

# INNOVATION IN KNOWLEDGE-INTENSIVE SUPPLY CHAIN RELATIONSHIPS

## Competitive Paper

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### Abstract

**Purpose:** The purpose of this paper is to help create a better understanding of the development of knowledge, innovation and the combining of resources in the interface between knowledge-intensive autonomous firms. The literature addressed is from the fields of combining resources, joint problem solving, innovation and knowledge, transaction cost economics and the theory of governing the commons.

**Research method:** Theoretically informed case study.

**Research findings:** The representative case study consists of two firms in a dyadic relationship. Their resources are combined in such a way that the activities of each firm are found to be reciprocally interdependent at the level of details. This is particularly evident in the solving of problems related to the designing of software that interacts within a shared HMI, in which the system undergoes continuous expansion with regard to functionality and number of system components. Differences have been found in the relations between the firms at the technical operations level compared to the strategic level. The operational level is characterized by cooperation and joint problem solving based on trust, with a combination of resources on the most technologically intense and detailed level where the parties sit together and work on each other's source code to solve interface problems and problems related to functional interaction. However, when it comes to the business worldview at management level the principal firm seem to "turn a blind eye to the facts on the ground", advocating an outlook where the suppliers are kept "at arm's length", and pursuing a transactional strategy rather than an interactive resource-based one. The causal explanation given for this is the reciprocal interdependency associated with activities and products requiring mutual coordination, and contingent causes where the agent offers continuity and practical tacit knowledge about how eventual problems have been solved before. The principal has a greater turnover of software experts. In sum, this means that joint problem solution is very useful for the principal, even though this is seen as strategically problematic and at odds with the prevalent business world view. In terms of strategic implications the agent's input represents a resource portfolio of increasing importance. Combined with a great degree of asset specificity in the relationship, the TCA theory indicates that vertical integration is a way forward. This is not considered a likely option, however. The theory of governing the commons can inform the development of an alternative strategy.

**Main contribution:** The main contribution of this paper lies in its theoretically informed analysis of a relationship between firms in a project oriented industry where the resource combination in the studied case is reciprocally interdependent at the operational level.

In addition, the combination of theories applied here brings new light to bear on the field in two ways: first, by including Child's knowledge concepts for learning in strategic alliances, and second, by the conceptualization of a joint problem solving mechanism based on a modified value shop concept and McEvily and Marcus' modelling of acquisition of competitive capabilities in embedded ties.

Keywords: Joint problem solving, reciprocal interdependence, value/supply chain relationship

## INNOVATION IN KNOWLEDGE-INTENSIVE SUPPLY CHAIN RELATIONSHIPS

### INTRODUCTION

In many value chains firms depend on combining their own resources with external ones in order to develop the further resources needed to develop, sustain and renew competitive advantage (McEvil and Marcus 2005, Porter 1990). The importance of acquiring competitive capabilities varies according to the type of industry, where project production (one-of-a-kind) of products based on advanced, compound and complex technologies, which require specialist competencies, are thought to represent some of the greatest challenges in value chains between autonomous firms. The fact that so many specialist competences are involved may cause vertical integration to appear less strategically attractive, and may in any case require exceptional capital strength while at the same time causing a potential reduction of the innovative dynamics of lead suppliers who also act as suppliers to competing firms. In addition, vertical integration is, among other things, associated with greater risk in relation to market fluctuations.

In relationships between firms which are as close as the ones dealt with here – which are close both in terms of knowledge and functions – a considerable development of knowledge and competence is expected to take place, channelled through and based on the joint solving of problems and the expansion of capabilities. In this paper we want to examine the nature of these processes. In other words, we want to explore the following: *How to explain and understand knowledge creation in value chain relationships of knowledge intensive firms.*

The study is theoretically informed and the research question is elaborated in a study of a “theoretically representative”, or “critical”, case (Yin 1989).

The selected case involves a representative value chain relationship between a supplier of drilling equipment to the global offshore oil and gas exploration industry (first tier) and a supplier of customized explosion-proof CCTV systems (second tier). For security and operational reasons, CCTV systems (Closed Circuit Tele Vision) are a necessary component in offshore state-of-the-art drilling operations. Engineering work constitutes a relatively large proportion of both suppliers’ output, and they share the market interaction strategy of “engineering-to-order” (Berry and Hill 1992). Both companies are engaged in global operations, and both are production units in multinational corporations. Finally, both of the studied production facilities are located in Europe.

The case is taken from the oil and gas industry. Aarseth et al. (2006) argue that this is probably one of the world’s most complex industries, whose value creation and future lies in the ability to shift from the “*competitiveness of the autonomous firm*” to “*the competitiveness of the value chain of firms*”. Offshore projects are unique, engineering intensive and faced with great uncertainties caused by the disproportion in size between what nature can do to us and what we can do to nature with our technology (Stinchombe and Heimer 1985). The oil disaster in the Mexican Gulf involving an offshore installation belonging to BP (2010) may serve as a reminder of the challenges faced by this industry. The suppliers in the oil and gas industry rarely have the competence and strength to deliver on their own, and are therefore dependent on comprehensive collaboration throughout the value chain (Reve and Jakobsen 2001). In most cases, information and communication technology are used mutually by companies in the chain, and in such close collaborative relationship the complexity increases (Bititci et al. 2004). Furthermore, due to a network of several interrelated activities, workflow and decision making processes can no longer be sequential, and are no longer so<sup>1</sup>. Complexity represents a major challenge in the design and management of collaborative value chains –

such as defining the boundaries and intensity of particular relationships where multiple relationships exist between the same companies (Fawcett and Magnan 2002).

This paper is divided into a theoretical and an empirical part. The first section provides an introductory overview of relevant knowledge, before addressing transaction cost economics and the theory of governing the commons. This is followed by theoretical perspectives on the concepts of value chain, network, innovation and value shop. Between the theoretical and the empirical parts of the paper we address the theoretical refinement of research questions and methodology. In the empirical part we start off by describing the context, before moving on to analyze problem solving and technical knowledge in the relationship. From there we take a closer look at strategic issues in the relationship between the firms. Finally, we discuss strategic options for the future development of the relationship, before offering conclusions to the research questions.

## THEORY

### Knowledge

A clear understanding of knowledge is required when studying knowledge-intensive firms. In this case, the understanding derives from several sources: from Davenport and Prusak (1998, 6), who conceive that “*knowledge derives from information as information derives from data*”; Machlup (1983, 641), who sees data as raw bits of information, information as organized data in context, and knowledge as the assimilation of the information and understanding of how to use it; and Polanyi (1962), who regards the acquiring and discovering of knowledge as both a social process and a deeply personal process. Related to human asset specificity Williamson (1996) also builds on Polanyi’s (1962) discussion of “*personal knowledge*” when he illustrates the importance of idiosyncratic knowledge and working relations.

Tacit knowledge, or tacit knowing, experience-based knowledge, theoretical knowledge and codified knowledge are central categories to any discussion of knowledge (Polanyi 1966; Karlsen 2008). Karlsen conceives of tacit knowledge as covering both experience-based and theoretical knowledge when he emphasizes *knowing* in Polanyi’s (ibid.) work. A distinction between these two types of knowledge can only be made in a theoretical analysis, and not through the observation of actions. It is action that communicates tacit knowledge, not language, whereas the opposite is the case for theoretical knowledge. Polanyi’s point is that we know more than we can express through words. Moreover, he maintains that it is possible to codify both experience-based knowledge and knowledge based on theory.

Child (2003) differentiates between three types of knowledge. Technical knowledge is basically about diffusing technical information (tacit, practical and codified). Furthermore, technical knowledge is framed by systemic knowledge, which arranges the context of use of technical information – a reference to organizational routines and procedures (tacit and formally codified). Hence, systemic knowledge can never be reduced to imitation, due to the tacit ingredient that is necessarily present in all codified knowledge (Karlsen ibid.). Essentially, it is a question of translation and learning. Moreover, systemic knowledge is conceived of as being framed by strategic knowledge – which refers to mindsets and business worldviews.

Innovation can be divided further, into analytical and synthetic modes of knowledge creation (Moodysson 2007; Laestadius 1998; Asheim and Gertler 2005; Simon 1969). The analytical mode is dominant in most natural science practices, which understand and explain natural systems through the discovery and application of scientific principles and laws. The synthetic mode is dominant in most engineering practices, which apply and combine existing knowledge in new ways that result in new human-made functional systems. It is not essential

to know exactly why systems work in specific ways as long as the mechanism is known. Knowledge creation relies on trials and tests based on parameter variation. The processes are likely to require the application of theoretical and practical knowledge in different combinations.

Transaction cost economics, governing the commons and trust

Vertical integration is the paradigm problem studied in transaction cost analysis (Williamson, 1996), and in 1975 Williamson employed a comparative institutional analysis in order to assess when and for what reasons market procurement gives way to internal organization. The main comparative institutional alternatives to be evaluated were incomplete short-term contracts versus vertical integration, or in other words market versus hierarchy (internal organization), buy or make – given the impossibility of comprehensive contracting (due to bounded rationality) and the need to adapt a supply relation over time (in response to change). According to Williamson (1996, 66), there are three main differences between market and internal organization: “*markets promote high-powered incentives and restrain bureaucratic distortion more effectively than internal organization; 2) markets can sometimes aggregate demands to advantage, thereby to realize economies of scale and scope; and 3) internal organization has access to distinctive governance instruments.*”

The key dimensions for describing transactions are asset specificity, uncertainty, and frequency, of which asset specificity is not only the most distinctive, but also the most important dimension. A high level of asset specificity paves the way for hierarchy and vertical integration of production in transaction cost economics. The full ramifications of asset specificity become evident only in the context of incomplete contracting, and went unrecognized in the pre-transaction cost era. Without claiming to be exhaustive, Williamson (1996, 59-60) identifies six kinds of asset specificity:

- Site specificity, such as successive stations being located in a cheek-by-jowl relation to each other so as to economize on inventory and transportation expenses.
- Physical asset specificity, such as specialized dyes required to produce a component.
- Human asset specificity that arises in a learning-by-doing fashion.
- Dedicated assets, which are discrete investments in a general purpose plant that are made at the behest of a particular customer; to which the author adds:
- Brand name capital and
- Temporal specificity.

Transaction cost economics pairs the assumption of bounded rationality with a self-interest-seeking assumption which is variously described as opportunism, moral hazard, and agency. According to Williamson (1996, 44), opportunism is a “*behavioral assumption of such pervasive reach and importance that it deserves coequal status with bounded rationality in any concerted effort to assess the comparative efficacy of alternative modes of contracting. Thus, just as the absence of bounded rationality would vitiate the need for internal organization, since all of the relevant contracting action could be concentrated in a comprehensive ex-ante agreement, so likewise would the absence of opportunism vitiate the need for added safeguards, since “contract as promise” could be used to annihilate ex-post defection from even incomplete contracts.*” The main point of bounded rationality and opportunism for transaction cost economics is to organize transactions so as to economize on bounded rationality while simultaneously safeguarding the transactions in question against the hazards of opportunism. Williamson (ibid., 60) discriminates between primary uncertainty (of the state-contingent kind) and secondary uncertainty that arises from lack of communication, “*that is from one decision maker having no way of finding out the concurrent decisions and plan made by others*”. Hazards are due to behavioral uncertainties that arise when incomplete

contracting and asset specificity are joined, and a point of special importance to the economics of organization is that the mitigation of hazards can be a source for mutual gain. The work published in 1975 by Williamson mainly addressed the two options of market and hierarchy for procuring goods. This was met with criticism, and in this context the work published in 1985 by Granovetter is well known (see below). In later works, Williamson has also recognized and included a third option for procurement, namely the hybrid modes of organization. Contracting for goods and services produced under market contracting gives way to “*bilateral trading (or, more generally, hybrid modes of organization), which in turn gives way to unified ownership (hierarchies) as the condition of asset specificity builds up*” (Williamson 1996, 45). Hybrid modes of contracting are supported by neoclassical contract law, and differ from classical market contracting in that they are mediated by a flexible contracting mechanism<sup>2</sup> which allows the parties to maintain their autonomy. Williamson (ibid., 45) argues that in the long term, incomplete contracts require special adaptive mechanisms to effect realignment and restore efficiency when beset by unanticipated disturbances.

Williamson’s concept of transaction cost economics (1975, 1985 and 1996) does not trust the market. The market might take advantage of you if you have a high level of asset specificity. In such cases, transactions should be organized within the firm. Ostrom (1990)<sup>3</sup> argues that although the market *might* take advantage of you, that this is not necessarily the case. It is possible to learn trust over time in governing the commons, e.g. knowledge, by building enough diversity in the governing institutions to deal with the complexity.

The *commons* refers to resources shared by a group of people. Governing common knowledge is an expansion from the traditional commons such as water resources, fisheries, forests, etc. However, questions for any analysis of commons inevitably focus on equity, efficiency, and sustainability (Hess and Ostrom 2007, 6). Equity refers to the issues of just or equal appropriation from, and contribution to, the maintenance of a resource. Efficiency deals with the optimal production, management and use of the resource. Sustainability looks at outcomes in the long term. Based on empirical studies of a significant number of traditional commons, Ostrom (1990, 90-102) has identified a number of design principles which characterize robust, long lasting, common-pool resource institutions:

- Clearly defined boundaries of the common resources
- Rules well-matched to local needs and conditions
- Individuals affected by the rules able to participate in modifying the rules
- External authorities respect the right of the community to devise their own rules
- Self-monitoring of behavior
- A graduated system of sanctions
- Community access to low-cost conflict resolution mechanisms
- Nested enterprises, so that the governance of regulations is nested in an organized structure

The eight listed factors were found to be present in the most robust institutions but absent in the systems that failed. The authors emphasize, however, that the factors are not prescriptive or models; rather, they are insightful findings in the analysis of small homogeneous systems, and whether they apply to the study of large and complex systems such as the knowledge commons is a question for further research (Hess and Ostrom 2007, 7). Ostrom and Hess (ibid.) further introduce a framework for institutional analysis and development that can be used to investigate repeated human interaction within the rules and norms guiding their choices of strategies and behaviors; and most importantly, it can offer a way out of existing patterns of practice when the ways of thinking surrounding these patterns have failed to yield solutions (Oakerson 1978, 15).

Granovetter (1985) argues that buyers and sellers in the market do not make their decisions on the basis of price signals alone; rather, their experiences over time lead to relationships founded on trust. This constitutes a critique of the transaction cost theory, which is sometimes thought to place too much weight on contracts. For Granovetter, the goal appears to be a reduction of transaction costs (Askildsen and Kalsaas 2009). Other authors (Lundvall 1992, 1995, 1996; Maskell 1996; Maskell and Malmberg 1999; Morgan 1997; Storper and Scott 1995) ascribe other qualities to these relationships. Although recognizing trust-based relationships between market actors as crucial; they do not see them primarily as a cost-cutting device, but as channels for knowledge creation and a basis for interactive learning triggering technological development and economic growth.

#### Value chains, networks and innovation

Studies of networks of legally autonomous but interdependent companies have received a great deal of attention over the last decades. Grabher (2006) traces this trend back to Simmel (1890), who distinguished between groups (defined according to a criterion of membership) and webs of affiliation. Grabher (1993) underlines four basic characteristics of such networks:

- reciprocity
- interdependence
- loose coupling
- power

Transactions in networks are constructed around an expected “reciprocity” from the other party and disappear if this fails to materialize. Frequently, the obligation to engage in such reciprocity is tacit and will be looked upon as relevant for the long term relation, rather than requiring that each transaction be perfectly balanced. Social relationships develop over time. The actors make mutual adaptations, and in the long run, reputation, friendship and mutuality will constitute central characteristics of the relationship. As a result of these adjustments, it becomes more common to solve conflicts by negotiations rather than resorting to terminating the relationship (“voice” instead of “exit” in Hirschmann’s (1970) terminology). The notion of “loose coupling” is related to the dynamism and flexibility characteristic of successful networks, meaning that mutual adjustment does not become too pronounced and that some space is preserved for freedom of maneuver. When relationships become too exclusive, this can prevent the actors from seeking alternatives and stimulates a group culture counterproductive to change. The attributes of reciprocity and interdependence should not be understood as always and everywhere representing a spirit of harmonic symmetry in the relationships, for power can be seen as a necessary attribute for exploiting the interdependence in relationships (Håkansson and Johansson 1993).

The discipline of Supply Chain Management<sup>4</sup> also builds on the existence of social relationships between firms (Halldorsen et al. 2007; Askildsen and Kalsaas 2009). According to Vrijhoef and Koskela (2000,170) the basic idea of SCM is to “recognize the interdependency in supply chains”, or in Williamson’s (1996) terminology, the “bilateral dependency”. Kim (2005) conceives of value chains as a form of strategic alliance. A strategic alliance involves a network of firms cooperating to achieve their strategic objectives (Child 2003). Structurally, it constitutes a blend of market transactions and business relations, and in engineering-to-order production, the project is the dominant operative organizational unit.

The SCM-approach is usually normative in that it addresses collaboration between the actors in the supply chain with the purpose of improving the flow of materials, work, information and money between the actors. Cost reduction in the overall supply chain is central here. However, value for the customer and customer service are also in focus. Simchi-Levi et al. (2000, 1) understand SCM as “a set of approaches utilized to efficiently integrate suppliers,

manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements". Christopher (2005, 5) defines SCM as the management of "upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole". Halldorsen et al. (2007, 287) place the relationship between firms centre stage when they see "supply chains as interconnected institutions", while also drawing on transaction cost theory, a resource based view of firms, principal-agent theory and network theory to explain structure and management issues in SCM. With the concept of "supply chain structure" Chopra and Meindl (2007) capture the trade-off between efficiency/cost and responsiveness on logistical and cross-functional drivers such as facilities, inventory, transportation, information, sourcing and pricing, which the authors relate to strategy. Responsiveness covers different aspects of customer service, but also the ability to build innovative products. Hence, innovation contributes to responsiveness in this conceptualization of SCM, and could be a strategy in a contextual market and strategy setting where innovative capability is a central factor.

The resource-based network theory (Gadde and Håkansson 2001), also applied by SCM-scholars (Askildsen and Kalsaas 2009; Halldorsen et al. 2007), focuses on how to understand and analyze the combination of resources in different companies in order to achieve economic growth and increased competitiveness. The theory contributes insights that can help develop new relationships and improve existing networks and value chains. As with innovation theory, long-term relationships and the building of trust are also significant factors in network theory. It is applied by Gadde and Håkansson (2001) to expand the approach of purchasing and procurement in SCM by what we may dub a new "value creating purchasing", which goes beyond the well-known applied concept of portfolio analysis identified by Kraljic (1983) in "Purchasing must become supply management". A central idea here is expressed in the title of the article "No Business is an Island" (Håkansson and Snehota 1989): firms are seen as interdependent and collaboration is the basis for their existence. A company is conceived of as "a bundle of activities".<sup>5</sup> The main concern is to "understand the role of the single company in terms of the overall structure, how its activities affect other firms' activities and how the company in turn, is affected by these other activities" (Gadde and Håkansson 2001, 59). Gadde and Håkansson build on Richardson (1972) when they emphasize the importance of understanding activities in terms of "similarity" and "complementarity" when analysing the analysis of the division of labor in networks. Activities are regarded as similar when they call for the same resources and capabilities to be effected and complementary when they represent different phases in a production process. Capability is defined as the ability to combine resources. Furthermore, increased complementarities between activities across firm boundaries are likely to require more intensive interaction between the actors (Gadde and Håkansson 2001).

Later, we will expand "different phases" to also include reciprocal interdependency as it relates to activities (Thompson 2003; Stabell and Fjeldstad 1998). The theory builds on the resource-based view of firms (Penrose 1959; Alchian and Demsetz 1972; Sherer 1970; Wernfelt 1984; Barney 1991), and the resource notion covers all the different kinds of input that contribute to increasing the value of a product, e.g. knowledge, labor, equipment and tools, organization, capital, parts and components, trademark and reputation. The external resources may be distributed over a large number of suppliers and customers, and demanding customers may be important for the principal firm's development of its resources (Porter 1985). Collaboration and interaction with other companies are regarded as an important aspect in the development of new resources (Håkansson and Ford 2002).

Prahalad and Ramaswamy (2004) take the network perspective whereby suppliers and partners are seen as a source of competence a step further in arguing that value is co-created

in the supply chain, and that the partners are both collaborators and competitors for value: so, they move from arm's length, market-based, transactions to collaboration as the co-creation of value. The authors address some obstacles related to the risks and costs of collaboration and suggest that they can be handled by addressing the following questions: 1) What information should be shared?; 2) Who pays the price for supply chain volatility?; 3) Who extracts the value from the new efficiencies?; 4) Who bears the burden of learning multiple systems; 5) Who owns intellectual property that is co-created through collaboration?; and 6) Who bears the cost of creating IT capabilities?

With relation to the present discussion, social relations in industry might be conceived of as a mechanism against opportunistic behavior and uncertainty related to the reduction of transaction costs, and as a medium for knowledge development, learning, innovation and economic growth. Hence, collaboration is a source of increased productivity (Askildsen and Kalsaas 2009). A relative shift from firms to value chains as the unit of production and competition requires a pervasive horizontalisation of vertical modes of organization both inside and between firms (Christopher 2005).

### Innovation theory

Innovation is an interactive knowledge process where “embeddedness” is essential for understanding the driving forces behind, and the rationality of, individual economic actions. Thus understood, embeddedness opposes the neo-classical economic view of markets as defined by instrumental rationality and utility maximization (Polanyi 1957; Granovetter 1985). Granovetter relates embeddedness to the “under-socialized” conceptualization of economic action, where “attempts to purposive actions are (...) embedded in concrete, ongoing systems of social relations” (487). Hence, economic actions are based on both instrumental and communicative rationality (Habermas 1984). Individuals can make choices of their own, but these are based not on strategic self-interest (utility maximization) alone, but also on respect for the social norms and culture developed in interaction with others – for instance in interaction within the firm or in interaction with employees in other firms.

Lundvall (1992) identifies two types of rationality: 1) “instrumental” rationality, which is based on the expected outcome of interaction (cause-effect); and 2) “communicative” rationality, founded on intuition, worldviews and other experiences related to communication. Instrumental and communicative rationality are strongly intertwined, but the relative importance of each dimension differs from situation to situation.

Moodysson (2007) deconstructs the notion of embeddedness and the two types of rationality according to Habermas' (1987) conceptualization of the “lifeworld” and the “system”. The lifeworld is where actors are found and where social interaction and communication take place, whereas the system refers to the economic, political and legal arena. The system is formally defined, with responsibilities, power and rules, such as in the formal system of organizations or in the political system. Furthermore, systems build primarily on instrumental rationality; whereas the lifeworld builds on communicative rationality. The lifeworld is, “so to speak, a transcendental site where speaker and hearer meet, where they can reciprocally raise claims [...] and where they can criticize and confirm those validity claims, settle their disagreements, and arrive at agreements” (Habermas 1987, 126). The mediators of the system, money and (formal) power, are in most cases predefined and authoritatively fixed; while the mediators of the lifeworld, (informal) influence and value-commitments, are gradually shaped and reshaped by continuous social interaction. Abstractly separated, the lifeworld and the system thus represent two intertwined dimensions of embeddedness as specified by Granovetter (1985).

The concept of communities (communities of practice and epistemic communities) exemplifies how the lifeworld and the system are intertwined in concrete knowledge

(Moodysson 2007; Lave and Wenger 1991). Communities of practice denote self-organized functionally interactive groups, framed by more or less formalized structures. The way in which engineers in development departments in different companies located along the value chain cooperate in R&D work and exchange information can provide a useful example here (Isaksen and Kalsaas 2009). Epistemic communities are made up of groups of people who work more or less independently of each other on a mutually recognized subset of knowledge issues, and who at the very least accept some common procedural authority as essential to their knowledge building activity. These are usually more loosely organized and in large part latent networks that are less likely to be organized within formal structures compared to communities of practice. An example of an epistemic community is the informal and latent network of academic researchers specializing in similar or related fields of knowledge sharing an “epistemic culture”, understood as a common attitude towards knowledge and ways in which to endorse or judge claims to give them the status of knowledge. This is in opposition to communities of practice, where cohesion is dependent on the frequency of direct contact between members connected to a specific task or a set of related tasks. On the other hand, epistemic communities maintain their adhesiveness independently of actual, operational, interaction (Håkansson, 2005).

The system plays a central role in communities of practice, because it is the system (e.g. organizations, inter-organizational alliances) that serves as the framework within which communities are developed. The lifeworld is important as a precondition for the system, since the community as such is self-organized and essentially built upon shared respect for social norms (Brown and Duguid 1991). The system has emergent powers, though, which “routinise, formalise and govern actions through specific signals and rules [...] which standardise and fix relationships and responses for long periods, until they are redefined” (Sayer 2001, 689).

Epistemic communities, on the other hand, are less dependent on the system dimension, since by default no formal structures or functional relationships exist in these. Several communities can co-exist, and individuals are more likely than not to be embedded in many overlapping networks. Moreover, relationships within one network can serve as a bridge to other networks.

### Joint problem solving mechanism

The value shop model (Stabell and Fjeldstad 1998) is a complementary model to Porter’s value chain model (1984), conceptualized to analyze value creation logics in firms based on intensive technology (Thompson 2003). Stabell and Fjeldstad argue that Porter’s value chain concept corresponds to Thompson’s long-linked technology, where value is created by transforming input into products. Organizing according to long-linked technology is characterized by handling sequential interdependencies, while reciprocal interdependencies underpin intensive technology. The mode of coordination involved in sequential interdependencies is planning, whereas reciprocal interdependencies involve mutual adjustment.

It is conceptualized that in an organization where reciprocal interdependency is found sequential interdependency is also found<sup>6</sup>. Organizations with reciprocal interdependency in their activity structure are the most complex.

The intensive technology in a value shop is characterized by the reciprocal interdependency on which it rests, understood as a situation where activity outputs become inputs for each other, and where each unit poses contingency for the other. That is why mutual adjustment is necessary in coordination. Intensive technology is a custom technology, and its successful employment rests in part on the availability of all capacities potentially needed, but also on the appropriate custom combination of selected capacities as required by the individual case or project (Thompson 2003). Stabell and Fjeldstad (1998, 423) argue that “learning and

innovative problem-solving is the modus operandi in firms with an intensive technology”. Moreover, the necessary mode of coordination by mutual adjustment in value shops requires rather intensive interaction between different experts and between the customer and the supplier. Such interaction is in harmony with interaction in the innovation theory, and it is likely that both communicative and system rationality occur.

Stabell and Fjeldstad (1998) conceive of five generic categories of primary value shop activities. Each of these is further divisible into a number of distinct activities that depend on the particular industry and the strategy pursued by the firm:

1) Problem-finding and acquisition: Activities associated with the recording, reviewing, and formulating of the problem to be solved and the choice of the overall approach applied in order to solve the problem; 2) Problem-solution: Activities associated with generating and evaluating alternative problem solutions; 3) Choice: Activities associated with choosing among alternative problem solutions; 4) Execution. Activities associated with communicating, organizing, and implementing the chosen solution; 5) Control and evaluation: Activities associated with measuring and evaluating to what extent implementation has solved the initially stated problem.

The traditional thinking of the value chain tradition based on Porter’s definition sees the value shop concept as a tool for strategic analysis within a firm, whereas in this paper its anticipated use is to inform the analysis of joint problem solving at a more detailed level (technical and systemic knowledge) in the interface between two firms, where all the steps described above are included in this joint solving of problems. McEvily and Marcus (2005) have modelled joint problem solving in a context of embedded ties enabling the acquisition of competitive capabilities, where joint problem solving builds on trust and the sharing of information. The assumption that a certain level of trust and information sharing is a precondition for problem solving in the modified value shop model is an expansion of this work. However, the problem solving mechanism is also factored into the loops described above, and supported by the concept of reciprocal interdependency and the power of explanation embedded in this with respect to understanding activities involving intensive technologies. The “joint problem solution mechanism” referred to in the rest of this paper combines McEvily and Marcus’ model with the modified value shop model for studying intensive technology in the interface between firms.

## REFINING THE RESEARCH QUESTIONS ON THE BASIS OF THEORY

Supply chain relationships represent a hybrid organization in the notation of transaction cost economics, where neoclassical contracts, including safeguards against moral risk and disruption, are substitutes for hierarchy and vertical integration. Hybrid organization may lead to vertical integration if there is an increase of asset specificity. The transaction cost theory leaves little room for trust in relations of legally independent but mutually dependent firms, as pointed out by Granovetter, among others. Governing the commons theory (e.g. governing shared knowledge in external value chain relationships) argues on the basis of empirical material that it is possible to learn trust and establish institutions for sharing the commons. Ostrom identifies elements in a mechanism that has the potential for creating such institutions. The resource based network theory is also based on the development of trust between firms, and on combining resources to increase competitiveness. As in the case of the McEvily and Marcus model of the acquisition of competitive capabilities, trust and information sharing is to some extent conceptualized as underpinning the modified value shop model. Grabher’s network theory identifies “loose couplings” as one characteristic of successful networks; and as a result one might expect the exchange of knowledge to be subject to limitations. According to the authors of the co-creating value concept, it is more a question of what knowledge should be shared. They also address questions such as who extracts the value from

the new efficiencies; who bears the burden of learning multiple systems; and who owns intellectual property that is co-created through collaboration.

A relative shift from firms to value chains as the unit of production and competition requires a pervasive horizontalisation of vertical modes of organization both inside and between firms when it comes to creating knowledge that is conceived of as embedded and as taking place in the value shop interface (joint problem solving mechanism) between the two studied knowledge-intensive firms. Furthermore, it is expected that the system will be more central than the lifeworld in the knowledge flow between the studied firms. The flow of technical knowledge can be studied at the operation level, where technical problems are solved, whereas one can expect to study strategic knowledge at the management level. Systemic knowledge is found in an intermediate position between technical and strategic knowledge.

The following research questions are designed to elaborate on the main question of “how to explain and understand knowledge creation in value chain relationships of knowledge intensive firms”:

- How is technical knowledge developed and transformed in the relationship?
- What stimulates and what hinders knowledge creation and innovation activity?
- What strategic implications can be envisaged for the relationship?

Answering the first question involves the connection of empirical data to how technical problems are solved in the interface between the two companies according to the joint problem solving mechanism, and by a widely defined usage of the different knowledge typologies, the lifeworld system and different rationalities, and the community terms. The second research question is analysed by connecting the concepts of functional bilateral dependence and reciprocal dependence to the joint problem solution mechanism. The idea of complementary resources and knowledge is associated with the different network theories, and the term of strategic knowledge has a central place in the analysis. Transaction cost analysis – in particular the aspect of asset specificity – and the theory of the commons form the point of departure for the analysis of the third question as well as the discussion of different options for organizing the studied pattern of value creation in the future.

#### Data sources and methodology

The main sources of data are personal interviews with key professionals directly involved in the interaction between the two companies at different levels and in different functions, covering market and strategic issues, software development and purchasing. A total number of 10 interviews were conducted, including one group interview with three respondents. The primary data was gathered in 2009; however, some data gathered in 2008 from the CCTV supplier also informs the study. Secondary sources found on the Internet, plus brochures and similar materials, were used to complement the interviews and to gain a better understanding of the technological specificities of the cases.

The reliability of the data may differ in quality between the two companies. Unfortunately, it was not possible to gather all the desired data from the drilling supplier. A group interview was conducted with a technological manager, a middle manager of the CCTV and a software developer of the CCTV interface, but follow-up questions were declined due to work pressure. Moreover, the attempt to approach employees from the purchasing department with questions was unsuccessful. This may be related to the applied strategic knowledge in the company, which is analyzed later. Seen from the company perspective and the perspective of associated strategic knowledge it is understandable that the respondents are reluctant discuss every strategic question related to their business. The companies were invited to comment on the first draft of the paper and some of the data was removed based on feedback from the drilling supplier. However, the deleted information was not crucially important for the main findings. In terms of the validity of the data, this case is one of analytical generalization (Yin

1989), which means that it is a study in which questions of how and why can be explored in depth based on the theoretically informed case study. In this respect it represents a partial test of the theory, and may serve as a basis for modifying it. The more instances of a theory being confirmed/proven useful, the stronger its claim. Herein lies the contribution of theoretically informed case studies.

The interviews aimed to capture the conditions and dynamic nature of the knowledge creation in the interface between the two studied companies. A semi-structured scheme with open questions/themes enabled in-depth discussions along three lines of inquiry: (1) the nature of the technological challenge; (2) the attributes of the relationship seen from the perspective of the other company; and (3) the nature of the development and technical implementation work in the interface between the two companies. The following are examples of the questions asked: How are the software developers working, and how is their effort coordinated? Why does the CCTV supplier receive such a large number of contracts? How are the developers working to solve problems? How is knowledge maintained? How has the relationship developed? Which external and internal actors are involved in the development process?

On the basis of these interviews and the secondary sources of information, the project was broken down into concrete activities and analyzed in line with the framework described above. The findings are presented below under the headings of these concrete activities.

## VALUE CHAIN RELATIONSHIP IN THE OFFSHORE OIL AND GAS SUPPLY INDUSTRY

### Empirical setting

The studied supply chain relationship is between a company (Drilling-supplier) that supplies systems for remote control of offshore drilling operations and a supplier of CCTV systems (CCTV supplier). For most oil and gas projects, the supplier of the drilling control technology and equipment is a first-tier supplier and the CCTV supplier a second-tier supplier. The drilling supplier is a production unit in a large multinational company whose main office is located on a different continent. The CCTV supplier is owned by a smaller multinational company whose main office is located on the same continent. Both production units are examples of bought-up firms founded by entrepreneurs on the basis of an expanding regional market within oil and gas activities.

Drilling operations are in a process of becoming more and more automated, with what used to be high-risk operations now being conducted by joystick and keyboard from the relatively safe environment of a driller cabin. Moreover, whereas the operation of earlier versions of driller cabins involved a large number of switches, monitors and different cables, the trend is to increasingly integrate different systems, thus making it simpler for the drillers to overview and conduct operations from one platform. This is a core strategy for the drilling-supplier. The driving force behind the development is to improve the HSE (Health-Safety-Environment) record, but the efforts also imply rationalization. We are here dealing with a rather radical innovation that has developed in incremental steps since the 1980s. It amounts to a move away from a hazardous work environment towards much safer drilling operations offshore.

When drilling operations become increasingly automated and remote-controlled the demand for CCTV systems increases. The function of CCTVs is to assist the driller by providing a visual verification of situations while drilling and when problems occur. A core element in the CCTV supplier's product is explosion-proof camera stations certified to operate in rough climates and in environments where there is a danger of gas explosions. To indicate the scale,

a recently delivered order from a customer in the offshore oil and gas exploration industry included three interconnected CCTV systems, each of which involved almost 100 cameras.

The drilling supplier's core product (trademarked) is an integrated operation and control center for drilling operations such as roughneck, top drive, pumping, drawback and logging data, from which CCTV control is also conducted by the same human management interface (HMI). Control centers and driller cabins are pre-manufactured by the drilling-supplier. A drilling cabin contains one or more control centers depending on the level of automation on the rigs involved. A control center can be compared to a business-class seat on a long-distance flight, but with keyboard and joystick attached to the armrests and with monitors in front of the seat.

The CCTV supplier delivers integrated systems for CCTV, including both hardware and software. CCTV is further integrated by the drilling supplier into the structure design of derricks and other structures and cabinets that fit the driller supplier's standards and appearance. However, the integration of software controlling systems designed under the skin of a shared HMI is the most central operation.

### Problem solving and technical knowledge

The technological challenge in the relationship is to integrate the functionality of CCTV control with a number of functions related to drilling operations. Above all, this means integration on the level of software/electronics and hardware, but also to some extent less challenging integration in relation to mechanical features such as cabinets and steel structures. The drillers (end users) experience the supplied drilling control system as one integrated unit with a common human management interface (HMI), as they apply the same joystick and keyboard for all drilling and CCTV operations. Under the skin, however, the system is made up from different modules. One of these is supplied by the studied CCTV supplier, who supplies an integrated module including both software and hardware that is ready to communicate with the other drilling modules. In software terms the different modules log on to each other depending on the commands given by the driller, as mediated by joystick and keyboard. Moreover, the functionality is designed such that if the drilling part breaks down, the CCTV module is still running. Hence, in this sense it is also a stand-alone system.

There was a divide in the development towards the current standard of integration of the products around 2003. During interviews it emerged that at this point the customer-supplier relationship was perceived as troublesome. The technological interface of the two systems was primitive and characterized by crashes and low score on uptime. These problems constituted a source of mutual accusations, where each party blamed the other, according to a respondent. However, the two companies met and embarked on a path of development to solve the problems, a venture into which both parties invested great effort. The challenges are not solved once and for all, though, as the utilization of CCTV systems and the level of automation continue to increase. Greater demands put the technological systems under pressure. As mentioned in the empirical setting section, a recently supplied system included three interconnected CCTV systems. Each of the three systems had almost 100 CCTV cameras. In contrast, only a handful of cameras went into each such system not too long ago. According to our gathered information, when the electricity supply breaks down, which occurs from time to time, *“computers restart with different speed, and our computers are designed to reply very fast, but if 14 of our computers try to log on to the CCTV supplier computers simultaneously it ends up in crash. We need to queue computer requirements and accept somewhat prolonged response time and make our software routines less aggressive. The CCTV supplier has solved this challenge on his part”*.

When problems and challenges occur, a software developer from the CCTV supplier visits the drilling supplier's premises (one working day travel time). He sits down with a software

developer from the drilling supplier: *“we sit together and dig into the source code, making efforts to improve functionality or fix errors”*, which is an example of execution and evaluation in the joint problem solving mechanism. On this level it is confirmed that the collaboration is close and characterized by a free flow of knowledge (tacit, codified and different combinations). Brainstorming is applied in the joint problem solution to problem finding, solution and choice. Moreover, the CCTV supplier assists the drilling supplier in factory acceptance tests (FAT), in which the different systems are connected and tested for the drilling supplier’s up-stream customer. The CCTV supplier provides supports on the connection part and is present if required during the FAT in case problems should occur. The gathered information indicates that these two kinds of close collaboration are rather frequent, and that the physical presence is also supplemented by communication by e-mail and telephone.

The data indicates that the drilling supplier has experienced a higher turnover of software developers than the CCTV supplier. The key CCTV person has cooperated with 3-4 different developers from the drilling supplier, and it seems that the drilling supplier benefits from the stability in this sense of the CCTV partner. In effect, the CCTV supplier’s developer informally assists his counterpart somewhat at the micro level, in relation to the source code in the interface between the different systems. This, and other similar aspects, is what constitute the free flow of knowledge and information in the collaboration on the development/implementation level, and where joint problem solving takes place.

Furthermore, during the customizing of software in the interface between the two parties we can identify a situation characterized by reciprocal interdependence, which is coordinated by mutual adjustment (sitting together) when the software developers from the two companies meet to solve problems, which confirms the intense technology aspect of the modified value shop concept applied in the prescribed joint problem solving mechanism.

When the software developers from the two companies meet, the framework is the system made up of the interests of the two companies and of formal organizational structures. However, the lifeworld and communicative rationality can also be identified in the micro development situation, where knowledge is exchanged and flows across the formal boundaries between the two companies, where discussions take place, improvements are suggested, disagreements settled and agreements made. The development manager of the CCTV supplier confirms that social skills (the capability to collaborate) are as important as engineering skills in their recruiting policy.

On the software developing level no common community of practice across the two companies was identified, but especially for the CCTV supplier the Internet was cited as an important source for new ideas: *“I use quite a bit of my spare time to search the Internet for new ideas and innovations, and attend lectures offered on the WEB on topical themes. Ideas and know-how are brought back to work.”* The drilling supplier interviewees emphasized the importance of learning by doing and the mixture of senior and junior professionals in their knowledge development: *“We are working with this every day, and if I have problems I ask...”*

In each company information is, moreover, diffused more generally from sales to the rest of the organization and meetings with customers and their own agents are also sources of information about new applications and such in the market – these being examples where the system and the lifeworld are intertwined in concrete knowledge. Epistemic communities were not identified as playing any crucial role. However, during their early development phase the CCTV supplier had some support from a regional university, and the company is at present involved in collaboration with the university by offering problem proposals students can use for their master’s theses, and by participating in a reference group for a master’s degree program in industrial management. The drilling supplier is performing research courtesy of a

regional research body, although not in the CCTV field. To sustain and improve their knowledge, from time to time the development department invites external resource persons to give a seminar for a small number of people (4-5).

Most software development is based on making adjustments to some basic modules of source code including input data, transformation of data and output of data, where testing for errors also plays a major role. Source code is written in some standardized logical language which can be compiled to issue computer instructions; hence we are dealing with the transforming of technical knowledge into codified knowledge. However, as suggested above, there is also a certain measure of practical tacit knowledge related to such programming, such as why a certain change was made and what qualities associated with a given procedure created instability. This amounts to contextual knowledge of a kind that may be vital to problem solving. A software developer in the studied business benefits from technical knowledge related to electronics, PLC, instrumentation, automation and cybernetics<sup>7</sup>, which in the studied relationship are identified as basic skills together with mechanical engineering and hydraulics.

A major function of the software development is to establish communication between the human interface and electro motors that generate power to move cameras, operate pumps, and so forth (PLC-programming<sup>8</sup>), but also to collect data from sensors of different kinds and transform it into meaningful human information. In human management interfaces (HMIs) we can identify organizational routines and procedures that arrange the context of technical information; hence we are dealing with systemic knowledge. Moreover, it has been confirmed that as systems grow and complexity increases, tacit knowledge about the software history is significant in order to understand the present applications, as is practical experience in the knowledge field. From this we can interpret further that the production of knowledge primarily takes place through applying and combining existing knowledge in new ways, thus resulting in new human-made functional systems, as exemplified with the software development described above. This means that we are dealing with a synthetic mode of knowledge production.

#### A closer look at the relationship

The growth of business between the two studied companies has shown a very significant increase in recent years. From 2004 to 2008 sales increased 50 times (nominal value). The drilling supplier explains this in part by pointing to the rise of many similar orders from their customers. CCTV systems are a more and more important part of the drilling supplier's product for the reasons explained above, and the drilling supplier confirms the good reputation enjoyed by the CCTV supplier in the market. Serious technical problems had made the social relationships between the firms increasingly difficult when a joint strategic problem solving approach was initiated in 2003. This was the starting point for the development towards the current level of business and trust.

According to the drilling supplier, the strength of the CCTV supplier is the ability to deliver both software and hardware, as well as the fact that the CCTV staff possess the competence to answer technological questions. This is in harmony with the CCTV supplier staff's own assessment of the company's competitive strength, namely the ability to deliver integrated solutions so that there is no question as to who is responsible if errors occur. An element of this is also their strategy of in-house control of core technology including the integration solutions in the interface between CCTV and associated technologies and drilling functionalities.

According to gathered data, the studied CCTV supplier's competitors are less vertically integrated and thus more dependent on sourcing knowledge and components to put together turnkey CCTV systems. The consequence is that they do not always possess the deep insight

into their product that is required to answer the customer's technical questions, meaning that it is often necessary to involve up-stream suppliers in the CCTV supply chain. From this we can derive that sourcing CCTV systems from competitors of the studied company is associated with higher risk for the buyers due to the fragmented knowledge on the supplying side. This is so because when problems occur it is crucial for operations in the oil and gas industry that problems be solved quickly as production losses have large-scale consequences. Furthermore, in terms of upgrading existing drilling systems (after market), the integrated solutions offered by the studied CCTV supplier are an advantage for the drilling supplier, also because it requires less resources from the drilling supplier to adapt new CCTV systems as an integrated element of the turnkey drilling system. Moreover, in the view of informants from the CCTV supplier, their documentation efforts create added value for the drilling supplier, whose customers demand strict documentation. The drilling supplier is regarded as a very important customer by the CCTV supplier, and the consensus among the CCTV supplier's staff is that no efforts are spared to meet the drilling supplier's needs.

In contrast, interviewees among the drilling supplier's staff regard the CCTV supplier as a supplier on the same level as other suppliers, and declare that *"the relationship cannot be characterized as partnership"*. *"We cannot be locked in to one supplier and some of our customers have preferences when it comes to which CCTV supplier to select"*. In particular when it comes to market for upgrading existing systems, customers may insist on using a particular CCTV supplier, according to the respondent. The source code for the CCTV controller and viewer is the property of the drilling supplier. In the data above we can identify that the drilling supplier interviewees emphasize the importance of keeping a "loose coupling" to the CCTV supplier, thus confirming Grabher's network theory.

Based on the volume and growth of business there is little doubt that the CCTV supplier is regarded as a lead/strategic supplier.

The gathered data, however, does not confirm the strategic formulation found on the drilling supplier's open web-page: *"In the past, larger concerns were able to pressure their sub-contractors on their own terms, but today the industry demands a totally different approach. We are first and foremost very dependent on them – the symbiosis is completely essential. Pushing and persuading suppliers into giving us things on our terms no longer functions. Now the suppliers feel that they mean something and that we can make it work together. It is very liberating to have alternative tools available– we need to make sure that we have a good collaboration."*

The "strategic knowledge" found at the drilling supplier's indicates a mindset and business worldview where the emphasis is on loose coupling and keeping the suppliers "at arm's length", to adopt a phrase from the relevant literature.

Strategic knowledge frames the systemic and technical knowledge in Child's conceptualization, and we have seen above that problems involving technical and systemic knowledge are solved by very close collaboration when it comes to bits and bites on the software development level. Hence, at the drilling supplier's there appears to be some contradiction between the strategic worldview and the realities in terms of how problems are solved on the level of technical knowledge.

Confidential data, however, can be interpreted as the existence of a de facto relationship between the two companies that also at the strategic level that is too close for comfort for the drilling supplier, and certainly closer than the drilling supplier is happy to publicly admit. Why information about a closer cooperation is perceived as unfortunate is not explained by the collected data beyond the fact that the analysis shows a discrepancy between the business worldview and the actual cooperation at the levels of technical innovation and implementation. Another possible explanation might be that strategic guidance is provided by the overseas head office which is at odds with those solutions which necessarily emerge due

to the extremely intensive technology as uncovered in the studied interface of product technologies.

There is therefore reason to believe that trust in a positive sense is an element underlying the relationship also at the strategic level too, a conclusion which is also supported by joint problem solving theory. Findings indicate, moreover, that management-level communication in the area of technology and procurement between representatives of the drilling supplier and the CCTV supplier part take place in a positive atmosphere. According to an informant from the CCTV supplier, "*The communication is friendly and informal, as it tends to be when you have much to do with a person over a long period of time.*" This is worldview in action.

Applying the perspective of the network theories related to collaboration and problem solving to our case, we can identify that the drilling supplier is strongly dependent on the CCTV supplier, to such an extent that collaboration can be regarded almost as necessary (reciprocal interdependence) for their main product, or at least to the extent that collaboration brings great benefits through reduction of uncertainty and risk. However, the relationship is one of bilateral dependence, as the orders from the drilling supplier represent a significant proportion of the CCTV supplier's turnover.

CCTV systems are highly complementary to the drilling systems, which are conceived as different systems, and we can identify the exchange of complementary resources in the new "value creating purchasing" described above. However, some of the skills and knowledge related to software development are similar and overlapping as they call for the same resources and capabilities to combine resources to be effected.<sup>9</sup> According to the resource based network theory, activities are complementary when they represent different phases in a production process that is seen as a chain of sequential activities. But, as analyzed above, what we are dealing with here are reciprocally interdependent activities across firm boundaries, which is a more complex matter calling for mutual adjustment in coordination. This may explain why the two companies best solve development challenges by sitting down together to find solution to technical and systemic problems in the integrated drilling system.

### Strategic implications

The technical and systemic knowledge provided by the CCTV supplier, particularly as developed since 2003, represents significant human asset specificity in the relationship. The stability of software developers on the supplier's side adds to this. While the key personnel at the drilling suppliers showed no awareness of the technical problem solving history during interviews, their counterparts at the CCTV suppliers were able to recount the history of the past decade. According to transaction cost economics, human asset specificity arises in a learning-by-doing fashion. This also captures a main point observed in the studied relationship.

We are dealing with a hybrid mode of organization. According to the TCA-theory, this may give way to vertical integration as the assets build up. The data indicates that CCTV systems are becoming increasingly important in drilling systems to control operations. Nevertheless, vertical integration is not considered very likely, for example because it involves greater risk and reduced flexibility in relation to market fluctuations, and not least because it might reduce the innovation dynamics of the CCTV supplier, who also supplies other customers and is committed to active innovation. Another option might be that the drilling supplier considers acquiring in-house CCTV competence or – still in the transaction perspective – attempts to develop a competitor to the studied CCTV supplier up to a comparative level of skill and integration.

The opposite strategy for the drilling supplier would be to consider interaction instead of transaction and to develop the relationship in direction of co-creating value and some kind of partnership. This would mean handling knowledge and the ongoing incremental steps of

innovation as common knowledge, and building an institutional framework inspired by the thoughts in governing the commons theory. To achieve this, the drilling supplier would need to replace the current transaction-oriented strategic knowledge.

## CONCLUSION

The purpose of this paper is to help increase our understanding of knowledge development, innovation and the pooling of resources in the interface between knowledge intensive, legally autonomous firms. The case study is based on two firms in a representative dyadic relationship. Their resources are combined in such a way that the activities of each firm are found reciprocally interdependent in terms of implementation on technical level. This is particularly evident in the solving of problems related to the design of software that interacts within a shared HMI, in which the system undergoes continuous development with regard to functionality and an increasing number of system components. In this sense, finding new ways of combining resources is an ongoing, continuous process. The organization of the activities of the two firms seems to represent a break with Stinchcombe and Heimer's decoupling principle in project administration given that the interface involves technologically detailed mutual dependence, but at the same time the resources of the firms in the dyadic case represent specialized and complementary areas of competence. The challenge lies in the integration of these competences in unique installation projects.

The paper deals with innovations that can be interpreted as rather radical, but that have evolved in incremental steps since the 1980s. The resulting innovations have turned what used to be dangerous drilling operations into largely automated processes, making them much safer as a consequence. Rationalization is also a driving force behind this innovation process. CCTV systems used for control and operation purposes play a vital and increasingly important part in this development, where the challenges include an extreme climate and the impending risk of gas explosions.

Technical and systemic knowledge is developed both internally and in the interface between the two studied firms. The principal party in the relationship seems to benefit significantly from the CCTV supplier's competence in the areas of problem solution and development work in the interface between the CCTV system and the overall control module, and strong horizontal forces were found to be in play. The underlying mechanism is triggered by the reciprocal interdependency on a very detailed operative knowledge-intensive level between the two firms. The data indicates that the collaboration on this level crosses the formal boundaries between the firms, such as when a software developer from the CCTV supplier helps solve problems in the customer's source code – an example of communicative rationality and the lifeworld. The system is the dominant factor in the relationship, however.

The nature of the product and service delivered by the CCTV supplier to the drilling supplier is crucial in order to understand the close collaboration and interaction on the technical problem-solving level. The nature of the technical problem solving is characterized by strong reciprocal dependency, complexity and continual changes in functional requirements and development (incremental innovation) for both parties. This constitutes a mechanism calling for collaboration and mutual adjustment on the level of technical and systemic knowledge. A factor that puts limitations on the collaboration appears to be the principal's dominant strategy of keeping suppliers "at arm's length" and taking a transactional rather than an interactive view of the relationship (strategic knowledge).

The technical and systemic knowledge provided by the CCTV supplier and in particular as this has developed since 2003 represents significant human asset specificity in the relationship. The employee stability of the software developers in the CCTV firm adds to this.

We are dealing with a hybrid mode of organization, but this could give way to vertical integration as the specific assets build up, according to the transaction cost theory. The data indicates that CCTV systems are becoming increasingly important in drilling systems for the purpose of controlling operations. Nevertheless, vertical integration is not considered a likely option, as it for example involves greater risk and reduced flexibility in relation to market fluctuations, and not least because it might reduce the innovation dynamics of the CCTV supplier, who also supplies other customers and is committed to active innovation. Another option might be that the drilling supplier considers acquiring in-house CCTV competence or – still in the transaction perspective – makes efforts to develop a competitor to the studied CCTV supplier up to a comparative level of skill and integration. A very different strategy for the parties might be to consider interaction instead of transaction with the aim of developing the relationship in the direction of co-creating value and some kind of partnership, where knowledge and the ongoing incremental steps of innovation would be handled as common knowledge enabling the construction of an institutional framework inspired by the thinking behind governing the commons theory. To achieve this, the drilling supplier would need to replace the current transaction-oriented business world view with one whereby business relations are regarded as amalgams of contracts and trust dependent upon mutual orientations. In terms of technical implications, Child's distinction between technical, systemic and strategic knowledge has been central in providing a framework of knowledge for the empirical analysis of the studied relation. Moreover, Habermas's systems and lifeworld theory was used to lend substance to a deeper understanding of the social interaction on a detailed level. A modified value shop concept was used in order to explain the dynamics of the joint problem solving in the interface between the two studied firms. This theory was originally developed for the strategic development of knowledge in firms where the value chain modelling of value creation is insufficient, but here it is applied at a detailed level and across two different firms. Value is created through the contributions of different experts – in this case from two firms – to problem solving in relation to the same object in loops that include identifying problems, technical solutions, choices, and assessment. The basis for this understanding is the underlying reciprocal interdependence of activities across the two firms, an interdependence that calls for mutual coordination. This is the key to explaining why the principal company in the relationship accepts and benefits greatly from close cooperation even though this seems to represent a strategy the company is not entirely comfortable with: the agent is supposed to be kept at arm's length.

In the case study, joint problem solving is implemented in order to achieve integrated solutions, as described. When technology is at its most intensive, software developers from the two companies sit down together to solve problems. These processes include a stream of smaller loops, such as adjusting a variable, testing and assessing, making new adjustments, and so on. The modified value shop concept is used together with McEvily and Marcus's model of acquisition of competitive capabilities in embedded ties between firms, according to which joint problem solving is built on trust and sharing of information. A necessary level of trust and sharing of information is a precondition for problem solving in the modified value shop model as well. However, here the problem solving mechanism is also examined in detail regarding the previously described loops; moreover, the related concepts of the coordination mode and the intensive technology term based on Thompson are also taken into consideration. Child's concept of knowledge has been vital in analyzing the empirical finding that the cooperation at the operations level is not reflected at a strategic level in the relation. The existence of differences in relations at different levels hardly constitutes news in the organizational literature. For instance, Burgelman (2005) has developed a processual model of internal corporate venturing according to which the development of knowledge and experience at the operations level moves upward after several processual steps in the

hierarchy to reach the level of strategies. However, the process of integrating experiences made at the operations level may be a lengthy one when the company leadership are located on a different continent and issue their instructions for local strategic management in relation to procurement etc. on the basis of their business worldview.

The transaction cost theory was used as an element in the overall analysis in order to shed light on the basic challenges to the principal-agent relationship connected to trust and the risk of opportunistic behaviour, and in relation to strategic implications where the TCA-theory's asset specificity and related question of vertical integration versus continued hybrid solution are central. The potential embedded in a management solution beyond the framework of understanding represented by TCA is to be found in the trust-based theory of governing the common – an area of study which remains to be explored in future research.

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<sup>1</sup> See for instance Thompson's (2003) notion of reciprocal interdependency.

<sup>2</sup> A flexible contracting mechanism could include regulations such as 1) contemplating unanticipated disturbances for which adaptations are needed, 2) providing a tolerance zone within which misalignment might be absorbed, 3) requiring the disclosure and substantiation of information if adaptation is proposed, and 4) providing for arbitration in the event of voluntary agreement failure.

<sup>3</sup> Ostrom and Williamson were both awarded the Nobel Memorial Prize in Economic Sciences in 2009.

<sup>4</sup> However, whereas the existing thinking on this topic distinguishes between value chains (value systems) and supply chains, these are treated as a single phenomenon in this paper (Askildsen and Kalsaas 2009).

<sup>5</sup> This is, however, not unique for the non-socioeconomic tradition, and the authors refer to Porter (1985) who conceptualizes a firm in the same way. But whereas Porter puts the primary emphasis on the singular company, network theory emphasizes the network of firms.

<sup>6</sup> Pooled interdependency is a third type in Thompson's typology for complex organizations, and is described as a situation in which each party makes a discrete contribution to the whole, and in which each is supported by the whole. The mode of coordination for pooled interdependency is standardization. Pooled interdependency is found in all complex organizations.

<sup>7</sup> Cybernetics refers to the science in which communication and control systems in electronic and mechanical devices are studied and compared with those in biological systems. It is related to artificial intelligence.

<sup>8</sup> PLC is short for Programmable Logic Controller, which is an electronic device used for machine control.

<sup>9</sup> In another case including a supplier of drilling equipment for land based systems, the studied CCTV supplier developed the software for both drilling functionality and CCTV. Land based systems are however, smaller and less complex compared to the offshore installations studied in this article.