13 COMPETENCE-BASED EVOLUTION OF R&D RELATIONSHIPS

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Abstract

This paper addresses the mutual evolution of ***competencies*** *and* ***interorganizational relationships*** *by using a longitudinal case study approach. The empirical phenomena that we investigate involve professional research and development services offered by VTT Electronics, a contract research organization. Within this context, we are interested in the relationships of one of the focal organization's research groups. We use as an example the research and development of fault diagnosis systems, computers embedded in various kinds of electronic products to perform real-time condition monitoring. Evolution of the fault diagnosis research and development relationships between VTT Electronics and its research partners and customers is analyzed and explained from the 1980s eighties to the present date by using an* ***R&D competence networking framework****. The analysis, which is mainly based on written case data, addresses both the basic characteristics of the fault diagnosis research and development competence and the effects of competence changes in the focal organization's relationships. The purpose of the analysis is explanatory: we wish to know how and why competence-based* *evolution of contractual R&D relationships took place. However, the key managerial implications of the analysis will also be discussed at the end of the paper.*

Keywords: Core competence, R&D relationships, fault diagnosis systems.

Introduction

Several theoretical and empirical studies have shown that collaboration with external partners is a valuable means for industrial organizations to foster innovation and improve the use of their resources. These studies have identified many kinds of potential collaboration partners capable of contributing to the development of the resources of the focal organization (Alajoutsijärvi and Tikkanen 1998; Håkansson 1987, Hamel and Prahalad 1994). Focusing on a contract research organization, we will analyze competence-based evolution of contractual research and development (R&D) relationships. Our research is a longitudinal case study, concerning VTT Electronics and its predecessor, VTT Computer Technology Laboratory, which are both later referred to as ELE. The viewpoint of the study is explanatory: we simply wish to understand better the complex phenomena involved in contractual research and development of industrial computer and information systems. Yet, this paper also includes the key managerial implications of our case analysis. We will explain, by using a *competence networking framework,* the evolution of ELE's fault diagnosis related R&D relationships from the late 1980s to the present date.

Competence Development in Industrial Networks

Elaborating the Concept of Competence

Since the publication of the article by Prahalad and Hamel (1990), the concept of competence has attracted a great deal of attention. According to Hamel and Prahalad, *competence* is "a bundle of skills and technologies rather than a single discrete skill or technology." Competence, at a general level, refers to knowledge and skills needed to choose what task to perform as well as why and how to perform the chosen task. The *content* of competence, i.e., the knowledge and skills related to a certain task, is thus important. The content of competence is typically divided into technological and managerial components. A more theoretical typology is presented by Sanchez (1995). Sanchez, Heene and Thomas (1996) view *capabilities* as "repeatable patterns of action in the use of assets to create, produce and/or offer products to a market." A *skill* is "a special form of capability, with the connotation of a rather specific capability useful in a specialized situation or related to the use of a specialized asset." In this research, we view capabilities and skills as building elements of competencies. Depending on *institutionalization*, competencies may involve individuals or different kinds of organizational groups. Firms as a whole can also be interpreted to have certain competencies, and some competence is generic, i.e., publicly available and used by many different parties.

An important issue in understanding competence is the level of *codification*: competence may be tacit or codified (Sanchez 1995). Tacit or implicit skills and capabilities are not articulated. They can be diffused only slowly in face-to-face situations and to a limited audience, under the conditions of trust and shared experience. Codified competence, in contrast, can be transmitted much more rapidly and impersonally to larger audiences. By definition, generic competence is well-articulated, while tacitness is typical to individual skills and capabilities.

Views to Interorganizational Relationships

Many researchers of industrial relationships have highlighted the interacting parties' motivational investments in the relationship and perception of the developing expectations, trust, satisfaction, and commitment (Dwyer, Schurr and Oh 1987; Wilson and Mummalaneni 1986). Another view to interorganizational relationships is provided by researchers examining the governance structures of dyadic relationships. Based primarily on transaction cost economics (Williamson 1985) and on the organizational dependence theory (Pfeffer and Salancik 1978), researchers have shown how exchange conditions influence the nature of the exchange. Within the industrial marketing and purchasing (IMP) group and based primarily on the resource interdependency notion, Campbell (1985) and Möller and Wilson (1995) have subscribed to the contingency of business relationships. Compared to the rather deterministic transaction cost analysis inspired work, this research assumes a more enacted view of the relationships.

A well-known conceptualization of the evolution of industrial relationships is presented in Ford, Håkansson and Johansson (1986). In this classic article, they argue that an intercompany relationship is basically ambiguous rather than clear cut. They propose four interrelated factors to characterize changes of relationships: capability, mutuality, particularity, and inconsistency. *Capability* describes the relationship between the interacting parties, be they organizations or individuals, in terms of what they can do for each other by using their resources. *Mutuality* is a measure of how much an organization is prepared to give up its goals or intentions in order to increase its own ultimate well-being. *Particularity* characterizes the relationship in terms of its direction and uniqueness, whereas *inconsistency* refers to the ambiguity or lack of clarity. The relationship can be inconsistent, for example, due to changes of the interacting people over time.

Integration of the competence and relationship perspectives is perhaps most apparent in studies of the role of resources in industrial relationships, although such studies a still rather rare. Easton and Araujo (1996) claim "the possibilities for the use of a specific resource can never be fully specified," but suggest that the ARA (activity-resource-actor) model (Håkansson and Snehota 1995) would be used to articulate what types of actors and resources exist and how their different configurations affect relationship structures and processes. We have taken the ARA model as a starting point in our research. Since the model is one of the most widely used and discussed conceptual frameworks of industrial relationships, we only summarize its main characteristics here. According to Håkansson and Snehota, three layers of the "substance" of a relationship can be identified by *activities, resources,* and *actors*. The effects of a relationship based on these three concepts are called “functions.” They can be identified for an individual firm, for a dyadic relationship, and for a network of several parties. At the level of a firm, *activity structures*, *resource collections*, and *organizational structures* can be formed. At the relationship level there exist *activity links*, *resource ties*, and *actor bonds*. Networks consist of *activity patterns*, *resource constellations*, and *webs of actors*. When the functions are put together at the three levels, a framework consisting of activities, resources, and actors vs. firms, relationships and networks is achieved. From the viewpoint of one company, the main problem is how to balance these functions to maintain its relationships.

Research Method And Case

We have chosen a longitudinal, explanatory case study approach in this research, because a profound understanding of the development of industrial relationships and competencies involves examining and understanding them as they are or were in real life. One of the most important issues in a case study is access to data. We have used both public and corporate archives, as well as the personal R&D diaries of the key actors. The research data has been validated both by method and informant triangulation, i.e., by comparing the data acquired with the help of different methods and by cross-checking the data given by different informants.

VTT Electronics, the case organization of this study, offers *contractual R&D services* in the field of electronics. The services of ELE cover a wide range of electronic technologies from microelectronics to computer, software. The engineering skills mastered by the institute include, correspondingly, a variety of electronics, computer and information systems techniques. In addition to electronics firms, ELE deals with companies that use electronics only as a supporting product technology. Within ELE, we address research and development of the so called *fault diagnosis systems* used in different kinds of electronic products to monitor and diagnose the condition of the product and to help to recover from errors. One of the main technologies used to implement fault diagnosis systems at ELE has been *embedded software*, computer programs incorporated in dedicated hardware. Moreover, ELE has used extensively the so called *knowledge engineering (KE) techniques*, a special area of information systems engineering techniques, in the development of fault diagnosis systems.

One of ELE’s research groups is specialized in these techniques and their industrial applications. Almost all of the group’s R&D activities are carried out as projects. Strategic research, *“green” projects,* is financed mostly by ELE itself and meant to build certain organizational competencies. Other projects are financed jointly by public funding bodies, ELE, and its industrial partners. The purpose of these *“blue” projects* is the further development and preliminary deployment of competencies. *“Red” projects* are carried out for and financed by individual customer companies or sometimes for consortia of several companies.

Competence Networking Framework

Substance of Research and Development

We use a specific framework to understand and explain competence-based evolution of R&D relationships. The framework, which is organized around the ARA model, consists of two layers. One of the layers that is used to describe the basic elements of contractual research and development is called the *substance layer* (cf. Håkansson and Snehota 1995; see Table 1). The firm, relationship, and network levels form the *focal net* dimension of the substance layer (Håkansson and Snehota 1995; Rosenbröijer 1998). At the substance layer, we are interested in the *types of elements* that exist, their main characteristics, alias *attributes* (Easton and Araujo 1996), and how they relate to each other. We use typologies to define classes and types of elements and values to define their attributes.

We have modified and extended the resource typology of Rosenbröijer and associated it with the typologies of R&D activities, actors, and relationships, as shown in Table 2. R&D skills and capabilities are the main resources utilized in the case organization's relationships. At the level of individuals, the possession of some expert skills is required to solve R&D problems. Physical resources are simply thought to be either products, documents, or development tools. Temporal resources are missing from the typology used in Rosenbröijer, although they are crucial in project-based research and development. The basic types of temporal resources planned for and controlled in projects—schedules, efforts, and calendar time—are therefore included in our typology. Project management is one of the most important organizational resources of contractual research and development, and professional reputation is a resource that is used, for example, when initiating relationships. Financial resources are almost always exchanged in contractual activities that involve external parties.

Table 1. The Substance Layer of the Framework

Focal net/ Substance	**Firm**	**Relationships**	**Networks**
Competencies			
Activities	*Activity structures: e.g., green project*	*Activity links: e.g., red project*	*Activity patterns: e.g., blue project*
Resources	*Resource collections: e.g., system design skills*	*Resource ties: e.g., an industrial fault diagnosis system*	*Resource constellations: e.g., joint system development tools*
Actors			
Parties	*Organizational structures: e.g., research group*	*Actor bonds: e.g., joint project team*	*Actor webs: e.g., joint project team*

Table 2. Typology of R&D Competence Elements

ELEMENTS	Classes	Types	Attributes
COMPETENCIES			
Resource			Relations, Time
	Human	Expertise	Application, Function, Technique, Technology, Maturity, Value
	Technological	R&D Service	Application, Function, Technique, Technology, Maturity, Value
		Product	Application, Function, Technique, Technology, Maturity, Value
		Document	Task, Existence, Value
		Tool	Task, Existence, Value
	Temporal	Calendar time	Time
		Time-table	Schedule
		Effort	Volume
	Financial	Expense	Value, Task, Actor
		Income	Value, Task, Actor
	Organizational	Management System	Type
	Reputation	Professional reputation	Reputation
Activity			Relations, Time Tasks, Value
	Human	Learning, Doing, Management, Evaluation	
	Technological	Tracking, Acquisition, Planning, Use, Transfer, Integration, Evaluation	
	Physical	Tracking, Acquisition, Use, Transfer Integration, Evaluation	
	Temporal	Planning, Use, Evaluation	
	Financial	Planning, Use, Evaluation	
	Organizational	Project management	
	Reputation	Professional appearance	

Attributes of different types of resources are also shown in Table 2 in order to make explicit the main characteristics of competencies. The existence of certain types of elements and the values of their attributes depend on time, which must also be made explicit. We focus on technical competence, i.e., the content of the services provided by ELE. It is characterized by the *application* domain involved, the *functions* accomplished by the product, the *techniques* on which the functions are based, and the *technologies* used to realize the product (cf. Abell 1980).

Activities are needed to take care of acquiring different types of resources; planning for, carrying out, evaluating, and utilizing the results of the R&D services; supporting individuals in developing and extending their expertise; taking care of project management; planning and controlling of financial matters; following general technical developments; and acting as a member of the professional R&D community.

Actors can be typed according to their level of aggregation that spans from individuals and teams to whole organizations (Seppänen, Alajoutsijärvi and Kurki 1998). In addition to the firm, relationship, and network levels of the focal net, there exist single transactions, such as meetings, events that take place in a short time when compared to longer-term relationships. The most important attributes by which we characterize relationships of the focal R&D net are the four variables proposed by Ford, Håkansson and Johansson: capability, mutuality, particularity, and inconsistency.

Management of Changes in the Focal Net

The management layer of the framework makes explicit how and why the focal net changes over time. In particular, we try to explain how the focal organization's competence affects the evolution of its external relationships. The basic types of changes that may occur in the focal net are rather simple: starting and ending of a relationship or a network, changing of a relationship to a network, and vice versa (Figure 1). However, these changes become much more complex when considering the control of resource exchange and sharing between the parties. In the case of ELE, the portfolio of green, blue, and red projects affects the ownership of resources being acquired or developed. Changes of the focal net must therefore be analyzed in terms of the three types of projects.

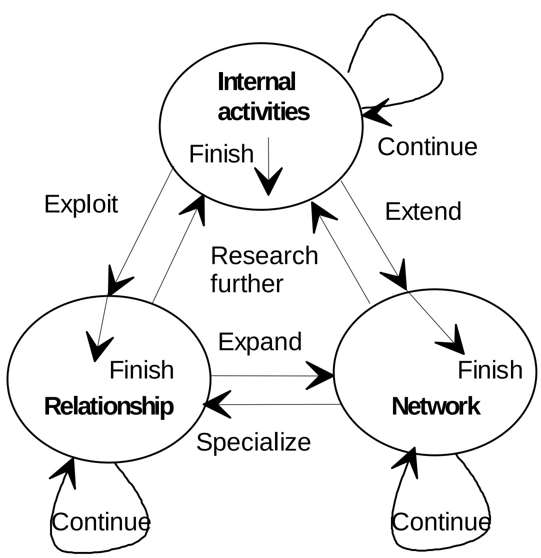

Figure 1. Changes in Contractual R&D Relationships

We use the four relationship attributes based on Ford, Håkansson and Johansson to explain competence-based changes of relationships. Table 3 shows how the attributes affect each other, with examples of the corresponding characteristics of the substance layer elements. Based on these interrelationships, four processes to manage the change of relationships can be identified (cf. Alajoutsijärvi and Tikkanen 1998). *"Balancing of the particularity of resources"* concerns the question about the extent to which the focal organization should tailor its resources towards relationships with particular counterparts. Because of the risks involved in the lack or excess of particularity, organizations must be concerned about the extent to which the mutuality of their activities is related to the particularity of their resources. We call the corresponding managerial process *"balancing of the mutuality of activities."* The management of inconsistencies involves *"assuring the desired level of capability"* and *"assuring the desired level of mutuality."* Having a desired level of capability concerns, for example, the development of skills among those individuals in the organization who take part in certain relationships. Assuring the desired level of mutuality is concerned with learning of the interacting persons. For example, inexperienced persons may be allocated to projects in which application-specific knowledge plays a central role.

Table 3. Interrelationships Between Relationship Attributes

Attributes	Particularity	Inconsistency
Capability	(1) Example: specialization in a certain customer application	(2) Example: only a few people possess knowledge of a technology important to many customers
Mutuality	(3) Example: a contractual consortium concerning a certain technology or technique	(4) Example: inexperience in the development of a customer's application

One of the key ideas of our framework is that changes in relationships can be associated with competence via the above mentioned four management processes (see Figure 2). The desired level of particularity (relationship-specificity vs. generality) of the organization's resources and mutuality (tailoring vs. generality) of its activities are maintained by these processes. Particularity of a resource depends on its codification, so that implicit resources are usually relationship-specific and explicitly coded resources generic. Mutuality of an activity depends on the institutionalization of the resource on which the activity is performed; personal tasks are usually more mutually oriented than organizational activities. The content of a resource affects its capability, but the content's effect on particularity and mutuality depend on its *life cycle*. We have borrowed the concept of a dominant design for defining the life cycle of the content of a resource (Uusitalo 1995). A simplified life cycle consists of incremental changes, discontinuity, substitution, competition, and dominance (arrow C in Figure 2).

Competence management involves activities that affect the content, codification and institutionalization of resources. Management of the particularity of the organization's resources and the mutuality of its activities is thus required. This can divided into five distinct processes (cf. Boisot 1994): problem-solving, diffusion, absorption, scanning and life-cycle management. *Problem-solving* refers to the process of codifying and giving a structure to tacit knowledge possessed by certain actors (direction A in

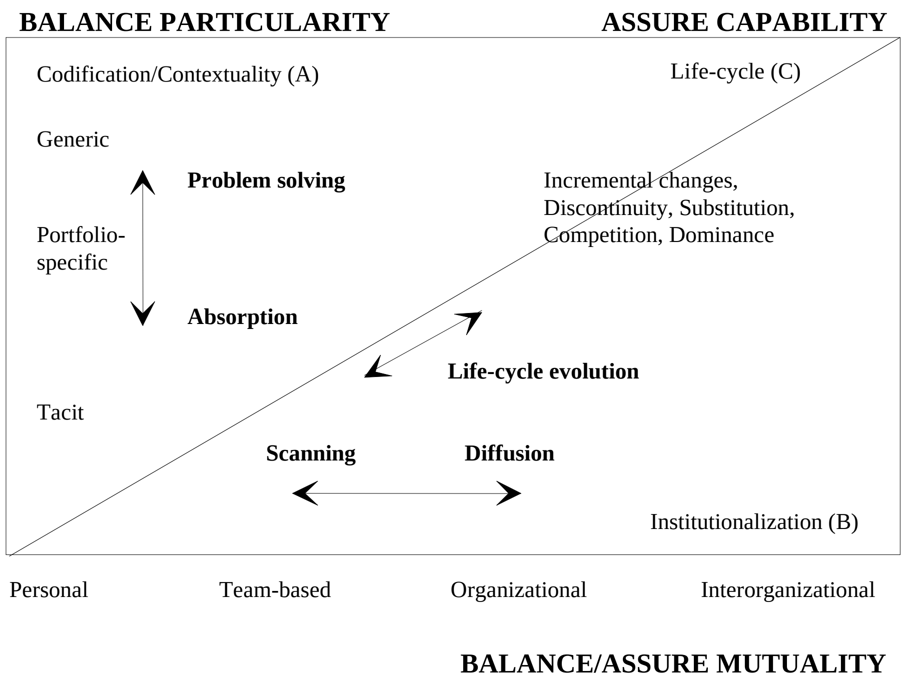

Figure 2. Management of Competence-based Evolution of R&D Relationships

Figure 2). However, this kind of codification always sheds tacit knowledge, because the transmitters consciously or unconsciously know more than they can ever say. *Absorptio*n is the process of applying the codified knowledge to different situations in a "learning by doing" or "learning by using" fashion (reversed direction A in Figure 2). *Diffusion* refers to the sharing of insights or institutionalization of knowledge within a larger community (direction B in Figure 2), *scanning* refers to the identification of the threats and opportunities that exist but are hidden in some data (reversed direction B in Figure 2).

The Case of Fault Diagnosis R&D

We will focus below on the analysis of the evolution of ELE's fault diagnosis related project relationships, based on changes in its technical competence. The use of the substance layer of the framework for modeling the elements of the fault diagnosis competence and relationships is discussed in Seppänen, Alajoutsijärvi and Kurki. We will omit it from this paper.

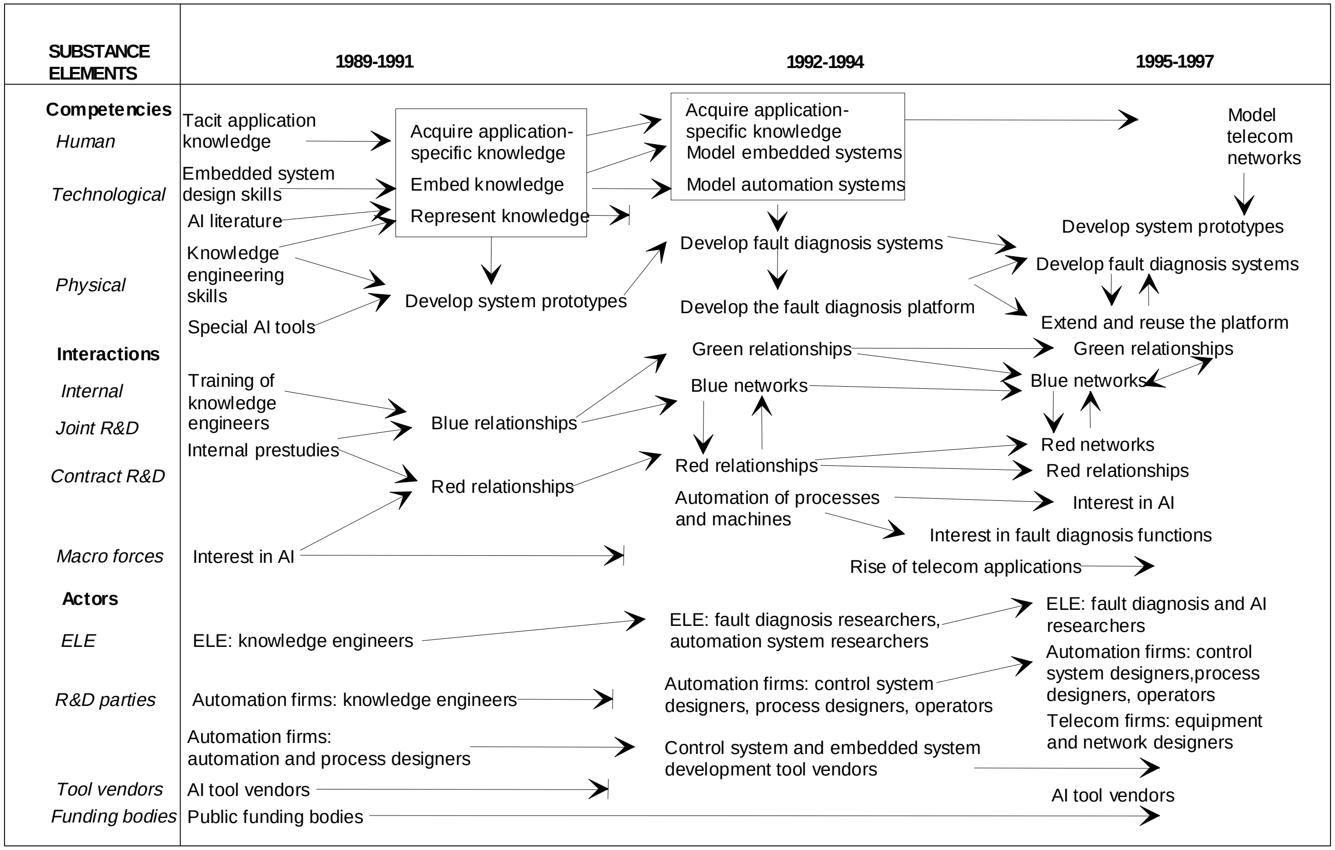

Figure 3. Competence-based Evolution of Fault Diagnosis Relationships

Figure 3 summarizes the changes that took place in the R&D fault diagnosis relationships during the past 10 years by showing the main elements of the competence and the focal nets that were involved. Relations between the events shown in the figure are depicted by dashed arrows. The finishing of a relationship is indicated by an arrow that ends with a cross-line. Critical relationship changes and change management processes will be explained and discussed in this section by using the concepts of the management layer of the framework.

1989–1991

Fault diagnosis was considered at ELE as one possible problem area to deploy knowledge engineering techniques. Much of the related knowledge was explicitly coded and generic. Relationships were established with knowledge engineers working in process and machine automation companies, which resulted in the combination of the generic knowledge with the formerly tacit application knowledge ("expertise"). The relationships were established for the acquisition of application knowledge and for the joint deployment of knowledge engineering skills, rather than for the deployment of fault diagnosis knowledge. ELE's personnel were neither closely associated with the customers' automation engineers nor with end users (machine operators). Knowledge of the implementation technologies of automation systems was less important; the so-called expert system technologies, including special development tools, were emphasized instead. These technologies were believed to win the competence of future information systems, i.e., to become the dominant paradigm of the nineties.

ELE's initial skills in fault diagnosis of automation applications were built *within* external relationships, mostly in red customer projects. Skill creation *for* relationships included studying different generic knowledge engineering techniques. The financial importance of the fault diagnosis projects, in terms of their volume, was rather low. ELE's own R&D investments were also modest, basically literature surveys for scanning new generic knowledge. As far as ELE was concerned, the relationships had at the same time a high degree of mutuality and particularity (cf. cell 3 in Table 3). ELE aimed at assuring a certain level of capability in knowledge engineering techniques and in some special implementation technologies.

1992–1994

In terms of Table 3, relationships stayed in cell 3, the degree of mutuality and particularity of ELE's relationships remained high. However, ELE's capability moved toward a wider engineering area in which the knowledge engineering techniques were used in a supporting role, rather than as a dominating element of competence. ELE's fault diagnosis capabilities had clearly diffused into the team-based level, from the skills of individual researchers.

The increased number of distinct projects meant that ELE was still busily absorbing its skills, but had not yet reached the problem solving level of explicit competence management. However, the rather wide combination of skills in automation applications, computer system modeling and knowledge engineering techniques may have created a barrier toward competitors—at least the customers themselves—to exploit the fault diagnosis knowledge that was made explicit.

The knowledge of automation applications, fault diagnosis functions, and implementation technologies that had been made explicit can be considered as portfolio-specific. This knowledge started to dominate subsequent project relationships and the further competence building activities. Skills in knowledge engineering techniques became incorporated into skills in computer system modeling techniques.

Certain skills, such as “embedding” of knowledge-based systems into electronic products, vanished together with the special tools used to develop prototypes of knowledge-based systems. These special tools became obsolete as the consequence of a technological discontinuity and were substituted by other kinds of engineering tools.

Most of the project relationships with industrial knowledge engineers ended. Public funding bodies were still not deeply involved, in terms of financing joint blue projects. This left room for ELE to continue carrying out red projects, so that industrial exploitation of the fault diagnosis competence was accelerated. The emerging portfolio-specific fault diagnosis competence helped ELE in the extension of its relationships, which in turn paved a road for competence building *for* relationships and increased the financial importance of the fault diagnosis projects. The first considerable internally funded green fault diagnosis projects were launched. By 1994, ELE was clearly moving away from cell 3 of Table 3.

1995–1997

A *fault diagnosis platform* emerged gradually as an explicit piece of core competence. Problem solving based on platform usage, extension, and management became important, in addition to absorption of the fault diagnosis competence in specific project relationships. The fault diagnosis competence was made explicit through a set of functions, in order to separate the platform from specific automation applications and their implementation technologies. A pool of knowledge engineering techniques was used to support these functions. It could be updated based on the life cycle of the techniques. For example, there was a rapid increase of interest in fuzzy logic in Finland during the early 1990s and this technique was taken in use in several fault diagnosis projects.

Generic computer system modeling techniques were used to link fault diagnosis functions to applications and implementation technologies. End users became involved in some projects where operator-assisted fault explanation and recovery functions were developed. This resulted in an increasing emphasis of user interface and usage support technologies.

The financial importance of the fault diagnosis projects still increased. They had become a backbone of the knowledge engineering research group.

A new project on telecommunication network diagnosis was marketed and planned, based on the idea of specializing the existing competence for a new application domain. From a relationship evolution perspective, ELE wished to exploit its existing competence for establishing new customer relationships. A red project network consisting of a group of equipment manufacturers was created. However, the customers of these firms, telecommunication operators, were not involved. A funding body was involved indirectly, by financing the participating firms. In the context of this project, ELE's mutuality and particularity were rather low and inconsistency high, because of the lack of knowledge of the application. The knowledge appeared to be highly tacit, and problems arose even concerning the notations in which it should be made explicit, not to speak of the content itself. Knowledge of a new technique, case-based reasoning (CBR), which was applied in the project, was generic, available through the literature, and supported by certain development tools. Yet, it was difficult to apply it into a complex application, the kinds of models produced earlier for automation applications were not feasible. Although ELE had aimed at an incremental extension of its fault diagnosis competence, it fell back into the early substitution state: fighting against the presently dominant network diagnosis solutions.

Discussion

We have presented a framework to explain competence-based evolution of R&D relationships, as well as to study the processes for managing the evolution. The substance layer of the framework is based on the ARA model, according to which competence is viewed as activities performed on certain resources. The management layer of the framework describes how relationships change over time due to the focus on different elements of competence. The framework was used to analyze the fault diagnosis case (Table 4).

Several life cycle phases, a few years each, could be identified in the case data. The first and the most recent phases were strongly affected by similar kinds of macro forces: interest in generic knowledge engineering techniques. In between, the ELE was developing and applying its fault diagnosis skills and capabilities mainly within fully contractual red projects carried out for industrial automation firms. One of the macro forces that helped to extend and expand relationships in this phase was the increasing interest in automation of processes and machines.

The fault diagnosis platform, an explicitly codified portfolio-specific piece of competence, resulted from carrying out several subsequent contractual projects, in which knowledge-based techniques were applied to develop fault diagnosis functions for automation systems. The emergence of telecommunication applications in the late 1990s seemed to offer an excellent opportunity for expanding both customer relationships and the core fault diagnosis competence. The difficulties that were encountered in this new domain were mostly due to the problems of understanding and making explicit tacit application-specific knowledge in a fully contractual consortium project in which new knowledge engineering techniques were also expected to be taken in use.

The overall evolution of the content of the fault diagnosis competence at ELE proceeded from knowledge engineering techniques via understanding the core functions and the whole problem solving process to new applications. Different technologies were used as implementation means in each phase. Generic techniques were useful especially in the first phase, but their dominance corrupted rather rapidly because of their common availability and the fall of special system development tools. At the beginning, the knowledge engineering skills of ELE depended largely on these tools. Focus on fault diagnosis functions helped ELE to build its competence to a more sound portfolio-specific basis. Dealing with a completely new application domain appeared to be very

Table 4. Summary of the Evolution of Fault Diagnosis Relationships of ELE

Period	**Focal R&D Net**	**Partners**	**Key Competence Elements**
1986-88	(informal)		Knowledge engineering techniques
1989-91	R&D projects, interaction of knowledge engineering experts	Process and machine automation firms	Knowledge engineering techniques, special tools, modeling of embedded systems
1992-94	R&D projects, interaction of diagnosis and automation experts	Machine automation firms, R&D partners (funding bodies)	Fault diagnosis functions, skills in automation applications, knowledge engineering and embedded system modeling techniques
1995-97	R&D projects, interaction of diagnosis and application experts (and end-users)	Automation and telecommunication firms, funding bodies	Fault diagnosis platform, knowledge, usage and embedded system modeling techniques

difficult, although the functional fault diagnosis platform was already available. Technology, as a means of implementing fault diagnosis functions, was not unimportant, but did not play any central role in any specific phase either. This is certainly an interesting finding, although it does not mean that technological skills are unnecessary in fault diagnosis research and development.

Technology transfer from green to red project relationships via blue networks is not obvious at all in the fault diagnosis case. In fact, the evolution of the competence was largely a reversed process. As an example, almost no self-funded green fault diagnosis research projects were carried out until the mid-1990s, so that the fault diagnosis platform emerged mostly as a spin-off of fully contractual red projects. The fault diagnosis case also indicates that the development and exploitation of the competence was a highly concurrent process. There was no clear distinction between the two phases, as opposed to the view of Sanchez and Thomas (1996).

Aiming at core platforms means mass-customized R&D, in which the organization takes advantage of its existing competencies, while simultaneously being active in the development of new capabilities. Reaching that state depends on both how the organization and its customers view and develop their relationships and how their competencies match and evolve:

- in an early phase of contractual R&D, it is often based on skills in new or incrementally improved technologies, or on the understanding of some generic techniques not yet fully applied to solve certain problems or not yet implemented as commercial technologies, whereas

- competence seems to "mature" to core platforms based on the understanding of functions that solve some problem for certain types of applications.

This would mean that the increase in the maturity of contract research and development builds on the top of technologies and generic techniques, but depends critically on portfolio-specific functional skills and capabilities. The organization must be cautious when extending the portfolio-specific competence by seeking new applications because of the tacitness of the application knowledge. In this process, technologies and generic techniques are used more as a means of ensuring technical ways that are flexible enough for solving problems than as competencies per se.

In the opinion of Gallon, Stillman and Coates (1995), capabilities in techniques and technologies would be *primary*, whereas functional capabilities would be *critical*. Knowledge of customers' applications and end-user needs would be either critical or primary, depending on the importance of a specific customer account. The case of the network diagnosis project shows the criticality of such knowledge when trying to extend portfolio-specific competence.

In order to manage an appropriate focus on competence, the organization would need to carry out its strategic and operational planning based on which new elements should be incorporated into the contents of its competencies *within* the current relationships, to pave a road *for* new relationships. Table 5 illustrates such planning by showing some possible new elements of the fault diagnosis competence of ELE.

Lowendahl (1997) uses the dimensions of strategic focus and resource base to assess the position of professional service firms (Table 6). The diagonal of this positioning consists of A, B, and C types of firms. On one dimension, the resource base of a firm can be controlled by the organization as a whole, independently by the professionals themselves, or as a mixture of the two approaches. Along the other dimension, a strategic focus on specific customers or customer groups aims at continuing interaction. Problem solving based strategies involve a high degree of innovation. Solution or output based strategies seek to extend markets for uniform services.

Contrary to Lowendahl and based on the experience gained from the fault diagnosis case, we believe that it would be beneficial for a contract research organization to be "stuck-in-the-middle" with core platforms, in order to be flexible enough in its R&D relationships and efficient enough in managing its competencies.

Table 5. Planning for the Content of Competence

Fault diagnosis competence	**New applications**	**New functions**	**New techniques**	**New technologies**
1998-1999	Electronics assembly lines (manufacturing firms)	Data mining, optimization	Neural networks, genetic algorithms	Assembly automation, neural network tools, databases
2000-2001	Intelligent appliances (instrument firms)	Explanation, visualization	Usability engineering, multimedia engineering	Smart user interfaces, vrtrual reality, Web, Internet

Table 6. Positioning of Professional Service Firms (Lowendahl 1997)

Strategic focus/ Resource base	**Client Relations**	**Creative Problem Solving**	**Adaptation of Ready Solutions**
Organizationally controlled resources	(D) Insufficient adaptiveness	* → ↓	(B) Efficient
Team-based, individual and collective resources	* → ↓	(C) Both	↑ ← *
Individually controlled resources	(A) Flexible (Effective)	↑ ← *	(E) Lack of coordination, discipline

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