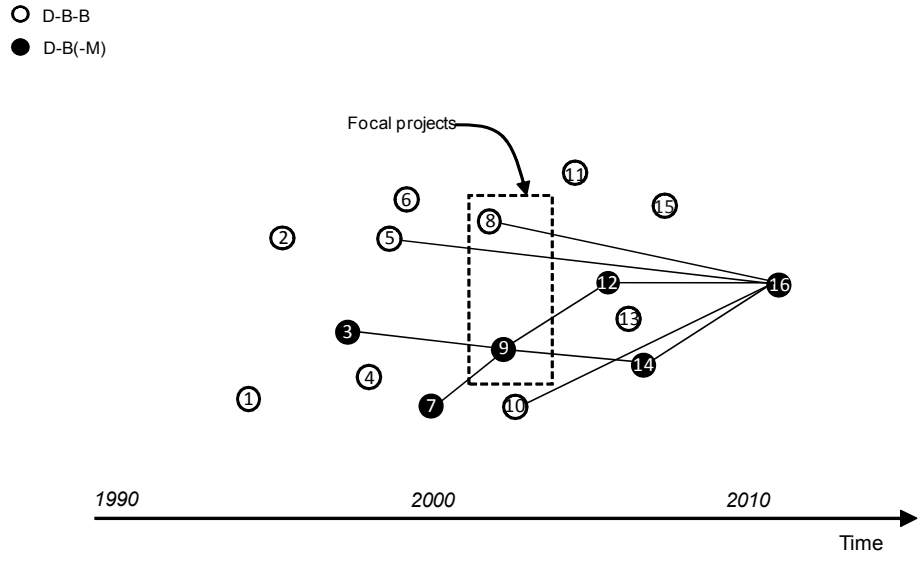

Figure 7.1 Illustration of connections between different projects according to the contractor of the unconventional case. Lines indicate connections between projects where performance specifications and measurements thereof have affected structural design in subsequent projects.

7.3.3 KNOWLEDGE GAINED

As in the case of the previous project procurement characteristics, several differences existed in the two cases regarding knowledge gained by the actors investigated. As is evident from both cases studied, both traditional and unconventional procurement methods provide a great many opportunities to gain knowledge for any actor involved. Although exhibiting comparatively different scopes, a large part of the knowledge gained by the actors involved in the projects can certainly be considered as individual, tacit and concerning standardized, already codified, aspects of relevance in daily work. This concerned particularly individuals new to the task gained knowledge by experience accumulation (cf. Zollo and Winter, 2002). However, as described below, there are still significant differences between the two cases.

Administrative

Administrative knowledge gained by the three actors studied is categorized based on whether it concerns contractual or financial aspects.

Contractual

In the traditional project, the administrative knowledge of the client and consultant during the design phase concerned almost entirely aspects already existing in the form of informal and formal institutions. Not only were the actors involved aware of the institutions, they were also acting and learning within them (cf. Levitt and March, 1988). This result means that the knowledge gained to a large extent can be considered as being of low degree. This observation has been made in other studies, both from the international (Fahmy and Jergeas, 2004) and the Swedish construction sector (e.g. Anheim, 2001; Styhre et al, 2004). The corresponding situation of the unconventional project is considered as radically different compared to the traditional project in this sense. In contrast to the D-B-B project studied, the uncertainties of the new unconventional D-B-M approach resulted in extensive interaction being needed within and among all the actors, but also establishment of explicit connections to other projects. This was particularly evident in the case of the preparation phase of the unconventional project regarding contractual aspects. However, subsequent project phases also showed evidence of interaction which resulted in knowledge. The comparably high degree of knowledge gained by the actors is also considered to have been positively affected by the extensive articulation and codification (cf. Zollo and Winter, 2002), which provided possibilities to utilize the knowledge in subsequent unconventional projects. An important example of such knowledge was the manifestation in new contracts. Consequently, knowledge gained not only affected uncertainty in subsequent projects but arguably also the type of procurement method utilized.

Financial

As in the case of the contractual aspects, the knowledge gained regarding financial aspects also differed between the two cases investigated. In essence, the traditional project provided few incentives to interact regarding financial aspects for all three actors, which also resulted in limited knowledge gains. The unconventional project on the other hand,

resulted in a higher degree of knowledge, especially for the client and contractor. The main reason for the higher degree of knowledge gained in the unconventional project is primarily related to the high degree of interaction, which provided access to more diversified, deep and explicit information. This finding can be compared to results presented elsewhere (e.g. Håkansson et al, 1999; Leiringer et al, 2009; Lind and Borg, 2011). In particular, Leiringer et al (2009) discussed a road project case study where the maintenance department did not have much contact with the construction department, which presumably negatively affected the ability to gain knowledge regarding life-cycle costs. The results of the current project suggest that the contractor realized both the needs and problems to organize and systematically obtain knowledge, e.g. regarding life-cycle costs, in order to be able to effectively compete in unconventional projects. Although financial knowledge is considered to have been gained by all three actors investigated in the unconventional D-B-M project, the results indicate that the consultant is the actor category that gained less. This result may partly be explained both by a lack of sufficient involvement due to that the contractor did not want to reveal certain aspects of importance for the bid, but also the limited uncertainty faced on this issue.

Technical

As in the case of administrative aspects, the unconventional D-B-M project is considered to generally have resulted in a higher degree of technical knowledge compared to the traditional project. However, the knowledge obtained was mainly gained by the contractor.

Material properties

Since technical issues in the traditional project to a large extent were predetermined based on existing requirements no significant new knowledge is considered to have been gained by either the client or consultant. The technical uncertainties and high degree of interaction in the unconventional project resulted in higher degree of knowledge, in particular, for the contractor.

Production technique
Since technical issues in the traditional project to a large extent were determined by the client no higher degree of knowledge is considered to have been gained by any actor. The technical uncertainties and high degree of interaction in the unconventional project resulted in higher degree of knowledge, especially for the contractor.

Structural design
The technical aspect of design appears as the most significant one regarding new knowledge distinguishing the two projects. The degree of knowledge gained by the actors involved in the traditional project is generally considered as low. In the case of the unconventional project, a high degree of knowledge gained, in particular for the contractor who not only utilized and gained knowledge regarding materials and production technique but also regarding how such knowledge can be utilized in design.

Table, 7.3 provides a concluding comparison between the two cases investigated. As indicated, there are some differences between the cases that appear as systematic. The generally low degree of knowledge gained for the traditional approach is considered as related to the low degree of interaction breadth and depth, which in turn is associated with degree of uncertainty. Even though the client is considered to have faced a slightly higher degree of uncertainty than the two other actors in the traditional case, the degree is not regarded as sufficient to provide interaction and knowledge due to the firm reliance on existing institutions. On the contrary, the high degrees of interaction and uncertainty of the unconventional project provided incentives for both the client and contractor to go beyond formal institutions, which also resulted in a higher degree of knowledge.

Table 7.3 Summary of findings from comparison of the cases.

Characteristic	**Indicator**	**Procurement method**	
		Traditional	**Unconventional**
Uncertainty	Administrative	*Generally low uncertainty for the consultant and contractor, while moderate for the client.*	*The client and contractor were subjected to a high degree of administrative uncertainty, while the consultant experience low uncertainty.*
	Technical	*Generally low uncertainty for the consultant and contractor, while moderate for the client.*	*The contractor was exposed to high technical uncertainty while the client and consultant experienced low degree.*
Interaction	Intra-project interaction	*Essentially dyadic, relatively high frequency, low breadth and depth.*	*High frequency, breadth and depth. Dyadic with some triadic tendencies.*
	Inter-project connections	*Few*	*Several*
Knowledge gained	Administrative	*Relatively low degree of knowledge by all actors.*	*High degree of knowledge for client and contractor. Consultant gained high degree regarding contractual aspects.*
	Technical	*Low degree of knowledge gained for all actors.*	*Contractor gained a high degree of knowledge. Client and consultant gained low degree of knowledge.*

8 DISCUSSION AND CONCLUSIONS

This chapter is devoted to discussing and drawing conclusions from the essential findings of the study as well as suggesting directions for future research.

8.1 RESULTS FROM THE STUDY

In this section, the empirical and theoretical results of the study are discussed and conclusions presented.

8.1.1 EMPIRICAL FINDINGS

As indicated in Chapter 1, the construction sector is commonly considered to exhibit a number of problems associated with efficiency and effectiveness, conclusions often drawn irrespective of the project procurement method used, and despite the common assumption that differences among approaches exist regarding these aspects. The findings from the current study suggest that significant differences can exist between project procurement methods, which may nuance the common picture of the industry. In order to illustrate such differences it is beneficial to conduct the comparison taking both the shorter and longer term into consideration.

Comparing procurement methods in a short perspective

It is interesting to note that the procurement method chosen for each focal project studied was in both cases, at least, partly motivated by rapid construction start, i.e. one of the three general project goals often referred to in traditional project management literature. The difference in actual choice, however, indicates contextual differences where the traditional D-B-B project to a large extent was already conceptualized on the drawing board, while the unconventional D-B-M project needed rapid design efforts in order to catch up with the desired time schedule. Consequently, both procurement methods were considered by the client to result in shorter delivery time despite such an argument often only being utilized in favour of unconventional approaches. The example concerning delivery time suggests that any advantage or disadvantage of a given procurement method is actually contextual.

Uncertainty

Although exceptions existed, Section 7.3 generally suggests that the traditional case showed a lower degree of uncertainty, interaction and knowledge gained compared to the unconventional case. One potential reason for this result is that the client possessed the essential uncertainty within the traditional project and, had therefore most reasons to devote attention to associated inquiries. However, although the client possessed the main uncertainty, it is still considered as comparatively small given the extensive reliance on established routines, technical solutions and the large volume and experience of projects procured using the traditional approach. Accordingly, the traditional project provided less incentive for actors, and in particular other actors than the client, to devote resources to aspects not covered by the institutions compared to the unconventional project investigated.

Interaction

The actors contributed with significant knowledge within both projects investigated, which partly resulted in episodes of a high degree of interaction frequency. However, the limited uncertainty identified for the traditional projects resulted in a lower degree of interaction compared to the unconventional project, which may be explained by several different courses including established roles, routines as well as aspects of the procurement method itself. The unconventional project, on the other hand, resulted in significant uncertainty, which is considered to have affected the degree of interaction, in particular regarding detailed inquiries of administrative and technical character including effects on financial issues, compared to the traditional project. One reason for the higher interaction is that the actors needed such information to reduce the uncertainty within the project by collaboration, evaluation and investigations. The commitments indicated probably resulted in additional costs that ultimately had to be borne by the project in question. However, the development and use of alternative procedures, materials and production methods within the unconventional project show that the actors both chose unconventional solutions, which in the example of technical solutions may both have reduced the price for the client but also resulted in a comparatively high degree of knowledge that could

potentially be utilized in the future. Although any quantification of such costs and benefits are difficult to establish with certainty, the results suggest, in contrast to other studies of unconventional projects (e.g. Leiringer et al, 2009; Borg, 2011), that actors not only adhere to already existing routines and technical solutions but also use and develop their own solutions in unconventional projects.

Knowledge gained

The analysis presented in Section 7.3 also suggests that a low degree of knowledge was gained by the actors participating in the traditional project. The low degree of knowledge gained is primarily considered as a consequence of the low degree of interaction and uncertainty. However, this result does not necessarily mean that the actors involved in traditional projects do not utilize or gain knowledge. Instead, the knowledge concerned can be considered as being individual, tacit and of a general nature, which is primarily due to the institutionalized and dyadic interaction emphasized to achieve high efficiency within the project by focusing on certain activities, sufficiently high quality standard and low investment costs. Consequently, knowledge is gained from traditional projects, but it is primarily obtained and transferred through institutions, such as routines and technical standards, rather than by organized and systematic knowledge management. In the case of the unconventional project, the extensive interaction in all phases studied provided more opportunities for the actors to gain knowledge. The knowledge gained was also successively applied during the course of the project, which means that knowledge developed early in the project was important later in the project.

A consequence of the characteristics indicated for the traditional approach is that a main mode of change in the traditional procurement approach, e.g. the introduction of new techniques and ways of doing business, is by the client who, if deemed important, revises existing formal institutions, which will subsequently be learned by the other actors.

Comparing procurement methods in a longer perspective

As indicated above, significant differences regarding the procurement methods can be observed by directly comparing the two focal projects. However, the influence of procurement method on uncertainty, interaction and knowledge gained becomes even more interesting if the timeframe is extended beyond the immediate projects studied.

Uncertainty

The relatively high degree of uncertainty of the unconventional approach was, in addition to the extensive undertakings also partly due to the procurement method of the focal project studied exhibiting a high degree of uniqueness. Accordingly, knowledge regarding several important administrative and technical aspects was lacking, incomplete and, therefore, not supporting decision-making in the absence of routines. However, even though relatively high, the resulting uncertainty was still sufficiently low to motivate efforts by actors to reduce them, not only within the unconventional project studied by extensive meetings and collaboration, but also at a more overarching level.

Interaction

As in the case of the shorter perspective, the interaction pattern also differed between the two cases investigated regarding the longer perspective. Although certain knowledge, primarily financial and production-related, is normally obtained, managed and used by actors in traditional projects, other types of knowledge, in particular technical, are seldom managed in this way. However, the results of the current study not only emphasize a high degree of interaction within projects to reduce perceived uncertainty, but also the importance of strategically gather information for future projects. The primary reason for the relatively high number of connections associated with unconventional projects suggests that explicit knowledge from those projects is useful in other unconventional projects as well. For example, a possible reason for connections associated with technical content being established to a greater extent in the unconventional case was that the contractor could handle perceived uncertainties within the projects using knowledge of other projects. Following investments in, for example, personnel and specialized equipment, it successively also became possible for the con-

tractor to monitor the performance of traditional projects, which provided additional knowledge useful in future projects. Consequently, the use of unconventional procurement approaches may not only encourage connections among unconventional projects but possibly also connections between unconventional and traditional projects as well.

Although the conclusions drawn so far may partly be a result of peculiarities of road projects, which can be considered as a special case of repetitive construction projects, it is probably still reasonable to argue that unconventional projects exhibit characteristics paving the way for connections beyond individual construction projects. However, whether and to what extent, the increased interaction detected is the result of the procurement approach being comparatively new to the participants, or of characteristics that are actually inherent to method, cannot be determined solely based on the observation and comparison of a single pair of projects. However, the investigation of projects performed years after the focal projects indicates that not only is stability achieved by the rise of new routines but also another degree of risk aversion as more knowledge is successfully gained by the actors. One example is the utilization of more radical technical designs, for example, based on cement-stabilization technique as used in a subsequent D-B-M project in 2010. Consequently, the increase in the number of unconventional projects runs parallel to changes in risk aversion, adaptations, and commitments in the form of routines to reduce uncertainty, and, thereby, the evolution at an organizational level exhibits a complex pattern.

Knowledge gained

Although a higher degree of knowledge in general was obtained from the unconventional project, significant differences could also be observed for the three actors studied. In the traditional project, all three actors participating in the project seem to have focused on exploiting existing knowledge. The evaluation of the project was almost entirely carried out by the client, and the contractor and consultant have therefore probably gained limited knowledge useful for the future. The D-B-M approach, on the other hand, is considered to have resulted in a higher degree of knowledge for the contractor during the execution of the project compared to the traditional project, which is due to the higher de-

gree of interaction breadth and depth as well as connections providing access to complementary information. The client gained a high degree of knowledge about how to conceptualize and carry out the project, for example, by formulating and expressing requirements and achieve a procurement procedure which the other actors embraced. The conclusion of the contractor that effective knowledge management in the form of establishing, developing and maintaining connections to previously performed projects is important in a market consisting of a significant amount of unconventional projects represents a major administrative insight. The contractor also seems to have initiated efforts to systematically gather and store such knowledge in codified form. Consequently, since transferability of knowledge is affected by the degree to which it can be codified, the explicit use by the client of performance requirements and corresponding investments in resources and capabilities of the contractor may counteract some problems of the construction sector. However, in the case of consultants, this actor category essentially conformed to existing standards in both cases studied and, accordingly, important aspects of knowledge did not differ among the two cases studied.

In summary, the traditional project promoted knowledge primarily by sequential project participation and the client´s updated standards and routines, while the unconventional project was characterized to a greater extent by knowledge gained from broad and deep interaction within projects and from other projects, which were managed by actors based on perceived uncertainty rather than strictly acting according to institutions. The current study also suggests that it is important to interpret individual projects as elements in a sequence of successive projects in order to analyze, not only the shorter time-frame of a given project, but also the long-term and hereditary phenomena. Such a perception is of particular importance as knowledge gradually accumulates and is transferred, not only within the current project, but also between successive projects. Consequently, although the conclusion drawn in this study generally agrees with, for example, Larsson and Sandberg (2003) and Styhre et al (2004), who emphasize the relation between actors involved in successive project phases increases the likelihood of organizational learning, the current study also emphasizes inter-project connec-

tions. In this case, connections are not only considered as a result of long contract time and overlap among project phases due to the number of activities contracted, but primarily due to the use of performance specifications, which tend to increase connectivity between projects since both the establishment and evaluation of requirements actually both need and permit empirical results from historical projects.

8.1.2 THEORETICAL FINDINGS

Chapter 2 reviewed both general and more specific theory on how to characterize complex organizational structures and concepts considered important for the study. The organizational phenomenon was studied by interpreting individual projects as small temporary networks comprising actors of different organizational origins and a model was presented where the three concepts of uncertainty, interaction and knowledge gained were assumed as interrelated. In this section, the theoretical implications from the study are discussed in more detail.

Uncertainty

Despite the inherent complexity of the phenomena examined, including the number of activities contracted, the contract length as well as type of technical requirements and design methodology used to evaluate technical quality were considered of utmost importance for the study other types of uncertainties are conceivable as well. However, although aspects such as payment mechanism or cooperation agreement in themselves also could affect the degree of uncertainty, the results from the study suggest that significant differences in uncertainty could be identified for the two project procurement methods investigated. Consequently, procurement approach affects the degree of uncertainty, which means that uncertainty can be considered as an important aspect of procurement methods. However, as also indicated from the study, uncertainty also seems to affect the other concepts as well, a conclusion which is supported by several other publications on the subject (e.g. Cyert and March, 1963; Håkansson, 1982; Cova et al, 2002).

Interaction characteristics

Interaction was used as a concept to represent both intra-project interaction as well as connections between successive projects. According to

the empirical study, it seems that the procurement method both directly and indirectly, through uncertainty, affects interaction. In the former case, the procurement methods required a different interaction pattern between the actors. The traditional procurement method often exhibited a high degree of interaction frequency, which to a large extent was needed to control the work and report information. However, the degree of interaction breadth and depth was lower in the traditional project, which was a consequence of the relatively low degree of uncertainty. This result may, however, be related to that the current study focused on uncertainties mainly associated with such interaction, while other forms of uncertainty, e.g. associated with compensation model and with project delivery time, may be more closely related to the frequency of interaction. In any way, one of the main empirical conclusions was that attention is seldom devoted to investigating the technical performance of traditional projects, a conclusion supported by other investigations of the construction industry itself (e.g. Kristoffersson, 1995; Rowlinson, 1999; Anheim, 2001). One explanation is that the more a given product is standardized, the fewer reasons there are to discuss technical aspects (Håkansson et al, 1999). In the case of the unconventional project, the interaction breadth and depth were relatively high, which is considered an effect of the high degree of uncertainty.

The uncertainty of the unconventional D-B-M project also resulted in more connections to other projects. The number of connections is again considered as a result of uncertainty and is supported by the actors establishing connections are also those subjected to most uncertainties. Of particular importance for the establishment of inter-project connections is the relevance of technical uncertainties. In a similar way as the traditional structural design model (cf. Section 5.1.2) constituted an effective institution to transfer knowledge between successive D-B-B projects, performance requirements provided another common basis facilitating inter-project comparability. In this case, performance requirements provide a means of transferring knowledge from one project to the next since the projects can be compared on similar bases, i.e. by aggregated performance parameters instead of abstract and detailed parameters as in the case of procedural specifications. This effect is thereby considered to facilitate the maintenance of inactive relationships between projects

(cf. Hadjikhani, 1992), which affect learning positively (cf. DeFillippi, 2001), since the cause-effect perception remains alive. Another important conclusion is that, in order to analyze and understand procurement methods and construction projects, it is important to both investigate and characterize the organizational phenomenon by taking the organizational context including other projects into account. This conclusion is also supported by more contemporary project management theory (cf. Engwall, 2003) and suggests that investigations of procurement methods based on snapshots of the market show significant limitations. However, the relation between uncertainty and interaction is not only unidirectional since the procurement method chosen determine how interaction will occur in order to reduce uncertainty. This was particularly evident in the case where the client decided which actor to interact with, for example, when utilizing a negotiated procurement procedure, to reduce the uncertainty in the unconventional project. Consequently, a double-directional relation between the three concepts (cf. Figure 2.2) can still be claimed.

One important aspect of interaction not discussed in this thesis concerns whether there is a limit on the amount of interaction. For example, given the broad and deep interaction between the contractor and consultant of the unconventional project, it seems difficult to increase the number of meetings, i.e. frequency, while still maintaining a high level of work in-between meetings. Consequently, it is probably the case that too a high degree of interaction breadth and depth restricts the degree of frequency achievable if sufficient efficiency is sought.

Knowledge gained

Another conclusion of theoretical relevance is that the greater the interaction, the higher the degree of knowledge gained, a conclusion which largely agrees with previous studies on industrial networks (Håkansson and Snehota, 1995; Håkansson et al, 1999; Lapre and Wassenhove, 2001; Lindkvist, 2001; Maaninen-Olsson, 2007). For example, the greater the overlap in projects, project phases and similarities in technology, the greater the possibility of information and knowledge flows (Bengtsson and Eriksson, 2002). This result is in accordance with observations concluding that traditional project-based work discourages actors to

spend efforts not contributing directly to project progress (Lindkvist et al, 1998; Berggren et al, 2001; Winch, 2002). The findings are also supported by e.g. Kadefors, (1995), Winch, (1998), Dubois and Gadde, (2002), who argue that the organizational fragmentation and reliance on formal institutions within the industry results in learning primarily occurring at an individual level while few mechanisms provide incentives for organizational learning. According to Styhre et al (2004) in their investigation of Swedish construction companies, successful utilization of local knowledge and experiences occurs but organizational learning capabilities do not materialize since the industry to a large extent also relies on informal and personal contacts rather than on formal knowledge management systems. However, although a relationship between interaction and knowledge is proposed, the current study suggests that it primarily is the degree of interaction breadth and depth that affects the degree of knowledge gained within a given project since the main difference between the two approaches seems to be the broader and deeper interaction within the unconventional D-B-M project. This conclusion suggests that complementary experiences are important to obtain new knowledge (cf. Håkansson and Snehota, 1995; Håkansson et al, 1999). However, in accordance with e.g. Nobeoka (1995) and Bengtsson and Eriksson (2002), the role of connections to other projects is also considered as important to gain knowledge. Consequently, both intra- and inter-organizational aspects are important to characterize knowledge gained. This conclusion was particularly evident in the case of performance requirements, where the search for detailed technical data to analyze previous projects regarding financial results provided means reducing uncertainty by both broad and deep interaction as well as connections.

As discussed above, the theoretical framework utilized in the current study contributes to previous research in that it provides a way of in-depth characterization of procurement methods and how knowledge is gained and what is the relation to interaction and uncertainty. First, in order to characterize procurement methods, it is important to take the temporary and organizational context into account. In this case, the network approach utilized appears to illustrate how the interaction occurs. An important theoretical conclusion is the inherent link between

uncertainty, interaction and, ultimately, knowledge gained. However, although the three concepts at first may appear as different sides of the same coin, i.e. occurring simultaneously, there is also an inherent evolution with time. As indicated in Figure 7.1, the use of subsequent unconventional projects suggest that knowledge gained also may affect interaction, uncertainty as well as the actual choice of procurement method, since the strategy of the client to achieve a high amount of unconventional projects was probably taken in the face of reduced uncertainty as knowledge was successively gained and the procurement approach became more institutionalized. This may in turn require a lower degree of interaction to achieve a given degree of efficiency. In essence, the model given in Figure 2.2 is believed, not only to contribute to the theoretical understanding of procurement methods, but also as a realistic way of illustrating their similarities and differences.

8.2 IMPLICATIONS FOR PROJECT MANAGEMENT

The research presented in this thesis does not provide any thorough investigation of all conceivable pros and cons of different procurement methods available, or any general and definitive position for or against any of the two approaches investigated. Instead, it is suggested that the two approaches studied show significant differences as well as effects.

The traditional procurement method is legitimized by logics similar to that of neoclassical economics, involving procurement of homogenous products, exploitation of price competition and elimination of uncertainties by project discretization and dyadic relationships, which are believed to result in a relatively high degree of efficiency and are thereby of great interest for society as a whole. However, the unconventional approach can be legitimized by dynamic competition, utilization of resource heterogeneity, relational interaction and anticipation of increased knowledge and innovations, which, as described in Chapter 1, are related to several of the main problems of this study as well as the effectiveness of the construction sector in general.

The different logics indicated suggest that the procurement methods may be complementary since an adequate balance between knowledge exploitation and exploration should be sought (March, 1994; Curado,

2006). Accordingly, a critical mass of unconventional procurements can trigger commitments by the actors, towards not only any unconventional project contracted but also traditional ones as indicated by the findings of Section 7.3, which can result in improved productivity and rate of innovations. This conclusion is to some extent in accordance with, for example, Huemer and Östergren (2000) who argued that contractors are better at exploitation than exploration but should work on the latter. In principle, the use of unconventional projects provides incentives for exploration efforts and, hence emphasizes the importance of the long-term perspective by knowledge that can be utilized in the future. In this case, traditional D-B-B projects may also benefit.

8.2.1 DEMANDS ON KNOWLEDGE MANAGEMENT

Although the findings in this study indicate that unconventional procurement methods can provide positive effects, any such results require increased commitment towards knowledge management. In particular, the actors need to establish and successively improve databases, where the organization can access the information to manage administrative and technical aspects, as well as tools to analyze the performance of, for example, materials and production technique. Such efforts may also provide data to further analyze whether any procurement provides advantages over competing approaches.

8.2.2 RELATIONS IN UNCONVENTIONAL PROJECTS

In principle, the established relationship between the three main actors investigated can be compared, at both a super-project level and in the traditional project, to the mature stage of the development episode described by Ford et al (2003), i.e. stable, long-established and extensively institutionalized. One explanation for the behaviour shown, especially by the consultant, is that this actor category often only receives negative feedback from the other actors, which results in additional adherence to existing institutions (Atkin, 1993). Furthermore, Fu et al (2006) argued that rule-implementers, whose work mainly involves complying with predetermined instructions and rules, are comparatively inactive in learning networks. The relationship between the three main actors studied during the unconventional project, on the other hand, may be

compared to an explorative stage (Ford et al, 2003), where significant interaction manifested by continuous negotiations occurs due to prevailing uncertainties about insufficient routines, technical standards and practices. Intuitively, the sheer existence of the unconventional project puts the finger on what Ford et al (2003) describe as a reconfiguration of an existing relationship, where the three actors once again engage in an intermediate stage, which provides both increased interaction as well as possibilities to learn.

One potentially important conclusion from the study is that it might be questionable for actors to cooperate in such a way that they end up sharing a joint responsibility in unconventional projects. Given the high degree of uncertainty, and extensive interaction needed to reduce this uncertainty, it may be wise to not participate in agreements where the responsibility is shared between two companies. For example, sharing the responsibility for the technical performance of a radical new design over an extended time between two larger contractors where each is contributing significantly to this performance is probably too difficult and costly. This conclusion is largely in accordance with, for example, Williamson (1985) and suggests that any delegation of responsibilities need to be clearly expressed. This could be achieved by assigning external consultants, subcontractors and suppliers using traditional agreements or by developing agreements where the responsibility is expressed by requirements further down in the requirement hierarchy (cf. Figure 1.2).

8.2.3 PROCUREMENT APPROACH AND STRUCTURAL DESIGN

Another important conclusion from the current study is the relatively technical issue that traditional design methodology is not sufficient in unconventional projects based on performance specifications since it is not able to handle technical uncertainties in the form of performance of individual projects. The explanation is that traditional design methodology is framed by the client´s intentions to achieve adequate technical performance for a portfolio of projects on average and, at the same time, obtain a clear distribution of responsibilities between the actors involved. When a consultant produces a design for a D-B-B project, this design is evaluated *ex ante*, based on technical standards and irrespec-

tive of actual performance. However, in the case of unconventional approaches, the contractor is responsible for explicit performance *ex post* and, thereby, essentially a result of his sense of risk management, which requires models with sufficient precision to predict the performance of individual projects in greater detail. Since neither the traditional design methodology nor testable models to verify the suitability of innovative materials and production methods within the time-frame of a given project (e.g. Nam and Tatum, 1988, Kadefors, 1995; Vincenti, 2000) are feasible to predict performance in the terms given in unconventional contracts, it is both necessary to continuously evaluate performance of these projects and to develop new design tools. Consequently, in order to compete on a market constituting unconventional projects, it is necessary, not only for the client but for contractors and consultants to devote resources and capabilities to continuously develop materials, production technique and other technical aspects. Furthermore, it is also considered necessary to actively monitor, develop models and analyze the performance of projects in such a way that technical risks can be determined.

8.2.4 A COMMENT REGARDING INNOVATIONS

Although the procurement approaches investigated resulted in different effects, no major innovation is considered to have been promoted by any actors studied. Even the D-B-M project showed few technical solutions that can be classified as innovations i.e. as motivated by improved efficiency, which may be explained by at least two reasons. First, since the market has historically been dominated by traditional D-B-B projects, there have been few incentives to develop new technical solutions. Consequently, no radical technical solution exist that simply can be pulled out of the drawer. Second, decision-making faced by uncertainty is primary governed by compliance with rules rather than conscious calculation of consequences. This behaviour was evident in both projects and explains why no radical solution was immediately utilized. Regarding the possibilities of increasing the number of innovations through unconventional procurement, the current study first suggests that it is difficult to identify innovations solely by investigating a project, or projects in isolation. Consequently, a series of projects, i.e. successive-

ly occurring projects may be necessary to actually identify actions as well as, probably incremental, outcomes from deliberate learning efforts. Second, although providing different incentives compared to traditional approaches, it also feels as if the optimism of unconventional procurement methods for promoting innovations lacks an understanding of the bounded rationality provided by both formal and informal institutions. It is well-known that routines persist over significant times due to the fact that there is a cost of learning new routines, which supports the tendency to adhere to prevailing practices and technical solutions even though apparent greater freedom exists not to. Despite such difficulties, it is probably fair to suggest that learning and new knowledge leads to innovations despite the slow process, requiring continuous commitment to unconventional procurement methods from all actors involved. It is especially the case for commitment to adequate knowledge management as well as an open mind that many new solutions not only result in higher costs but, at least sometimes, also in failures such as inferior quality.

8.3 FURTHER RESEARCH

Following the results of the current study, a number of suggestions for future research are also given:

- As indicated in Section 2.1.1, project performance has often been evaluated comparatively shortly after a given facility has entered service. A major research objective seems to evaluate costs, delivery time and technical quality over time. This objective should both reflect projects in service as well as over time as new projects are launched.
- As indicated by the short literature study in Section 1.2.1, comparison of project performance with respect to procurement method has hitherto mainly concerned cost and delivery time in the short perspective. Quality has seldom been explicitly addressed despite the obvious possibility of comparing performance outcomes of different projects irrespective of procurement approach. Do unconventional procurement methods result in better, equal or inferior technical performance?

- The current study has primarily been devoted to three main actors. However, whether and to what extent other actors such as subcontractors, suppliers and non-business actors are also affected by procurement method remains to be studied in the future.
- Other projects or construction types, for example, buildings, are obviously also of great interest to investigate regarding the above issues.
- The current research was devoted to empirical data of two, so far, comparatively successful projects. An interesting research question is to investigate whether any of the theoretical concepts employed in the study, or others, by any negative project outcome.

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