FERDINAND JASPERS

# Organizing Systemic Innovation

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**Het Organiseren van Systemische Innovatie**

Proefschrift

ter verkrijging van de graad van doctor
aan de Erasmus Universiteit Rotterdam
op gezag van de rector magnificus
Prof.dr. S.W.J. Lamberts
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op
donderdag 12 februari 2009 om 13.30 uur

door
**Ferdinand Pieter Hugo Jaspers**
geboren te Breda

ERASMUS UNIVERSITEIT ROTTERDAM

Promotor(en):
Prof.dr.ir. J.C.M. van den Ende

Overige leden:
Prof.dr. G.M. Duysters
Prof.dr. W. Hulsink
Prof.dr. S.L. van de Velde

**Erasmus Research Institute of Management – ERIM**
**Rotterdam School of Management (RSM)**
**Erasmus School of Economics (ESE)**
Erasmus University Rotterdam
Internet: http://www.erim.eur.nl

**ERIM Electronic Series Portal:** http://hdl.handle.net/1765/1

**ERIM PhD Series in Research in Management**, 160
Reference number ERIM: EPS-2009-160-ORG
ISBN 978-90-5892-197-0


**Design:** B&T Ontwerp en advies www.b-en-t.nl
**Print:** Haveka www.haveka.nl

Voor Liesbeth, Vera en Seline

# Preface

On the cover of this thesis you find a wonderful specimen of a barite crystal. It has emerged on top of a landscape of goethite, which is clearly visible inside the transparent crystal. The crystal and the goethite landscape are tightly coupled, which means that the crystal cannot be easily removed or modified without affecting its platform. Similarly, tightly-coupled product components cannot be improved without changes to other components. This change of interdependent components is labelled systemic innovation.

Whereas mineral crystals emerge from naturally evolving processes, firms require a wide range of organizational capabilities to successfully develop new products. These capabilities for instance involve resolving technical problems, collaborating with other firms, learning new technologies, and coordinating systemic changes. More specifically, I argue in this thesis that firms require specific configurations of these capabilities. In other words, the performance of new product development is determined jointly by the firm's capabilities. Similarly, the beauty of the barite crystal is the result of a unique arrangement of molecules that are themselves a specific configuration of different atoms, i.e. barium sulfate ($BaSO_4$). Furthermore, the crystal's goethite intrusion is a perfect metaphor for my conviction that organizational configurations need to fit the rough and the multifaceted characteristics of innovations, such as their uncertainty and their systemic nature.

In this thesis I report the results of my research on the organization of systemic innovation. I started working on this thesis in February 2004. Next to my interest in the subject of this thesis, a main personal driver was to become better trained as an academic researcher. I certainly feel that I have achieved that aim, and I look forward to further develop the necessary skills in the future. Many people in my personal and in my professional life have supported me over the years. It's impossible to thank you all, but I do want to express some special words of thanks.

First of all, I would like to thank Jan van den Ende for giving me the opportunity to start a PhD project, and for supporting and guiding me throughout this intensive, but enjoyable process. I also would like to thank all my (former) colleagues from the department Management of Technology and Innovation, where I spent almost six unforgettable years. To name just a few pleasant memories: the IMP conference, the yearly retreat, the case study book, the countless soccer trophies, travelling abroad with many of you to attend conferences, chatting and joking with Carmen (mind you, I am still in the building!), carpooling with Wendy, chatting about the kids with my roommate Geerten, etc. I look forward to fruitful and pleasant partnerships in the future!

On the private side, I first of all would like to thank Fred for his warm friendship. You are sorely missed. Special thanks go to my parents, who have supported me greatly in so many ways. Finally, lieve Liesbeth, thank you for being such a great partner in life and for being such a wonderful mother to Vera and Seline, our two little sunshines.

# Contents

# List of Figures

# List of Tables

# 1. Introduction

## 1.1 Systemic Innovation

In 2007 the largest passenger airplane ever built, the Airbus A380, made its first commercial flight. The development of this superjumbo was delayed by several years however. A major source of delay involved problems with the cabin wiring. After test-flights revealed the need to adapt several parts of the airplane, many wire bundles had to be modified or had to be replaced altogether. This was a very costly and an extremely time-consuming process, since the cabin contains more than 100,000 wires with a total length of 500 kilometers. In 2008, the parent company of Airbus, EADS (the European Aeronautic Defence and Space Company), had to announce for the fourth time a delay in the delivery schedule of the A380. Estimations are that the delays will cost EADS an additional five billion Euros. This example perfectly illustrates a fundamental characteristic of many new product development efforts, namely that different parts of a product are highly interdependent, and that a change in one part of a product therefore demands changes to one or more other parts. In the literature this is referred to as *systemic innovation* (Teece, 1984; De Laat, 1999; Maula et al., 2006).

Systemic innovation is the norm rather than the exception for many firms developing new products and services. This is especially true for complex product systems, such as airplanes, Formula 1 cars, oil refineries, etc. These products consist of a large number of components that are based on a wide variety of technologies. For these products it is critical that all of its components combine into a coherent whole. As illustrated by the example of the Airbus A380, products can simply fail if two of its components are misaligned and it can result in huge delays and extra costs. Besides complex products, systemic innovation and the need for a coherent product design is characteristic just as well for most ‘plain’ products and services, including software, automobiles, drugs, and mobile phones. Furthermore, systemic innovations have become more prominent in recent times as a result of rapid technological progress and the combination of multiple technologies in new products. The integration of Internet technology and mobile telecommunications, for instance, has resulted in more complex mobile networks and applications, e.g. mobile payment services and location-based multi-player games.

Given its prevalence, the management and organization of systemic innovation involves a critical capability for innovating firms. This capability can be referred to as *systems integration* (Brusoni et al., 2001; Prencipe et al., 2003; Hobday et al., 2005). Systems integration involves a firm’s capability to design and develop a coherent product and to align the efforts of those responsible for the development of individual components, such as internal units or divisions, joint ventures, outside suppliers. Effective systems integration is difficult to realize however, as it builds upon a multitude of interrelated organizational capabilities.

For instance, innovating firms require a detailed understanding of their products. This not just involves knowledge about the individual technologies that are embedded in their products, but also knowledge about how technologies and components interrelate, i.e. how they operate together and how they depend on each other. This knowledge is needed to develop a coherent product and to understand the systemic implications of changes. Furthermore, to improve the understanding of component interrelationships and also to align activities effectively, intense coordination is needed between those responsible for the development of interdependent components. Hence, learning and coordination are important elements of a firm's systems integration capability.

Especially for complex and entirely new products it will be very difficult however to fully understand the details of individual components, let alone how they interrelate. Consequently, such development efforts are likely to be confronted with technical problems, for instance as result of difficulties with component interfaces. The management of systemic innovation therefore also pertains to the capability of firms to generate and implement solutions for problems affecting multiple parts of the product, such as problems with the design of the Airbus A380.

A complicating factor in the management of systemic innovation is that processes of learning, coordination, and problem-solving are likely to span the boundary of the innovating firm. Few firms are able to design and develop new products completely internally. In order to succeed they have no choice but to exploit as much as possible the capabilities of external actors, such as suppliers, users, alliance partners, and universities. This practice of Open Innovation (Chesbrough, 2003) makes it more difficult however to divide and monitor tasks, to align interests, and to coordinate changes, thus increasing the complexity of systems integration.

In sum, systemic innovation is a fundamental characteristic of new product development. In order to successfully initiate, respond to, and complete systemic innovation processes firms need a wide range of organizational capabilities that together can be labelled 'systems integration'. Prior studies have generated substantial knowledge in this area, but opportunities exist to further improve our understanding of this important organizational capability. This thesis takes several steps to seize some of these opportunities. Before we discuss in greater detail the objective of this thesis and its contributions, the next section first of all positions this thesis in the innovation literature and delimits its scope.

## 1.2 Defining innovation

In today's society change is ubiquitous and pervasive, be it social, economic, political, or technological. Innovation is both a major driver of change and an important means to adapt to changes. Innovation has to do with 'something new,' such as new ideas, new technologies, new products, new processes, or new ways of organizing. Innovation is an important driver of economic growth and has a strong influence on social welfare. Because of the important role that innovation plays in many parts of society, innovation is being studied by different scientific disciplines, such as economics, psychology, marketing, engineering, and sociology. Each discipline has its own perspective and assumptions, which makes innovation difficult to define (Gopalakrishnan and Damanpour, 1997). To identify different areas of innovation research and to define innovation, Gopalakrishnan and Damanpour (1997) distinguish three primary dimensions to conceptualize innovation:

(1) the type of innovation; (2) the stage of the innovation process; (3) and the level of analysis. These dimensions are very useful to position this thesis.

***Types of innovation***

First of all, innovations can be categorized into several contrasting types. Two common dichotomies of types of innovation are product versus process innovation and radical versus incremental innovation (Gopalakrishnan and Damanpour, 1997). Product innovations involve new products or services that are introduced in the market for the benefit of customers, whereas process innovations pertain to new ways of producing these products and services, for instance by transforming inputs using new tools and devices. This thesis only considers product innovation.

Products are typically product systems that are structured as 'nested hierarchies' (Simon, 1962), i.e. as systems of subsystems that are themselves also composed of subsystems, etc. The mobile phone is for instance composed of a display, an antenna, a battery, and a computer chip, but the mobile phone is itself also a subsystem of the larger mobile telecommunications system, which also consists of base stations, switches, user databases, billing systems, etc. Hence, what to consider a system, a subsystem, or a component is a matter of definition. Unlike many studies, this thesis provides clear definitions of our unit of analysis. The failure to provide such definitions hampers the accumulation of knowledge in the field of innovation management, because it complicates the comparison of findings (Gatignon et al., 2002). The development of a product system is for instance a different task than the development of a new component.

Besides components and subsystems, product systems also comprise linkage or interface technologies that enable components to interoperate. Examples are telecommunication protocols and other communication standards, but also physical interfaces, such as those determined by the size and shape of components, determine the joint performance of components. New products, new components, and new interfaces each have their own technological trajectory and can vary considerably in terms of their novelty (Tushman and Nelson, 1990; Brusoni et al., 2001; Van den Ende, 2003). Incremental innovations involve only minor adjustments and changes and/or result in only limited performance improvements. In contrast, radical innovations are completely new, possibly even new-to-the-world (e.g. Ehrnberg, 1995; Levinthal, 1998; Gatignon et al., 2002).

In the context of product systems, a further distinction can be made between autonomous innovations and systemic innovations (Teece, 1984; Chesbrough and Teece, 1996). *Autonomous innovations* are stand-alone innovations of individual components or subsystems that have no implications for other parts of the system. In this case the interfaces that specify how components interrelate are reinforced. A fine example of autonomous innovation is provided by modular products, such as PCs. In this context existing modules, e.g. hard disk drives, chips, monitors, and peripheral devices, can often be replaced by new modules without fundamentally affecting the many other parts of the system (e.g. Baldwin and Clark, 1997; Schilling, 2000).

Unlike autonomous innovations, *systemic innovations* have an effect on multiple parts of a system or even on the entire system (Teece, 1984; De Laat, 1999; Maula et al., 2006).

Most new products start as integral products with highly interdependent components. This means that the change of one single component demands substantial changes to a large number of other components, i.e. more than one component changes as part of this innovation. The design and development of a new product is therefore typically a systemic innovation process. Whereas products tend to become more modular over time, few products become perfectly modular. As a result, the improvement of existing products is likely to be a systemic innovation process too.

Furthermore, even in a perfectly modular product system, a component change can demand changes to other components even if interfaces are unaffected. The development of a new and advanced software application may for instance require the development and implementation of a new computer chip to make sure that the application performs as intended. In this example the product's technical interfaces remain intact in spite of the systemic 'imbalance' (Rosenberg, 1976; Brusoni et al., 2001) that results from the component change. In specific cases, systemic innovations reinforce the technological underpinnings of a product's components, but change the interfaces between these components. A classic example of such an 'architectural innovation' involves the reconfiguration of a ceiling-mounted room fan into a portable fan (Henderson and Clark, 1990). Here, the size and the shape of components change, as well as their positioning in the product system, but their technological foundations are unaffected. In this thesis we explicitly consider the novelty and the systemic nature of product innovations.

***Stages of the innovation process***

Secondly, the innovation process consists of several stages, most notably that of generation and adoption (Gopalakrishnan and Damanpour, 1997). Innovations are first of all generated, i.e. an idea has to be generated and then turned into a new product. Next, this innovation has to be brought to the market and needs to be adopted and implemented by its prospective users. This thesis is primarily concerned with the development process to turn an idea into a new product.

Gerwin (2006, p.2) describes the new product development process as follows: *"[it] is a process that usually starts with knowledge of technological or market opportunities. Strategic choices defining what is to be developed are made in the upstream phase of the process, while the downstream phase, which absorbs the bulk of committed resources, involves detailed design and testing. The process ends with a new product, service, or some combination, ready for full scale operations and distribution. It may be used as part of a higher level system such as an aircraft, it may be sold to customers, or it may serve both purposes"*. In a systemic context, the development of a new component may not only involve the design and development of the component itself, but also the change of interrelated components.

***Levels of analysis***

Finally, innovation is studied at different levels of analysis, such as the industry level, the organization level, and the organization subunit level (Gopalakrishnan and Damanpour, 1997; Gupta et al., 2007). Research at the industry level for instance focuses on differences between industries, e.g. in terms of R&D expenditures or technology and product life-cycles. At the organizational level of analysis, research typically focuses on the innovativeness of organizations either as an independent variable, e.g. innovativeness as a predictor of organizational effectiveness, or as a dependent variable, e.g. innovativeness as a result of competitive intensity or organizational structure.

Research on innovation within firms, i.e. the subunit level of analysis, studies topics like the innovation process in new product development (NPD) projects, or the innovation process within and between different departments, such as marketing, research & development, and manufacturing. The innovation process might also occur between firms, e.g. in alliances and networks. This thesis operates at this subunit level of analysis as it focuses on NPD projects within or between firms. Hence, in light of the three abovementioned dimensions, this thesis defines innovation as *the development of products within or between firms*. In this definition 'product' can refer to product systems, product subsystems, or product components, depending on the adopted level of analysis. Furthermore, product development will more often than not pertain to systemic innovation.

**1.3 Research objective**

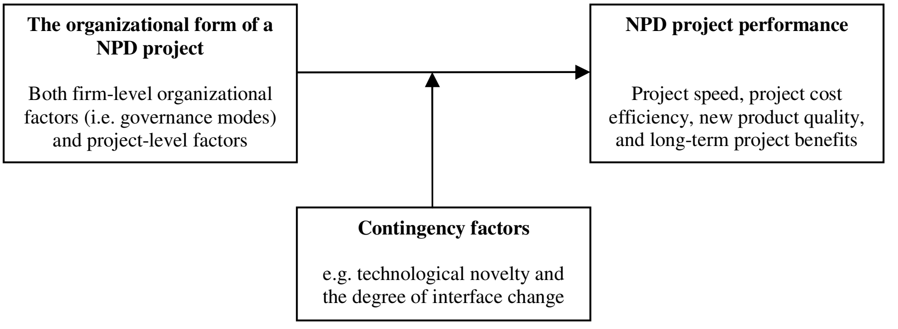
Any new product development effort faces inherent commercial and technical risks and it can therefore be no surprise that NPD is plagued by high failure rates (Tidd and Bodley, 2002). This seems especially true for the development of complex product systems, which involves many different components and technologies that are highly interrelated. In spite of its inherent risks, the development of new products and services can lead to superior financial performance when a firm is consistently more successful at NPD than its competitors (Dougherty, 1992; Tidd, 2000; Danneels, 2002). A wealth of research therefore exists on success factors for NPD (e.g. Brown and Eisenhardt, 1995; Montoya-Weiss and Calantone, 1995; Henard and Szymanski, 2001; Van der Panne et al., 2003). In trying to explain the performance of new products, these studies distinguish between different groups of success factors, such as product characteristics, market characteristics, firm characteristics, and organizational characteristics of the NPD process. This latter aspect of NPD - broadly defined - is the focus of this thesis, i.e. this thesis fits into the field of research that investigates how firms organize and manage NPD projects.

Tidd and Bodley (2002, p.128) state the following about this field of research: "*Much research on the management of innovation attempts to identify some "best-practice"… However, there is unlikely to be "one best way" to manage and organize product development as industries differ in terms of sources of innovation and the technological and market opportunity, and organization-specific characteristics are likely to undermine the notion of universal formula for successful innovation.*" In line with this view prior literature has reached no consensus about any particular organizational form as a universal success factor for NPD (Van der Panne et al., 2003). Since different types of innovation present different challenges, it can be expected that different approaches are demanded to organize NPD projects (e.g. Langerak et al., 2000).

Based on the above discussion, the objective of this thesis can be formulated as follows: *the objective of this thesis is to increase our understanding of the organization of systemic innovation, i.e. systems integration, by building and testing theory about how the performance of new product development projects can be explained by their organizational forms and how this depends on the characteristics of the innovation.* Figure

1.1 illustrates the general conceptual model that is implied by this objective. In this section we discuss this objective and its various parts in some greater detail. This provides the foundations for a more detailed discussion in the next section of the specific contributions that we aim to make.

**Figure 1.1 General conceptual model**




First of all, it becomes clear from Figure 1.1 that the performance of NPD projects is the dependent concept in this thesis, i.e. this is ultimately what we aim to explain. The performance of NPD projects has multiple dimensions (e.g. Tatikonda and Montoya-Weiss, 2001; Kessler and Bierly, 2002; Sheremata, 2000). Most notably, NPD is assessed in terms of project speed (the time it takes from idea generation to product launch), project cost efficiency (the financial resources required to develop a new product), and the quality of the new product (the extent that the innovation is technologically advanced or the extent that it meets user needs).

Strong trade-offs may exist between speed, quality, and cost efficiency (e.g. Sheremata, 2000; Eisenhardt and Tabrizi, 1995; Bayus et al., 1997). An increased emphasis on for instance new product quality might substantially increase the time and resources needed to complete projects. From the perspective of the firm, direct project outcomes may not be all-important though. Instead, a project might be especially valuable to the firm in terms of its long-term benefits. Projects can for instance result in valuable relationships with other actors, such as suppliers, users, or universities, and – regardless of the immediate product quality – a project may generate new technology or skills that increases the firm's innovativeness and competitiveness in the future (e.g. Danneels, 2002; Sobrero and Roberts, 2002). Furthermore, in the context of product systems, project performance may also refer to the coherence of the product system as a whole or to the extent that a new component fits in the larger product.

Secondly, Figure 1.1 demonstrates that a project's organizational form is our main independent concept, i.e. we are interested in its role as a determinant of project performance. As indicated in the previous section, innovation is essentially a multi-level phenomenon (e.g. Gupta et al., 2007). Reflecting this characteristic this thesis considers a project's organizational form at two levels of analysis. The first approach considers the organizational form *of* NPD projects or their 'governance modes' (Van den Ende, 2003). In this approach we adopt the perspective of systems integrators - firms responsible for the development and the integration of product systems - and we consider their involvement in product and component development projects. At one extreme, a systems integrator can completely integrate a development project (internal projects). At the other extreme, this firm can rely entirely on external actors (external projects). In between these extremes, the firm may share risks and divide tasks with other actors, such as universities, suppliers, or even competitors. In other words, this perspective deals with the boundary of the firm for NPD projects. The organizational form *of* a development project therefore considers a project's organizational form at the level of the firm.

The second approach focuses on the organizational form *within* projects, i.e. it investigates the structuring and the organization of the development processes that are executed within NPD projects. This project-level approach is closely related to the literature about NPD success factors (e.g. Brown and Eisenhardt, 1995; Montoya-Weiss and Calantone, 1995; Henard and Szymanski, 2001; Van der Panne et al., 2003). This literature for instance investigates the extent that project team members exchange information, the extent that they have authority over the way they perform their tasks, and the seniority of the manager in charge of the project.

Finally, as shown by Figure 1.1, we expect that the effects of a project's (firm-level and project-level) organizational form on project performance are contingent upon specific project characteristics. Previous studies have for instance pointed to the technological novelty of innovations and the degree of interface change as important contingency factors (e.g. Tidd, 2001). As pointed out in the previous section, both factors have a strong influence on the systemic nature of innovations. Now we have defined innovation and outlined the basic objective of this thesis, we will explain in the next section the specific contributions of this thesis.

## 1.4 Contributions

How do we aim to contribute to what we already know about the relationships outlined in Figure 1.1? What specific 'gaps' do we identify and address? Below we address these questions as we indicate the main contributions of this thesis.

***Multiple firm boundaries …***

First of all, this thesis aims to improve our understanding of the organization of innovation by conceptualizing the organizational form of NPD projects more accurately and more comprehensively than in prior studies. Inspired by transaction cost economics (Williamson, 1975; 1985), the dominant approach to conceptualize the (firm-level) organizational form of NPD projects is by means of only one concept: the degree of vertical integration. This concept refers to the boundary of the firm, i.e. make, buy, or ally, for the development of a new product (e.g. Pisano, 1990). However, the relationship between a firm and its environment is more complex than a legal demarcation in terms of ownership or a set of contractual specifications (Robertson and Langlois, 1995; Santos and Eisenhardt, 2005; Araujo et al., 2002). One way to further this field of research is therefore to forsake the simplicity of prior studies in favor of theories that conceptualize more accurately the multidimensional nature of the boundary of the firm. In this regard, an important first contribution of this thesis involves the conceptualization of the organizational form of NPD projects in terms of four 'dimensions of integration': ownership integration, coordination integration, task integration, and knowledge integration (see also Jaspers and Van den Ende, 2006). Although these four dimensions have been investigated - under different labels - in prior studies, to date they have not been considered in a single study. Below we briefly outline the four dimensions and position them in existing literature. We point out that these four dimensions are especially relevant in the context of systemic innovation.

First of all, we build on the distinction made by Robertson and Langlois (1995) between coordination integration and ownership integration as two distinct dimensions of vertical integration. The literature about vertical integration typically assumes that the organization of an activity, such as a NPD project, within the hierarchy and the legal boundary of the firm aligns interests as well as facilitates information exchange (e.g. Teece, 1984). Robertson and Langlois (1995), however, linked the alignment of interests and the exchange of information to two conceptually distinct, but related dimensions of vertical integration. *Ownership integration* reflects the firm's formal control over activities based on legal ownership. This dimension primarily serves to align interests and to alleviate appropriation concerns. Robertson and Langlois (1995) refer to *coordination integration* as the dimension of vertical integration that serves to resolve interdependencies and to achieve unity of effort by means of information exchange. Irrespective of their extent of ownership integration, Robertson and Langlois point out that different units, such as project teams, departments, and divisions, can be integrated in different degrees in terms of the extent of information exchange between them.

The distinction between ownership integration and coordination integration resonates with Richardson (1972), who proposed inter-firm cooperation (low ownership integration and high coordination integration) as an alternative for market-based coordination (low ownership integration and low coordination integration) and intra-firm coordination (high ownership integration and high coordination integration). Likewise, Gulati and Singh (1998) made a distinction between control mechanisms and coordination mechanisms for different types of strategic alliances. Furthermore, in the context of buyer-supplier relationships in NPD, Sobrero and Roberts (2002) made a similar distinction between the contractual characteristics of relationships and the extent of information transfer. Put differently, the boundary of the firm is not only about what is inside and what is outside the firm, it is also very much how the relationship between different actors is organized (Araujo et al., 2003), such as in terms of coordination (Takeishi, 2001).

The third and the fourth dimensions are inspired by the literature on systems integration. Focusing on systems integrators, Brusoni et al. (2001) made a distinction between the firm's production boundary and the firm's knowledge boundary (see also Fine and Whitney, 1996; Takeishi, 2002). The production boundary of the firm refers to the activities that the systems integrator performs internally. This is what we label the degree of *task integration*. With the increased involvement of for instance suppliers in NPD projects, ownership integration can be high, but task integration can at the same time be very low. A systems integrator might for instance fully finance a component development project, but the majority of the project tasks (e.g. the basic design of the new product or component, its detailed design, the actual development work, assembly activities, and product testing) might well be performed by suppliers.

As a fourth dimension, the knowledge boundary of the firm refers to the extent that a firm possesses a detailed understanding of a certain activity. This is what we label *knowledge integration*. In terms of a component development project, this for instance refers to the component's technological basis and to its interrelationships with other components. Whereas a systems integrator may outsource large parts of a component development project, they can still possess or develop deep knowledge about these outsourced activities (Brusoni et al., 2001; Takeishi, 2001). The degree of knowledge integration can therefore exceed the degree of task integration. Or put differently, firms might 'know more than they make' (Brusoni et al., 2001).

Because of the complexity of many products, systems integrators cannot develop every component internally (Hobday et al., 2005). By knowing more than they make, systems integrators are able to coordinate the network of specialized component and technology developers (Brusoni et al., 2001). In a narrow definition of the term, Brusoni et al. (2001) label this coordination mechanism 'systems integration'. They position it as a coordination mechanism in between the extremes of the market and the hierarchy. On the one hand, coordination by means of systems integration allows systems integrators to benefit from the incentives and the specialized capabilities of external component and technology developers, i.e. differentiation, which is typically associated with the market. On the other hand, based on their understanding of component technologies and component interrelationships, systems integrators are able to coordinate external actors, i.e. integration, which is typically associated with the hierarchy (Brusoni et al., 2001).

This definition of systems integration as a coordination mechanism in terms of differentiation and integration means that this concept goes to the heart of organization theory. The division of tasks, their allocation to different (specialized) units, and the activities to achieve unity of effort among them are central topics in organization theory. A key principle involves the reduction of task interdependence between units to delimit any systemic consequences of change (e.g. Thompson, 1967; Lawrence and Lorsch, 1967). This principle also holds for the partitioning of tasks in the innovation process (Von Hippel, 1990). Furthermore, integration and differentiation are not only relevant with respect to interdependence, they are also important determinants of a firm's capability to reduce uncertainty and to solve problems in the innovation process (e.g. Burns and Stalker, 1961; Sheremata, 2000). While originally studied within firms, issues of differentiation and integration are also key in an inter-firm context, such as for the design of strategic alliances (e.g. Gulati et al., 2005) and - of course - for the management of component developers by systems integrators (Brusoni et al., 2001). In sum, by disentangling these four dimensions of integration we are able to pinpoint more accurately and more comprehensively the fundamentals of the wide range of possible organizational forms.

***… and a configurational approach***

The second contribution of this thesis is that we use the abovementioned dimensions of integration as building blocks in the development of a configurational theory. Whereas most studies in management research consider the direct or the moderating effect of individual concepts, configurational theories consider the interplay of multiple explanatory concepts. In our case, this means that we conceptualize the organizational form of NPD projects as a configuration of the four dimensions of integration. More specifically, we propose that so-called 'ideal-typical configurations' of these dimensions contribute to the performance of NPD projects. Whereas configurational theories might be more accurate than the traditional 'variance theories' (Mohr, 1978) - in the sense that they come closer to the reality faced by practitioners (George and Bennett) - there is an inherent trade-off with another desirable feature of theories, namely their simplicity (Weick, 1979). Configurational theories are more complex, because they require the development of middle-range theories that explain for each ideal type how and why the internal consistency of this organizational form contributes to performance (e.g. Doty and Glick, 1994). Furthermore, the configurational approach recognizes the possibility of equifinality, which means that different configurations can result in the same outcome (von Bertalanffy, 1952; Katz and Kahn, 1966; Gresov and Drazin, 1997).

For three reasons we are of the opinion that the configurational approach offers a fruitful way forward for the field of innovation management. First, in the fields of organization theory and strategic management configurational theories have proven to result in insights that are highly complementary to the findings from studies that are primarily interested in the strength of individual direct effects (Short et al., 2008). The configurational approach has hardly been applied in the innovation management literature, but it holds great promise to develop more fine-grained theories and to provide more precise advice for managers (Tidd, 2001). Our study takes steps to fill this gap.

Secondly, empirical findings for the traditional type of theory have been inconsistent. Existing literature points to many factors that influence a firm's boundary with respect to NPD projects, such as the specificity of project investments, the interdependence of activities, the tacitness of the knowledge involved, the trust between firms, and the extent that the innovation destroys existing competences and routines (Tidd et al., 1997). These determinants come from a wide range of theories, including transaction cost economics (Williamson, 1985), information-processing theory (e.g. Tushman and Nadler, 1978), the knowledge-based view of the firm (Grant, 1996), and the literature about product modularity (e.g. Sanchez and Mahoney, 1996; Schilling, 2000).

Although it is widely recognized that multiple theories have to be considered to develop an understanding of the organization of innovation (e.g. Robertson and Langlois, 1995; Sobrero and Roberts, 2002; Takeishi, 2002; Gulati et al., 2005; Hoetker, 2005), many contrasting empirical findings exist regarding the extent that they explain the degree of vertical integration (Wolter and Veloso, 2008). Hence, what is needed is a model that takes into account the multidimensional nature of the boundary of the firm and that relates this to its many different determinants. The configurational approach offers a way to achieve this.

Third, prior studies do occasionally adopt a configurational approach, albeit implicitly. For instance, as indicated above, Brusoni et al. (2001) conceptualize a systems integrator's organizational form in terms of a combination (read: configuration) of integration and differentiation. In this thesis we aim to build upon this study by distinguishing four instead of two dimensions and by adopting very explicitly a configurational approach. This latter for instance means that we aim to develop detailed middle-range theories and that we take into account equifinality. To be more precise, and based on the principle that each organizational dimension has its own antecedents and brings with it its own organizational capabilities (Cray, 1984), we argue that different configurations of the four dimensions of integration represent different organizational forms that are capable of dealing with the characteristics and the challenges of different types of innovation.

Unlike for instance the alliance literature, we include in our analysis the full spectrum of possible organizational forms. At one extreme, projects are fully internalized, e.g. firms finance and own these projects (legal boundary), perform all of their tasks (production/task boundary) and integrate all the relevant knowledge (knowledge boundary). At the other extreme, projects are organized completely external to the firm, i.e. no investments, no task execution, and no automatic learning about the innovation. In between, we find many different organizational configurations, including different combinations of integration and differentiation in alliances (e.g. Gulati and Singh, 1998; Gulati et al., 2005).

Furthermore, we are able to conceptualize different types of buyer-supplier relationships (e.g. Takeishi, 2001; Sobrero and Roberts, 1998). Internally financed projects (full ownership) can for instance be performed in various degrees by suppliers (based on the degree of task integration) and firms can maintain more or less detailed knowledge about these outsourced activities (the degree of knowledge integration). As far as we know, no other studies have explicitly adopted a configurational approach to the study of firm boundaries (for the organization of NPD projects). In sum, this approach contributes to and extends the systems integration and the innovation management literature, but it also contributes to the literature that investigates the multiple boundaries of the firm (e.g. Santos and Eisenhardt, 2005; Araujo et al., 2002; Brusoni et al., 2001).

***Multiple levels of analysis***

In section 1.3 we already outlined that the organization of innovation is a multi-level phenomenon. However, very few studies exist that explicitly take this into account (Gupta et al., 2007). Above, we also outlined that this thesis considers two levels of analysis: the project's firm-level organizational form and its project-level organizational form. Chapter 9 of this thesis explores how organizational choices at these two levels of analysis interact in their effect on project outcomes. This is a clear contribution to the scarce multi-level innovation management literature. For instance, a recent special issue of *Organization Science* did not address these two levels of analysis (see Gupta et al., 2007), even though plenty of research exists for each level of analysis individually. Good opportunities therefore exist to complement and improve the research at these two levels of analysis. Below we indicate in more detail how this thesis addresses this gap, but before that it is helpful to outline very briefly what we mean with the two levels of analysis.

First of all, the four dimensions of integration as discussed for the previous two contributions pertain to the firm-level organizational form of development projects. Configurations of these four dimensions indicate how and to what extent the focal systems integrator is involved in a specific project. Secondly, the project-level organizational form operates at a lower level of analysis, as it deals with the specific ways in which projects - that can vary in terms of their firm-level organizational form - are structured, organized, and managed. The existing project-level literature suggests that the systemic nature and the technological uncertainty of projects have a strong influence on the way that projects are structured and organized (Shenhar, 2001; Sosa et al., 2004). For instance, higher technological uncertainty affects the intensity of communication within projects, and projects of greater complexity tend to be organized with greater centralization and formalization (Shenhar and Dvir, 1996; Shenhar, 2001). In this way, the project-level organizational form - just like the firm-level organizational form - influences the project's integration and differentiation capabilities (e.g. Sheremata, 2000; Atuahene-Gima, 2003; Takeishi, 2001) and therefore influences the project's overall systems integration capability. It is largely unknown however, how firm-level dimensions and project-level dimensions interact in their effect on project outcomes.

This thesis addresses the abovementioned gap by investigating (in Chapter 9) the interaction of a project's type of ownership integration, i.e. single-firm projects or alliance projects, and several elements of a project's project-level organizational form. This strongly resonates with the call in prior studies for the consideration of organizational boundaries in the field of project management (Shenhar and Dvir, 1996). Typically, the project-level organizational form of NPD projects is studied for projects that keep the degree of ownership integration constant. For instance, the literature on NPD success factors (e.g. Brown and Eisenhardt, 1995; Henard and Szymanski, 2001) generally investigates projects that are performed within a single firm, i.e. internal projects (high ownership integration). Relatively few studies investigate a project's project-level organizational form in other firm-level organizational forms, such as contractual alliances (Gerwin and Ferris, 2004) or buyer-supplier relationships (Takeishi, 2001). In Chapter 9 we explicitly investigate how (strongly) the two levels of analysis interact in their effect on project performance.

***Specific contingencies***

Next to the project's organizational form, another key element in the general conceptual model of this thesis (Figure 1.1) is formed by the contingencies that influence the performance effects of a project's organizational form. In this thesis we investigate several contingency factors that have received little attention thus far, but that can be considered to play an important role in the innovation process. These contingency factors involve various characteristics of the product or the component that is being developed in the project.

First of all, in Chapter 4 we consider the novelty of the innovation. This is a classic contingency factor, but we aim to improve our understanding of its impact on the organization of innovation by studying it in a very specific context, namely that of complementary products. Whereas regular components are incorporated in a product system during assembly, complementary products have a market of their own. Video games, for instance, are sold independently of video game consoles, such as the PlayStation 3 and the Xbox 360. In this context, we can make a distinction between the novelty of the complementary product and the novelty of the product system that it complements. In this chapter we investigate how both types of novelty influence the appropriateness of different organizational forms for the development of complementary products.

We examine this topic in the context of mobile telecommunications. More specifically, we adopt the perspective of mobile network operators to investigate the extent that these firms integrate the development of individual value-added mobile applications, such as mobile games, mobile office applications, and mobile messaging applications. Although a product platform and its complementary products can have separate development and commercialization processes, this does not mean that they are unrelated. On the contrary, the development of complementary products requires coordination to achieve technical interoperability, and the commercialization of complementary products is argued to be critical to attract and retain users for the product system (Van den Ende, 2003). Because this interrelatedness can be argued to depend on the novelty of both the system and the complementary product, it seems relevant to investigate how these contingencies influence the appropriateness of different organizational forms.

Secondly, in Chapter 6 we consider the development of a special type of architectural innovation, i.e. architectural innovations that combine existing technologies from different industries into new product systems. An example of such a technology fusion (Kodama, 1992) or such an 'inter-industry architectural innovation' is the integration of mobile telecommunications and financial services to create mobile payment and mobile banking applications. This type of innovation is truly systemic in nature, because it has to be explored how the new product configuration impacts each of the different subsystems. No prior knowledge exists about subsystem interrelationships, and as a result the product's design and coordination has to be performed without the leadership of a knowledgeable systems integrator. In other words, this study explores how firms organize new product development within the context of the specific contingencies of this particular type of systemic innovation.

Finally, in Chapter 7 and Chapter 8 we consider the effect of a project's project-level organizational form on project performance. To be more precise, we consider whether this effect is mediated by the team's proficiency to solve technical problems. Little empirical insights exist about this mediating effect (Brown and Eisenhardt, 1995; Sheremata, 2000; Atuahene-Gima, 2003). We add to this literature by investigating two potential moderators. First of all, we consider as a moderator the extent that a project's problems are systemic rather than autonomous. In the development of product systems problems might involve individual components (autonomous problems) or might be related to multiple of the product's components (systemic problems). In Chapter 7 we investigate how the type of problem moderates the effects of a project's organizational differentiation and integration mechanisms on the proficiency of the team to solve problems proficiently, i.e. fast, cost-efficiently, and with high-quality solutions. Secondly, in Chapter 8 we investigate whether and how the effect of problem-solving proficiency on project outcomes is moderated by the number of problems in the project, i.e. problem frequency.

### 1.5 Thesis structure and research questions

Including this introduction, this thesis consists of ten chapters. Below we briefly introduce each chapter. We outline the underlying research questions and we also briefly indicate how we aimed to answer these questions. The chapters are grouped in three parts. Part 1 (Chapters 2 and 3) are introductory in nature as they provide a theoretical foundation for the other chapters in this thesis. Chapter 2 introduces configurational theory and contingency theory. Chapter 3 introduces in greater detail the concept of systems integration. Part 2 (Chapters 4, 5 and 6) adopts a configurational approach to study the firm-level organizational form for different types of development projects. Part 3 (Chapters 7, 8, and 9) investigates how the organizational form within NPD projects influences project performance and how this depends on several contingency factors. Chapter 10 summarizes and concludes the thesis.

## PART 1. THEORETICAL BACKGROUND

### *Chapter 2. Contingency theory and configurational theory*

As an introductory chapter, Chapter 2 describes what is known as 'contingency theory' and 'configurational theory'. As indicated above, an important principle in this thesis is that different innovations require different organizational forms (see also Figure 1.1). Contingency theory is an overall 'metatheory' (Schoonhoven, 1981) which states that a certain value of the dependent concept (e.g. the success of a NPD project) is determined by 'the degree of fit' between the independent concept (e.g. the extent that the system firm performs project tasks itself) and the contingency concept (e.g. the novelty of the innovation). Chapter 2 provides an overview of different ways in which this principle can be incorporated in theories and how these can be operationalized.

Contingency theories consider the interplay of only two concepts, i.e. the independent concept and the contingency concept, in the explanation of the dependent concept. In this respect contingency theories are 'bivariate theories of fit' (Meilich, 2006). Configurational theories consider a larger number of concepts and they focus on how these concepts contribute to a certain outcome jointly rather than individually. Chapter 2 introduces configurational theory in greater detail and discusses its differences and similarities with contingency theory. Finally, Chapter 2 outlines how subsequent chapters make use of both types of theory.

### *Chapter 3. Systems integration: how and why firms know more than they make*

Whereas Brusoni et al. (2001) have stressed *why* systems integrators should know more than they make, i.e. for reasons of coordination by means of systems integration, they were less concerned with the mechanisms that firms can apply to access and absorb external knowledge to increase their knowledge boundary. This chapter aims to increase our understanding about *how* firms develop systems integration capabilities. The research question that underlies this chapter reads as follows:

*How can firms increase their knowledge boundary beyond their production boundary?*

To answer this question and to generate several options that can assist in the creation of a systems integration capability we performed a conceptual analysis that integrates the systems integration literature and the Open Innovation literature. This latter literature (e.g. Chesbrough, 2003; Chesbrough et al., 2006) is very relevant in this respect, because of its concern with the potential of externally residing knowledge and capabilities to assist a firm's innovation process. Finally, this chapter also serves as an introductory chapter for the rest of the thesis as it provides an introduction to the systems integration literature.

## PART 2. SYSTEMS INTEGRATION: A CONFIGURATIONAL APPROACH

***Chapter 4. How to organize the development of complementary products?***

As indicated in section 1.4, Chapter 4 investigates how systems integrators organize the development of complementary products. This chapter makes a first step to a more detailed conceptualization of a project's organizational form by making a distinction between the system firm's ownership of the project (ownership integration) and its active involvement in the project (coordination and task integration). In this way it becomes possible to conceptualize the involvement of system firms in a development project, although they are not the owner of the project and its outcome, i.e. systems integration. More specifically, this chapter investigates how the organizational form of the project depends not only on the novelty of the complementary product itself, but also on the novelty of the larger product system. This is reflected in the following research question:

> *Taking into account the novelty of the system and the novelty of the complementary product, what are appropriate organizational forms for systems integrators to organize development projects of complementary products?*

To address this question we analyzed the involvement of mobile network operators in the development of mobile telecommunications applications. Based on existing literature we propose a contingency model that suggests appropriate organizational forms for the development of value-added mobile applications for different combinations of network novelty and application novelty. Quantitative analysis provides a first indication of the validity of this framework.

***Chapter 5. Organizational configurations for component development projects***

Chapter 5 distinguishes between the four abovementioned 'dimensions of integration' to reflect different relationships between the firm and its environment. In this way it extends Chapter 4, which only considers two firm-level organizational dimensions. Chapter 5 explores how the four dimensions can be combined to form different configurations that are suitable to address the specific characteristics of different types of component development projects. The research question for this chapter reads as follows:

> *What are appropriate organizational configurations for systems integrators to organize component development projects?*

Based on existing literature and on case studies of development projects of mobile telecommunications applications, Chapter 5 proposes a tentative configurational theory. For six different types of component innovation this theory suggests organizational configurations that seem appropriate for the development of these innovations. Whereas Chapter 4 explicitly focused on complementary products, which can be considered a very specific type of part or component of a larger product system, this chapter focuses on components in general. Normally, components are directly integrated in the product and have no market of their own in which users make decisions to buy the component or not.

***Chapter 6. Inter-industry architectural innovations***
Chapter 6 considers systems integration for a special type of systemic innovation, i.e. inter-industry architectural innovation. These innovations are new product systems - rather than components or complementary products - that are created as a result of the first-time combination of technologies from different industries. Given the existence of technology specialists, given the absence of prior ties among these specialist firms, given their different structures and cultures, and given the lack of architectural knowledge about how to design and develop the new product system, this chapter poses the research question:

*How can development projects of inter-industry architectural innovations best be organized?*

This research question is explored by means of an inductive analysis of three in-depth case studies. These cases involve a mobile payment start-up, a mobile banking alliance, and an informal alliance for the development of a mobile television application. Hence, these three projects each integrated mobile telecommunications technology with technology from another industry, i.e. the financial services industry and the broadcasting industry. The organizational form as investigated in these three projects considers elements both at the level of the firm (e.g. internal within the start-up or in different types of alliances) and at the level of the project (e.g. different types of project management and information exchange).

## PART 3. SYSTEMS INTEGRATION AND PROBLEM SOLVING

***Chapter 7. Problem solving in NPD: systemic problems versus autonomous problems***
This chapter investigates the implications of the systemic nature of innovation processes within NPD projects. Whereas most of the literature about systems integration takes a firm-level perspective, i.e. the system firm's boundaries with respect to various types of innovation, we investigate how systems integration can occur within projects. More specifically, we investigate how a project's organizational form in terms of differentiation and integration (i.e. two main building blocks of systems integration; Brusoni et al., 2001) can assist project teams in their capability to solve technical project problems. More in particular, we investigate how project differentiation mechanisms (e.g. external search for ideas, decentralization) and integration mechanisms (e.g. team meetings, senior managers) can help project teams to solve different types of technical problems. We make a distinction between systemic problems, which have implications for multiple components of the product system that is being developed in the project, and autonomous problems, which are restricted to individual components. As outlined in the previous section, this distinction adds a new perspective to the literature about problem-solving in NPD projects (e.g. Sheremata, 2000; Atuahene-Gima, 2003). The research question associated with this contribution is the following:

*How is the effect of the project-level organizational form on the project's problem-solving capability moderated by the extent that project problems are systemic rather than autonomous?*

Assisted by prior literature (e.g. Brown and Eisenhardt, 1997; Sheremata, 2000; Atuahene-Gima, 2003), we develop several hypotheses related to the moderating effect of the type of problem. We test these hypotheses statistically based on survey data about problem-solving in development projects of web applications.

***Chapter 8. More on problem solving***

This chapter complements the previous chapter as it investigates whether (and if so how) problem-solving proficiency acts as a mediator of the effect that a project's organizational form has on project performance. In addition, we investigate how the relationship between problem-solving proficiency depends on the frequency of the problems during a project. This points to the following two questions:

*Does problem-solving proficiency mediate the effects from the project's organizational form on project performance?*
*Does problem frequency moderate the relationship between problem-solving proficiency and project performance?*

***Chapter 9. Interrelationships of firm-level and project-level organization***

This penultimate chapter studies the interrelationships between a project's firm-level organizational form and its project-level organizational form. This chapter integrates several concepts that were studies separately in previous chapters. On the one hand, the firm-level organizational factor of ownership integration (Chapter 4 and 5) is considered. On the other hand, it takes into account project-level dimensions such as decentralization, free flow of information, and project management influence (Chapter 6, 7, and 8). It is investigated how projects are organized at the project-level for different ownership structures (i.e. integrated in a single firm, or dispersed across two or more investing firms) and how this affects project performance. This multi-level analysis makes use of the same survey data as the study in chapter 7. The central question in Chapter 9 is the following:

*Do ownership integration and project-level organizational factors complement each other in their effects on problem-solving proficiency and project performance?*

***Chapter 10. Conclusions***

Finally, Chapter 10 provides some overall conclusions, limitations and implications.

# PART 1.

# THEORETICAL BACKGROUND

# 2. Contingency Theory and Configurational Theory: An Overview of Perspectives and Methodological Issues

## 2.1 Introduction

In this chapter I describe and discuss contingency theory and configurational theory. These two types of theory are core to much of the research in the field of management and organization. Also the chapters that follow use these approaches extensively. This chapter therefore provides an important background to the remainder of this thesis. This chapter starts with an introduction to contingency theory. This type of theory posits that the effect of a causal factor is dependent (contingent) on another factor - the contingency factor. As a result, there needs to be a 'fit' between the causal factor and the contingency factor for a certain effect to occur. Different conceptualizations of 'fit' are discussed, as well as ways to make them operational.

The second section of this chapter introduces configurational theory, which can be considered an extension of contingency theory. Rather than investigating bivariate fit, i.e. fit between one explanatory factor and one contingency factor, configurational theories focus on combinations (configurations) of multiple factors. This second section also outlines the major differences between contingency theory and configurational theory. It also addresses several methodological issues for configurational theories. The third, concluding section outlines how the contents of this chapter will be applied in the chapters that follow.

## 2.2 Contingency 'theory'

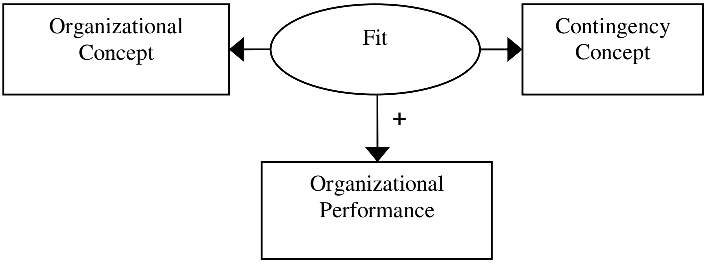
Contingency theory has its origins in the literature on organization design (see for instance Dill [1958] and the classic studies of Woodward [1965], Thompson [1967] and Galbraith [1977]) and has become "*the most widely utilized theoretical approach to the study of organizations*" (Meilich (2006) citing Scott, 1998, p.97). It has influenced and continues to influence numerous fields of management research, such as strategic management (e.g. Venkatraman and Camillus, 1984), innovation management (e.g. Tatikonda and Montoya-Weiss, 2001), knowledge management (Argote et al., 2003), human resource management (e.g. Delery and Doty, 1996), management control systems (e.g. Fisher, 1995), and operations management (e.g. Das et al., 2006). Contingency theory is not a *theory* however, in the sense that it is not a specific set of concepts with well-defined interrelationships (Bacharach, 1989). Rather, contingency theory is a 'metatheory' (Schoonhoven, 1981) that guides the study of organizational concepts.

The central idea in the contingency theory approach is that different circumstances confront organizations with different challenges and that organizations therefore need different organizational approaches to deal with these challenges effectively. According to Tushman and Nadler (1978, p.613) it were Burns and Stalker (1961) who '*presented the idea that different approaches to structuring organizations might have differential effectiveness under varying conditions'* and ever since *'much work has been done attempting to identify the critical contingencies of design.'* Phrased more formally, contingency theory argues that the effect of an organizational concept, such as decentralization or communication frequency, on organizational performance depends on a third concept, the contingency concepts. This contingency concept often refers to an exogenous factor, such as task uncertainty or environmental turbulence. Burns and Stalker (1961) for instance claimed that organizations operating in highly uncertain environments require organic structures, whereas mechanic structures are more suitable for organizations operating in stable environments. The better the 'fit' between the organizational concept and the contingency concept, the higher performance is expected to be. Contingency theory in this way contrasts universalistic theories, which 'only' study causal direct effects between organizational concepts (e.g. formalization, centralization, etc.) and organizational performance. Whereas the universalistic approach therefore essentially claims a 'one best way' to organize that is beneficial for all organizations under all circumstances (e.g. the more formalization the better), contingency theory would argue that '*it all depends*' (Schoonhoven, 1981, p.371).

### *The concept of 'fit'*

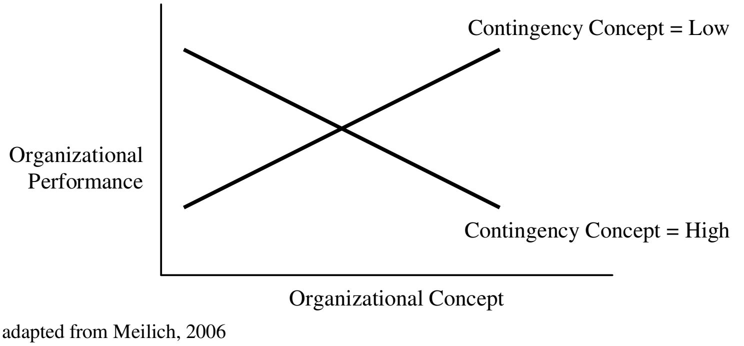
Central to contingency theory is that a separate concept is introduced to explain performance (see Figure 2.1 for an illustration), i.e. in order for a preferable outcome to occur there needs to be 'fit' between the organizational concept and the contingency concept. The better this match, the higher performance is expected to be. Failure to achieve fit (i.e. misfit) will result in suboptimal performance. The popularity of contingency theory can largely be explained by the strong intuitive appeal of this idea of fit. At the same time, this concept is also the major criticism of the contingency approach, because it tends to be ill-defined and deviations often exist between the (implicit) definition of fit and its operationalization.

**Figure 2.1 Basic building blocks of contingency theory**




Despite the frequent use of contingency theory, it has received mixed empirical support (e.g. Mohr, 1971; Pennings, 1975, Schoonhoven, 1981, Meilich, 2006). According to Schoonhoven (1981) this might be explained by the fact that contingency theory suffers from a lack of clarity about the meaning of 'fit'. Often, researchers use the concept of 'fit', or equivalent concepts like 'alignment', 'congruence', 'match', and 'consistency', without providing a precise definition of its theoretical meaning. Without such a precise definition it becomes very difficult to test whether an organization achieves fit or not (Pennings, 1975) and to compare research findings. To facilitate rigorous empirical testing, rich verbal theories about the relationships between specific organizational and contingency concepts need to be translated into mathematical functions to make sure that the operationalization of fit is grounded in theory (Schoonhoven, 1981; Venkatraman, 1989). Most theories of fit are bivariate theories of fit, i.e. they aim to explain performance differences from the fit between one organizational concept and one contingency concept (e.g. Drazin and Van de Ven, 1985; Venkatraman, 1989). The dominant bivariate type of fit involves 'fit as interaction'.

**Figure 2.2 Fit as interaction**




Source: adapted from Meilich, 2006

***Fit as interaction***
The interaction approach (e.g. Schoonhoven, 1981; Baron and Kenny, 1986) argues that the impact of the organizational concept on performance varies over the range of the contingency concept. To be more precise, the interaction approach typically assumes a linear relationship between the organizational and the outcome concept and argues that the interaction effect increases or decreases the slope of this relationship (Meilich, 2006). A positive interaction effect implies that the slope of the relationship between the organizational concept (i.e. the moderator) and the outcome concept increases (decreases) as the contingency factor increases (decreases). In contrast, a negative interaction effect means that the slope of the organization-performance relationship decreases (increases) as a result of increases (decreases) in the contingency concept. Figure 2.2 illustrates the interaction model of fit. In this example a negative interaction effect is depicted because an increase of the contingency concept (i.e. from low to high) changes the slope of the organization-performance relationship from positive to negative.

Interaction fit is typically operationalized by including the interaction term (the product) of the organizational variable and the contingency variable in a regression model with the direct effects of these variables (i.e. the classic interaction model). To prevent problems of multicollinearity between the interaction term, the structural term, and the contingency term, another possibility to operationalize and to statistically analyze interaction fit is the deviation or difference scores approach (e.g. Dewar and Werbel, 1979). In this approach fit represents the similarity between the actual value organizational concept and an ‘ideal’ value of the organizational concept, which is then itself considered as a separate concept that can be used to explain performance (Edwards and Parry, 1993). In this approach the contingency factor determines the value at which the organizational concept results in optimal performance.

Deviation is typically operationalized as the absolute or the squared difference between the structural and the contingency variable. The essential prediction in this approach is that the extent of deviation from the optimal point (either as a result of insufficient or excessive ‘structure’) reduces performance. In this respect the classic interaction approach and the deviation approach are identical, i.e. they both essentially assume a high-performing ideal for different values of the contingency concept and they assume that departure from this ideal reduces performance. Statistically they are different however (Drazin and Van de Ven, 1985), i.e. the product of the contingency variable and the structural variable (in the classic interaction approach) versus for instance the squared difference between the structural variable and the contingency variable (the deviation approach).

***Critique on bivariate models of fit: the polynomial regression alternative***
Several authors (e.g. Edwards and Parry, 1993; Meilich, 2006) address the operationalization of the classic interaction approach and the deviation approach in greater detail. According to Meilich (2006) these approaches make it less conducive to detect fit, because they are based on several problematic constraints, such as the assumption of linearity and the combination distinct structural and contingency concepts into a single score. These constraints can be relaxed by operationalizing fit using polynomial regression analysis (Edwards and Parry, 1993; Edwards, 1994; Edwards, 2001, Meilich, 2006). According to these authors polynomial regression is an effective way to test contingency

theories as it is based on a more comprehensive model of fit which tests different possible effects of the contingency concept simultaneously, including the deviation approach and the interaction approach. In other words, the interaction approach and the deviation approach are constrained cases of the polynomial regression model, and if tested these constraints often do not hold (Edwards, 2001).

Polynomial regression analysis adds the squared term of the organizational variable (and possibly also the squared term of the contingency variable) to the regression model with the direct terms and the interaction term. Just as in the deviation approach the result can be represented in a three-dimensional surface with the structural variable on the X-axis, with the contingency variable on the Y-axis, and with performance on the Z-axis. Keeping the organizational variable and the contingency variable apart (as opposed to the deviation approach) facilitates a better interpretation of causal effects (Edwards, 1994). The inclusion of the squared term for the organizational variable allows for a curvilinear relationship between the organizational concept and performance. This allows for a better test of the interaction effect, as it prevents confounding between the interaction term and the squared term (Edwards, 1994; Venkatraman, 1989).

**Box 1. The difference scores approach, the interaction approach and polynomial regression**

Edwards and Parry (1993) and Meilich (2006) state that the difference scores approach and the interaction approach are constrained cases of the polynomial regression model. They illustrate this point as follows. Equation 1 shows a typical regression equation for the difference scores approach. Here the difference between X and Y (e.g. the structural and the contingency variable) is the single predictor for Z (e.g. organizational performance). Equation 2 shows that this model is similar to the assumptions that X and Y are related to Z with an equally large regression coefficient albeit that X is related positively to Z and Y negatively. A model without these constraints is provided in equation 3.

$$Z = b_0 + b_1(X - Y) + e \quad (1)$$

$$Z = b_0 + b_1 X - b_1 Y + e \quad (2)$$

$$Z = b_0 + b_1 X + b_2 Y + e \quad (3)$$

A different way to operationalize the difference scores approach is the use of squared differences (see equation 4). This equation can be rewritten as in equation 5, which shows that the squared difference approach basically assumes that Z is a function of the squared terms of X and Y and the interaction term of the two. In addition, the squared terms have an equal effect on Z while the interaction term is twice as large, but with a negative sign. Relaxing these constraints and with the appropriate lower-order terms results in the polynomial regression equation (equation 6). This polynomial regression equation also tests the difference scores approach and the interaction approach, but without their associated constraints.

$$Z = b_0 + b_1(X - Y)^2 + e \quad (4)$$

$$Z = b_0 + b_1 X^2 - 2b_1 XY + b_1 Y^2 + e \quad (5)$$

$$Z = b_0 + b_1 X + b_2 Y + b_3 X^2 + b_4 XY + b_5 Y^2 + e \quad (6)$$

Applying polynomial regression analysis to contingency theories has shown to result in new theoretical insights (Edwards and Parry, 1993) and in statistically significant improvements in terms of variance explained (Edwards, 1994). Although the polynomial regression model is often the preferred model to test contingency theory, the resulting three-dimensional surfaces are typically difficult to interpret, which might explain the limited usage of this approach (Edwards and Parry, 1993). Box 1 provides a mathematical overview of the constraints assumed in the interaction approach and the deviation approach and contrasts them with polynomial regression.

***The strength of the selection regime***

As a final note regarding contingency theory, Meilich (2006) points to the importance of investigating the correlation between structure and contingency before any attempt is made to explain performance. This correlation reflects the strength of the selection regime and this strength influences the possible and preferable ways to assess fit. In a strong selection regime (roughly correlation .95 or beyond) the difficulty to separate the explanatory power of the structural and the contingency variable means that performance differences cannot be explained. Therefore, selection is the only notion of fit that can be assessed under these circumstances. With a less strong selection regime (.70-.95) a comparison should according to Meilich be made between the polynomial and the interaction-only regression model to assess their relative predictive value and assess the multicollinearity problems of the polynomial model. For medium and low selection regimes (correlation values below .70), which are most common, Meilich recommends the polynomial model for assessing bivariate contingency models.

### 2.3 Configurationalism

Contingency theory as discussed in the previous section is interested in the effects of fit between a contingency concept and an organizational concept. This bivariate approach has the advantage that knowledge can be developed about the links between specific concepts, but it is seen by some as a 'reductionistic' approach in the sense that it assumes that the interaction between a single contingency concept and a single organizational concept is capable of significantly explaining variation in performance (e.g. Meyer, Tsui and Hinings, 1993). Other factors might influence this interaction effect and pose conflicting contingencies, thereby resulting in conflicting empirical findings. Some authors therefore question the theoretical meaningfulness of the bivariate approach (Venkatraman and Prescott, 1990; Miller, 1981). Anderson & Zeithaml (1984, p.5) for instance make the following claim about strategy research: *"…strategy researchers have searched for a construct or contingency variable with broad explanatory power. The attractiveness of this kind of construct is self-evident. It would simplify strategy formulation and implementation. No single construct or combination of constructs has however emerged as predominant in the industry. This is probably due to the large number of environmental and organizational variables that affect the performance of businesses."*

Configurational theories (here considered synonymous with 'typological theories' or 'typologies') take the complexity of social and business phenomena into account by arguing that organizational design and organizational performance can only be understood by considering simultaneously multiple, conceptually distinct organizational and contingency factors. This multivariate 'holistic' or 'systems' approach aims to capture the synergistic effects and internal consistency of these factors (Khandwalla, 1973; Miller and Friesen, 1984; Drazin and Van de Ven, 1985; Doty and Glick, 1994). A distinctive feature of typological theories is their ability to deal with equifinality, which means that a certain level of performance can be achieved with more than one configuration. Hence, organizations can follow different paths to reach the same result (Katz and Kahn, 1966; Miller, 1981; Gresov and Drazin, 1997). Porter (1980) for instance, specifies different generic competitive strategies that each are thought to result in industry positions that confer sustainable competitive advantage. The configurational approach is quite common in several areas of management research, such as organization design (Doty et al., 1993), strategy (Miller, 1986), human resource management (Lengnick-Hall and Lengnick-Hall, 1988; Delery and Doty, 1996), management accounting (Chenhall and Langfield-Smith, 1998), and marketing (Vorhies and Morgan, 2003). Furthermore, several well-known studies, such as Miles and Snow (1978) and Mintzberg (1979) constitute typologies.

Parsimonious sets of viable and equifinal combinations of factors are popular for research and pedagogical goals (Bozarth and McDermott, 1998) and at the same time they are argued to result in higher practical relevance for managers and policymakers (George and Bennett, 2005). Mintzberg (1979) for instance famously theorized about five internally consistent configurations of organizations (the simple structure, the machine bureaucracy, the professional bureaucracy, the divisionalized form, and the adhocracy) in terms of: (1) key parts of the organization (e.g. the strategic apex or support staff); (2) prime coordination mechanisms (e.g. direct supervision or mutual adjustment); (3) main design parameters (e.g. centralization, formalization, and unit size); and (4) several contingency factors (e.g. the size and age of the organization and the stability of the environment). An internally consistent organizational configuration is for instance the 'Simple Structure.' In this organizational configuration the strategic apex is the most important part of the organization and coordination between different parts of the organization is largely based on direct supervision. Furthermore, the structure of these organizations is typically highly organic and centralized, and these organizations are generally young and small.

In contrast to 'classifications' or 'taxonomies', which partition instances of a phenomenon in different types that are preferably mutually exclusive and exhaustive, configurational theories or typologies are considered here as theories that aim to explain variation in organizational performance (e.g. Doty and Glick, 1994; Short et al., 2008). As pointed out by Doty and Glick (1994), typological theories contain two types of constructs (first-order constructs and second-order constructs) and two types of theories (middle-range theories and a grand theory). First-order constructs - the explanatory constructs in bivariate studies - constitute the building blocks of typologies. While the number of combinations of first-order constructs may be huge, many combinations will be unlikely or even logically impossible. The configurational approach believes that '*only a finite number of coherent configurations are prevalent in the social world*' (Meyer et al., 1993, p.1192). These coherent configurations or 'ideal types' - the second-order constructs in typological theories - are internally consistent combinations of the first-order building blocks.

The overall prediction of typological theories, i.e. their grand theory, holds that deviation from an ideal type reduces performance. Hence, the main independent concept in typologies is the extent of deviation or misfit from an ideal type. Put differently, the closer observations resemble the ideal profile, the higher performance is expected to be. Supporting this universal law, Ketchen et al. (1997) found in a meta-analysis that about 8% of performance variance can be explained by configurational membership. At a finer level of detail, typologies consist of 'middle-range theories' (Merton, 1957). In the context of normative typological theories, middle-range theories explain for each individual ideal type the internal consistency of its first-order constructs and how this contributes to performance. Each middle-range theory therefore offers a very specific explanation that holds under the assumptions and contingencies of an individual ideal type. Hence, *"…theories of the middle range attempt to predict and explain only a subset of all organizational phenomena. As such, each midrange theory makes different sets of assumptions about organizations, considers different parameters to be important, and leads to entirely different prescriptions for practice from other midrange theories"* (Pinder and Moore, 1979, p.100). Contingency theories constitute the first step from universal theories to middle-range theories, but configurational theories take an extra step to develop much more fine-grained middle-range theories. Because middle-range theories constitute the theoretical foundations of typological theories, we will discuss them below in some greater detail.

***Middle-range theories***

Rather than rich and thick descriptions, ideal-typical configurations require precise definitions of the interrelationships among its basic building blocks, because this is central to the conceptualization of fit (Gerdin and Greve, 2004) and because this is a prerequisite for modelling fit (Doty and Glick, 1994). Hence, there is a trade-off between the number of dimensions to include in configurational analyses and the purpose of configurations as generalizable abstractions of reality (Meyer et al., 1993). More accurate configurations are gained at the cost of increased complexity because of the requirement to specify a middle-range theory for each ideal type (Venkatraman and Prescott, 1990; Doty and Glick, 1994).

According to Miller (1996) it is of crucial importance to show how and why the first-order attributes in specific ideal types interrelate. To improve the theoretical understanding of ideal types, Miller argues that research should focus on what he labels 'central orchestrating themes' which bring about complex systems of interdependence between the attributes of configurations. In his field of interest – strategy – such a theme is the primary goal or focus of an organization, such as its focus on cost reduction and efficiency, or its focus on innovation and R&D. In this sense, organizations can differ in terms of their 'degree of configurationalism', i.e. the extent that a single integrative theme orchestrates the dimensions of the configuration to cluster together in a particular way. According to Miller (1996) 'a high degree of configuration' is likely to be a greater source of competitive advantage than any individual element of strategy. In his view, firms can also be too obsessed with a single theme, thus resulting in an excessive and dysfunctional degree of configuration.

Ideal types and their middle-range theories can be specified either empirically or theoretically (George and Bennett, 2005). Empirical approaches, such as cluster analysis (e.g. Bensaou and Venkatraman, 1995), often lack theoretical significance as they are dependent on the selected variables and the sample from which the clusters are derived (Miller, 1996). Some authors (e.g. Doty and Glick, 1994) therefore prefer the theoretical development of typologies. Das et al. (2006) however point to the difficulty of developing and specifying middle-range theories, because bounded rationality prevents us from knowing all relevant first-order concepts. Although it is possible according to Das et al. (2006) to make a reasonable, literature-based identification of the most relevant first-order elements, existing theory is in general insufficiently developed to enable deduction of complex ideal types.

Examples of more complex ideal types are 'contingent middle-range theories' (George and Bennett, 2005; Doty and Glick, 1994). In addition to the explanation of 'internal fit' among organizational concepts, more complex middle-range theories might specify how one or more contingency factors determine under which circumstances an internally consistent configuration results in high performance. Such theories therefore also consider 'external fit' (Miller, 1992). For these more complex middle-range theories we can imagine circumstances of conflicting contingencies and conflicting pressures for internal and external fit (e.g. Gresov, 1989; Miller, 1992).

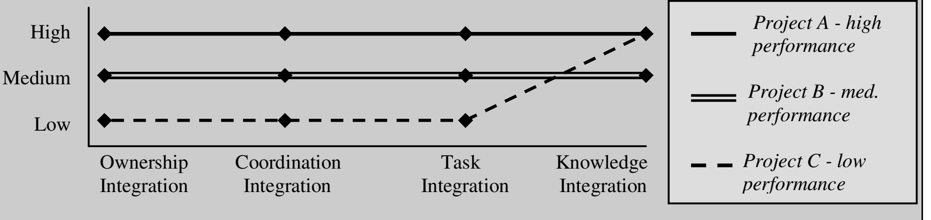
George and Bennett (2005) argue that contingent middle-range theories fill the theoretical vacuum that is typically left by the broad and abstract predictions made by contingency theories. They argue that these context-specific theories are deliberately limited in scope and that they reduce the gap between scientists and practitioners because contingent generalizations of typologies are generally more useful for managers and decision-makers in guiding their actions in specific circumstances. In this respect, Mintzberg (1979, p.vi) states that his aim is to develop 'descriptive theory' and that he leaves the application and prescription based on this knowledge to practitioners and consultants who are much more familiar with their specific contexts.

***Differences between contingency theory and configurational theory***

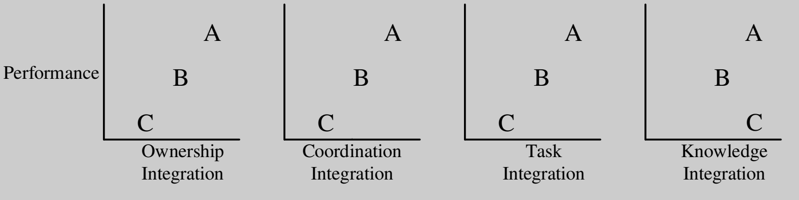
The contingency approach and the configurational approach are often seen as two totally different paradigms in the study of organizations (Meyer et al., 1993; Doty and Glick, 1994; Gerdin and Greve, 2004; de Treville and Antonakis, 2006). Whereas contingency theories typically hypothesize linear and interaction effects of one independent concept and one contingency concept, typologies highlight the synergistic effects among multiple first-order concepts within each ideal type (Bozarth and McDermott, 1998; Das, Narasimhan and Tallure, 2006). Unlike contingency theories, typologies therefore do not specify the direct relationships between individual first-order concepts and performance, because the way that first-order concepts combine to determine the dependent variable can vary across the set of ideal types. Typologies therefore allow for the specification of synergistic, nonlinear relationships among first-order constructs that cannot be represented with linear models (Meyer et al., 1993).

Gerdin and Greve (2004, p.306, emphasis in original) argue that "results (empirical or theoretical) based one school of thought should not be validated by comparisons with those of the other. In fact, *even if applied to the same empirical data, the two approaches may yield very different results."* Hence, both paradigms are "*competing rather than complementary approaches to fit*." The difference between both approaches is illustrated in Box 2.

**Box 2. Comparing the configurational approach and the contingency approach**
That contingency theory and configurational theory are distinct approaches can be illustrated with the following example drawn from chapter 5 of this thesis[1]. In this chapter it is argued that architectural innovations involving core components require an organizational configuration consisting of high values for the four organizational dimensions of coordination integration, task integration, ownership integration, and knowledge integration. The figure below depicts three different organizational forms. The organizational form for Project A perfectly matches the ideal organizational form. Performance is high for this project. Project B shows medium values on each organizational dimension and therefore results in a lower performance than Project A. Project B performs better however than Project C, since Project C shows a greater total distance from the ideal profile than Project B (a total deviation on three dimensions and perfect fit on one dimension for Project C versus a slight misfit on all four dimensions for Project B).




From a contingency perspective it could be hypothesized for each individual organizational dimension that a positive relationship exists with performance. For ownership integration, coordination integration, and task integration this hypothesis is supported in the above example. As the figures below illustrate, a positive correlation exists between all three organizational dimensions and performance. However, knowledge integration is not positively associated with performance, because Project C performs poorly despite its high value for knowledge integration.




This example supports the main configurational proposition that deviation from the ideal type reduces performance. Hence, knowledge integration is seen as an element of a configuration that helps explain performance. In contrast, the contingent hypothesis is not supported in this example, meaning that this approach would consider knowledge integration as an unimportant factor for the explanation of performance for architectural core component innovations. The difference between the contingency approach and the configurational approach becomes even more obvious if one considers that equifinal configurations might exist, which further reduce the possibility of finding linear relationships between individual independent variables and the dependent variable in a population.

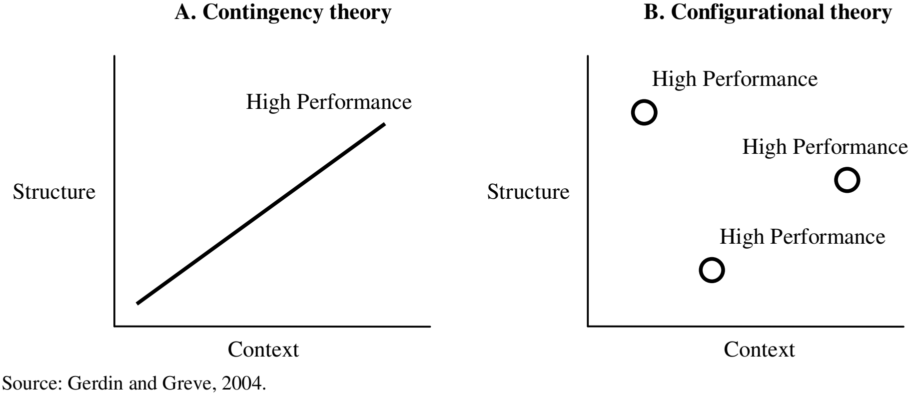
Thus far the discussion of bivariate and configurational types of fit adopted a static perspective. This is also the focus in this thesis, but it must be recognized that achieving fit is a dynamic and never-ending *process* (Venkatraman, 1989) whereby the organization is

[1] This example follows the logic of a similar example in Gerdin and Greve (2004, p.306).

continually "*shooting at a moving target of coalignment*" (Thompson, 1967, p.234). Organizations are constantly confronted with forces that move it away or towards equilibrium, but achieving both internal and external fit, i.e. fit among the structural elements and fit between multiple organizational characteristics and environmental contingencies, is difficult to obtain (Miller, 1992) and might even be an elusive goal (Gresov, 1989; Sinha and Van de Ven, 2005). Hence, organizations need to be able to deal with the negative effects of misfits and must constantly strive for organizational change to improve fit (Donaldson, 2001). Furthermore, organizations may have to trade-off the short-term and the long-term benefits of fit (Miller, 1992).

In terms of processes of change, another fundamental difference often exists between contingency theory and configurationalism. This is due to "*the difference between fit as a continuous line in a multidimensional space and fit as a limited number of discrete system states*" (Gerdin and Greve, 2004, p.305; see Figure 2.3 below). In contingency theory (A in Figure 2.3) small and incremental changes are the primary mode of change (Meyer et al., 1993), whereas such small changes from a configurational perspective (B in Figure 2.3) could result in the destruction of the synergy among the elements of the configuration (Gerdin and Greve, 2004). Effective organizational change in configurationalism might mean change on all dimensions of the configuration to form 'giant leaps' or 'quantum jumps' from one high performing configuration to the other (Miller, 1996; Gerdin and Greve, 2004).

**Figure 2.3. Different views of fit**




Source: Gerdin and Greve, 2004.

***Operationalization of configurational theories***

In the configurational approach the concept of fit is typically operationalized using profile similarity indices (PSIs). These indices reflect the overall congruence (i.e. fit) between the ideal profile and observed profiles, which is then used to predict performance (e.g. Drazin and Van de Ven, 1985, Gresov, 1989, Venkatraman, 1990; Venkatraman & Prescott, 1990; Doty et al., 1993). An important category of profile similarity indices is based on the sum of differences between profiles (see Box 3). Basic to this approach is first of all that the difference is calculated for each pair of corresponding elements (i.e. the differences between the $i^{th}$ element of the ideal profile and the $i^{th}$ element of an observed profile). Subsequently all differences are summed to reflect overall profile congruence.

Just as the common ways to operationalize bivariate models of fit, PSIs have several methodological problems (Edwards, 1993). First of all, PSIs result in the loss of relevant information. PSIs for instance combine conceptually distinct first-order elements into a single second-order profile. Furthermore, they combine two conceptually distinct profiles (e.g. the ideal and the observed profile) into a single score: the deviation or misfit score. In this approach information about the contribution of each element and of each profile is lost. The combination of concepts into a single score might therefore give the impression of a parsimonious approach, but this is achieved only with the introduction of considerable conceptual ambiguity.

**Box 3. Profile similarity indices based on the sum of differences**

Edwards (1993) describes several profile similarity indices based on the sum of differences between profile elements. Three of these are described and discussed here in some greater detail. First of all $D^2$ represents the sum of squared differences. This approach operationalizes configurational fit by summing the squared differences between all corresponding elements (Equation 1). Because this approach squares the differences, two important consequences are that (1) the sign of the difference is neglected (i.e. it does not matter whether the value for an observed profile element was below or above its 'ideal' value); and (2) that larger differences are assigned a greater weight.

$$D^2 = \sum (X_i - Y_i)^2 \qquad (1)$$

D, the square root of $D^2$, represents the so-called Euclidian distance measure (see Equation 2). Because this approach also squares the differences, it results in a non-directional measure as well. Unlike $D^2$ however, the square root means that a geometric interpretation is possible for the (Euclidean) distance between profiles.

$$D = \sqrt{\sum (X_i - Y_i)^2} \qquad (2)$$

The absolute difference between elements $|D|$ (Equation 3) is also non-directional, but assigns equal weight to differences and therefore D reflects the cumulative distance between profiles.

$$|D| = \sum |X_i - Y_i| \qquad (3)$$

Additionally, with the use of PSIs information is lost about the absolute magnitude of the observed profile. This is because the traditional configurational hypothesis, i.e. 'configurational fit is associated positively with performance', assumes that only the difference explains variation in performance and that the absolute values of the profiles are irrelevant. For example, the explanatory power of a small difference between two profiles with high values for each element is considered similar to an equally small difference between two profiles with low values on each element. This assumption of iso-performance is also an assumption in contingency theory (Donaldson, 2005). Donaldson (2005) proposes to replace this idea with that of hetero-performance. He illustrates this with the example of organizational size and formalization: fit between high formalization and a large size could result in greater performance than fit between low formalization and small size. PSIs also loose information about the direction of differences between compared profiles. This is due to the calculation of squared differences or the absolute value of differences in many PSIs (see Box 2). Hence, it is assumed that positive and negative differences relate similarly to performance. Researchers are therefore advised to study the effects of insufficient and excessive ‘structure’ (e.g. Reuer and Arino, 1998).

Finally, Edwards (1993) shows - in a similar way as for bivariate models of fit (see Box 1) - that PSIs impose a restrictive set of constraints on the coefficients in regression models that relate PSIs to performance. Edwards (1993) therefore argues that PSIs should no longer be used and that its problems can be avoided by using polynomial regression analysis. This also solves the problems associated with aggregating distinct concepts into a single measure. Polynomial regression in the case of configurational theory means that the regression equation should contain the individual first-order elements, their squared terms, and the interaction term for each pair of the elements for which otherwise the difference would be calculated. Hence, polynomial regression captures the individual effects as well as the holistic and synergistic effect of the multidimensional profile by means of the total variance it explains ($R^2$). Profiles are usually built from a considerable number of elements however, which requires a large sample size to achieve sufficient statistical power and which complicates the interpretation of the regression results.

***Configurationalism and case study research***

In statistical tests of contingency and configurational theories the general hypothesis typically holds that fit between observed and predicted profiles increases the *likelihood* of high performance (Doty et al., 1993; Doty and Glick, 1994). The fit-performance relationship is therefore assumed to be probabilistic in nature. The alternative approach holds that the causal effect of individual (combinations of) variables on the dependent variable is deterministic, i.e. in terms of (combinations of) necessary and/or sufficient conditions (e.g. Mackie, 1965). Dul and Hak (2008) for instance adopt the perspective of “pragmatic determinism”, which holds that “*it is sometimes preferable to act as if a complete determinism exists, although it is acknowledged that there might be some exceptions to the assumed determinism*” (Dul and Hak, 2008, p.75). In this approach it is possible to test theories rigorously with case study methodology (Goertz and Starr, 2002; Dul and Hak, 2008; Jaspers and Van den Ende, 2008). In this thesis we consider causal effects to be probabilistic rather than deterministic however. Below we explain the rationale for this approach and what this means for the application of case study methodology in this thesis.

Organizational phenomena are typically influenced by a large number of causal factors. Consequently, many variables will inevitably be omitted from the analysis, which makes it inherently uncertain whether a particular combination of scores on an independent variable and a dependent variable reflects the causal effect between the two (King et al., 1994; Mohr, 1982). Individual real-life cases can for instance impossibly be exactly repeated with another value of the independent variable to assess the associated change in the dependent variable. As a result of this overdetermination, causal inference remains uncertain when comparing two or more cases - even if many factors are controlled for (King et al., 1994), i.e. there might always be countervailing forces that obscure a true effect (Glick et al., 1990).

In this case of overdetermination our understanding of organizational phenomena can be improved in two ways (Glick et al., 1990). The first (idiographic) approach is to describe and analyze the dynamics of individual instances in-depth. This approach therefore provides the possibility for case-to-case generalization, e.g. by practitioners (Firestone, 1993). The second (nomothetic) approach aims for knowledge about the causal strength of variables in wide theoretical domain or in a specific population of instances. This second approach recognizes that true causal effects can be obscured by countervailing forces, but it assumes that these forces occur at random. Hence, it is assumed that: *"any causal effect is a probabilistic rather than a deterministic event*" (Glick et al., 1990, p.297).[2]

Under the assumption of probabilistic theories, it is difficult to assess the strength of a causal effect with case study research, let alone to state for individual cases that "X determines Y". A more appropriate strategy to estimate the strength of a probabilistic causal effect is to apply statistical techniques (Dul and Hak, 2008), and this is perfectly possible for configurational hypotheses (Doty et al., 1993; Doty and Glick, 1994; Edwards, 2001). However, while inferior as a technique to test probabilistic theories, case study research is highly complementary to statistical techniques because of its capability to study within cases the causal mechanisms that show 'how and why' a certain effect is produced (King et al., 1994; Yin, 2003; George and Bennett, 2005; Gerring, 2007). Suppose one finds evidence within an individual instance about how a high value of X contributed positively to Y. Even though the actual value of Y in this instance might be low (due to one or more other explanatory variables), the observation of such a causal process *at a lower level of aggregation* does provide support for the theory that X has a particular effect on Y (King et al., 1994; Van de Ven, 2007).

This benefit of case study research is particularly strong for configurational theories (George and Bennett, 2005). Whereas statistical data analysis focuses on *causal effects* (e.g. regression coefficients), case-study research is highly complementary to this approach because of its capability to study *causal mechanisms* (George and Bennett, 2005). In other words, while statistical research is able to investigate how much an independent variable (or "fit with an ideal profile") explains performance, i.e. the strength of a causal effect, case study research is capable of providing insights about how and when a factor matters. These benefits of case study research are especially relevant for middle-range theories, which are more complex and at the same time more limited in scope than bivariate models of fit. Whereas statistical research studies individual causal effects or lumps them together in a single measure of fit (e.g. PSIs), (comparative) case study research is capable to elucidate interaction and synergy among variables at a lower level of aggregation (King et al., 1994; George and Bennett, 2005; Gerring, 2007), i.e. to study "*the cogs and wheels behind the regression coefficients*" (Davis and Marquis, 2005, p.341). Chapter 5 builds upon this principle and discusses it in greater detail.

[2] Interestingly, Glick et al. (1990) refer to Mohr (1982) and to Markus and Robey (1988) as methodological considerations of the idiographic approach. Both studies theorize about processes of change in terms of (combinations of) necessary conditions. In other words, this implies that the idiographic approach rests on the assumption of determinism. Contrary to what one might believe based on Glick et al. (1990) it is shown elsewhere (Jaspers et al., 2008) that it is perfectly possible to generate generalizable knowledge about these 'process theories' (Mohr, 1982) by means of rigorous theory testing. Hence, this is not only the realm of the nomothetic approach.

## 2.4 Conclusions and relevance for this thesis

This chapter introduced and discussed several key characteristics of contingency and configurational 'theory'. Although important differences exist between these two types of theory, they both focus on the explanatory power of 'fit' between concepts. This idea has strong intuitive appeal and this might be why many theories are based more or less explicitly on contingency or configurational logic. The overview presented in this chapter by no means aims to be comprehensive, but it does provide a sufficient background to the chapters that follow. As already outlined in Chapter 1 (see for instance Figure 1.1), all chapters are founded on the idea that successful innovation requires fit between the characteristics of the innovation and the characteristics of its organizational form.

The next chapter (Chapter 3) considers whether systems integrators should be 'open' or 'closed' with respect to the design and development of new products and components and how this is contingent on the technical characteristics of these innovations. Part 2 of this thesis (Chapters 4, 5, and 6) adopts a configurational perspective as it views the organizational form of NPD projects as a configuration of two or more organizational elements. Furthermore, these configurations are expected to be contingent on the technical characteristics of the innovations. Chapter 4 focuses on the involvement of mobile telecommunications operators - in terms of integration and ownership - in the development of mobile telecommunications applications. This chapter operationalizes fit using a combination of the deviation and the interaction approach. Chapter 5 involves a qualitative analysis of thirty cases in order to refine a theoretically-developed configurational theory. This analysis is based on the assumption outlined in this chapter that social phenomena can be considered to be probabilistic in nature. Under this assumption, case study research is a valuable method for the purpose of theory refinement and for the elucidation of causal mechanisms. Chapter 6 focuses on the characteristics of one very specific type of development project, i.e. the development of so-called inter-industry architectural innovations, and explores which organizational configurations fit the characteristics of this type of project.

Part 3 of this thesis applies the classic contingency approach to the conceptualization of fit. Chapter 7 initially tests such a bivariate interaction effect using moderated regression analysis. In addition analyses, a less constrained model is tested using polynomial regression. Chapter 8 and chapter 9 also involve moderated regression analyses to test bivariate (interaction) theories of fit.

Whereas the current chapter provides a theoretical background to this thesis in terms of the types of theories that will be developed and tested, the next chapter provides a more detailed introduction to systems integration, which is one of core concepts in this thesis. More specifically, Chapter 3 explores the concept of systems integration in relation to Open Innovation, which refers to an overall approach to innovation management that has received a lot of attention recently.

# 3. Open Innovation and Systems Integration: How and Why Firms Know More Than They Make


**Abstract**

This chapter investigates the application of Open Innovation for the development of complex products. Open Innovation refers to a popular approach to the management of innovation that seeks to improve the value of a firm's innovation efforts by making use as much as possible of the firm's environment. In particular, we investigate the relation between Open Innovation and systems integration. Systems integration refers to the capability to design new product architectures and to align existing product systems in the face of component innovation. We argue that Open Innovation and systems integration are complements. Open Innovation essentially results in firms that 'know more than they make' as this approach stimulates firms to monitor and to absorb external technological developments. Systems integrator firms integrate this 'excessive' knowledge to generate detailed architectural knowledge about component interrelationships, which is core to their systems integration capability. This suggests a balanced approach to Open Innovation, i.e. open as far as abundant knowledge and capabilities about individual components and technologies are concerned, and closed with respect to the generation and exploitation of scarce architectural knowledge. Furthermore, we suggest a contingent approach to Open Innovation, as different types of component innovation require different Open Innovation mechanisms to provide systems integrators with the knowledge they need to ensure the integrity of their product systems.


This chapter is important as a background to the remainder of this thesis, because systems integration is a core concept in the chapters that follow. As will be outlined in this chapter, systems integration is critical to the management of systemic innovation. In addition, the discussion of systems integration relative to Open Innovation is relevant because Open Innovation has received a lot of attention recently by both academics and practitioners. It is therefore important to position this thesis relative to this popular trend and to investigate whether opportunities exist for cross-fertilization. Furthermore, by discussing Open Innovation in this introductory part of the thesis, we are able to discuss in subsequent chapters how our findings are able to improve our understanding of Open Innovation.


*The authors (Ferdinand Jaspers and Jan van den Ende) thank Andrea Prencipe for his useful suggestions. This chapter is conditionally accepted for publication in the special issue "Broadening the Scope of Open Innovation" of the International Journal of Technology Management.*

### 3.1 Introduction

Open Innovation - as put forward by Rigby and Zook (2002) and Chesbrough (2003a) - refers to the trend that more and more firms adopt an 'open' innovation strategy. Whereas firms used to perform the entire innovation process internally (i.e. from idea generation to technology commercialization), Open Innovation deviates from this classic 'closed' approach in that firms extensively interact with and rely upon their environment for one or more stages of the innovation process. For instance, firms may actively search for and absorb ideas from universities, users, suppliers, or firms from other industries, and they may also actively involve them in the development and testing stages. In addition, firms may use external actors in the commercialization of their intellectual capital, e.g. by licensing technologies and by creating spin-offs.

Existing literature has indicated that Open Innovation is a pervasive phenomenon that can be found in a wide variety of industries (Chesbrough et al., 2006; Chesbrough and Crowther, 2006), including consumer electronics (Christensen et al., 2005), manufacturing (Laursen and Salter, 2006), mobile telecommunications (Dittrich and Duysters, 2007), agricultural biotechnology (Vanhaverbeke and Cloodt, 2006), and open source software development (West and Gallagher, 2006). Furthermore, evidence exists that Open Innovation influences the innovative performance of firms, but that firms must be careful not to become excessively open, e.g. as they might 'over-search' for innovative ideas (Laursen and Salter, 2006).

According to Chesbrough (2003a) the fundamental reason for the emergence of Open Innovation is that firms operate more and more in '*a landscape of abundant knowledge*' (Chesbrough, 2003a, p.xxv). Whereas firms used to have all relevant technologies in-house and used to rely on its own experts, in the last decades numerous 'erosion factors' have made closed innovation untenable. For instance, employees are much more willing to seek employment elsewhere; suppliers have become much more capable to support their customers; venture capital has emerged as a way to finance external innovations; and people in general are more educated than ever before. These forces have resulted in the adoption of Open Innovation practices that exploit external knowledge and capabilities in order to improve the speed, the quality, and the cost of innovation and - ultimately of course - to improve the value that firms create and capture with own innovate effort. Practices included in the umbrella concept of Open Innovation for instance include the well-known ideas of supplier involvement, technology monitoring, licensing-in and licensing-out, establishing spin-offs, and university collaborations. In the quest for competitive advantage the increased adoption of such practices is seen as a critical source of competitive advantage (Rigby and Zook, 2002; Chesbrough, 2003a). There is no room for the Not Invented Here syndrome.

Although we have a basic understanding of the emergence of Open Innovation over time, the development of 'an Open Innovation theory' to explain the (innovation) performance of firms is still in its infancy. To fully understand this phenomenon in today's economy and to provide managerial guidance, we need a better understanding about why, how, and when firms do or do not apply Open Innovation and what its performance consequences are. In other words, research is needed to explore the boundary of this relatively new concept and theory, e.g. in terms of assumptions about values, time, and place (Bacharach, 1989). In this regard an important approach is to 'broaden the scope of Open Innovation' by investigating and 'challenging' this paradigm in extreme settings, because this increases the likelihood to find new insights and important scope conditions (e.g. Firestone, 1993; Eisenhardt and Graebner, 2007; Gerwin, 2006).

In this chapter we focus on the application of Open Innovation in the development of complex product systems, such as mobile telecommunications networks, flight simulators, jet engines, oil platforms, defense systems, and large construction works (Miller et al., 1995; Hobday, 1998; Brusoni et al., 2001; Van den Ende, 2003). Several studies have touched upon the issue of Open Innovation in the context of complex products (e.g. Chesbrough, 2003a [Chapter 3], Chesbrough, 2003b, Maula et al., 2006) or have called for future research in this area (Laursen and Salter, 2005; West et al., 2006), but to our knowledge no studies have explicitly aimed to integrate the literature about Open Innovation and the literature about the development of complex products and - more in particular - systems integration. Our study therefore involves a first integrative analysis of both bodies of literature. This is based on the conviction that fruitful research at the intersection of both fields can only proceed if prior findings are used to identify and to clearly define conceptual linkages and to guide the development of questions and propositions for future research. This approach seems all the more relevant given the substantial body of literature that has developed on the issue of complex product development in recent years (e.g. Brusoni et al., 2001; Prencipe et al., 2003; Hobday et al., 2005).

Complex product industries provide a unique context to study Open Innovation. First, complex products consist of many technologically distinct components and subsystems. No single firm can therefore master all technologies involved and develop internally all of the product's components and subsystems (Hobday et al., 2005). Open Innovation is therefore most likely to be applied in this context, which means that findings for this setting can have strong implications for our understanding of this concept and its theoretical claims (Markus, 1989; Gerring, 2007). Not surprisingly, the empirical literature about complex product systems has indeed pointed out that the development of complex products typically involves substantial networks of collaborating component and technology developers (e.g. Miller et al., 1995; Brusoni and Prencipe, 2001b).

Secondly, complex products are typically highly interdependent and require interoperability among its customized components for the product as a whole to perform as intended (Hobday, 1998). Hence, there is a strong and apparent need in this setting for coordination and control, which can be regarded the major benefits of the traditional 'closed' approach to innovation (e.g. Teece, 1986). This need for coordination and control seems even more important in the face of rapid technological change and given the necessity to recoup the substantial investments that are required for complex product innovation. In other words, the innovation process for complex products is characterized by the need for being simultaneously open and closed. This gives rise to our central research question, i.e. how firms (should) manage the dilemma between being open and being closed in the development of complex products and why?

The literature about the development of complex products indicates that networks of component and technology developers are typically coordinated by ‘systems integrator firms’ that ‘know more than they make’ (Brusoni et al., 2001). By maintaining and improving knowledge about externally developed technologies and components these firms are able to design coherent product architectures and to align components in the face of technological change (Brusoni et al., 2001). Our conceptual analysis points to strong complementarities between Open Innovation and this concept of ‘systems integration’. We illustrate the findings from our integrative literature study by presenting a brief case of Intel’s innovation strategy. This case is well-known as an example of Open Innovation, and by analyzing this case from the perspective of systems integration we are able to show how much both concepts are intertwined. We go as far as to claim that one cannot go without the other.

One the one hand, Open Innovation forms an integral part of systems integration, because systems integrators do not and cannot have the capabilities to master every technology and to develop every component. In particular, whereas systems integration indicates *why* firms need to ‘know more than they make’, Open Innovation provides mechanisms and practices indicating *how* firms may access external knowledge. Furthermore, we propose that the application of Open Innovation mechanisms is contingent on the type of technological change that needs to be integrated. In this respect, we propose a tentative model of Open Innovation for different types of component innovation. In sum, systems integration cannot be effective without Open Innovation.

On the other hand, Open Innovation cannot be successful without systems integration. In this respect, systems integration clearly points to the limits of Open Innovation. Whereas Open Innovation is based on the premise of ‘abundant knowledge,’ the context of complex products stresses the scarcity of architectural knowledge about how technologies and components interrelate. To optimally benefit from one’s own capabilities and from the external knowledge and ideas that can be accessed through Open Innovation, some form of systems integration is needed to integrate and combine them into new products. Furthermore, systems integration literature points to the competitive advantage one could derive from introducing entirely new product architectures, and to the durability of this advantage as a result of the unique mix of internal and external capabilities.

The chapter is structured as follows. First we briefly introduce the literature about systems integration. After that we explore its relationships with Open Innovation in two separate sections for two different subclasses of systems integration (i.e. static and dynamic systems integration). Subsequently, we present the illustrative case of Intel’s strategy of Open Innovation. The concluding section discusses our findings, presents opportunities for future research, and points to several manager implications.

### 3.2 Systems integration and complex product innovation

Unlike most (commodity) products, the 'ideal-typical' complex product system consists of a large number of technologically distinct and interdependent components and subsystems (Miller et al., 1995; Hobday, 1998). Examples are aircrafts, submarines, flight simulators, telecom networks, etc. For individual firms it is simply impossible to develop and produce these products entirely in-house (Hobday et al., 2005; Nosella and Petroni, 2007). Instead, firms responsible for the design and development of complex product systems, i.e. prime contractors or 'systems integrators' (Brusoni and Prencipe, 2001b), rely extensively on networks of external actors (e.g. suppliers, users, complementors, universities, and research centers) for the development of components and technologies. This indicates that Open Innovation is an integral part of the innovation process of complex product systems.

However, whereas the detailed design and development of many components is performed by external parties, Brusoni et al. (2001) found that systems integrators tend to develop and maintain a basic technological understanding of these components and their dynamics, i.e. these firms 'know more than they make'. Furthermore, systems integrators integrate this external knowledge and their own capabilities to develop a detailed understanding about component interactions and the design of the product architecture. This architectural knowledge (Henderson and Clark, 1990) is fundamental to the system firm's capability to design coherent product architectures and to coordinate technological changes (Brusoni et al., 2001). Systems integration is therefore far more than the capability or the activity to assemble components, instead it also refers to the higher-order capability to understand and integrate multiple technological disciplines (Prencipe, 2003).[3] Consider the case of the Airbus A380. The development of this multi-billion airliner involves a completely new aircraft design and consists of a huge amount of complex components and subsystems (e.g. with the cabin wiring alone consisting of 100,000 wires and more than 40,000 connectors). Airbus maintained overall responsibility for the design and the integration of the aircraft, but for many components and subsystems (e.g. engines, materials, electronics, etc.) it cooperated with and relied upon many different actors, such as suppliers and universities. This tight integration for the airplane as a whole was needed to ensure that the plane would meet its strict security demands and design trade-offs, in terms of for instance its weight, strength, and durability.

Whereas Open Innovation is based on the principle that firms operate in 'a landscape of abundant knowledge', the case of complex product innovation shows that systems integrators are focused on the internal generation, maintenance, and nurturing of high-quality architectural knowledge. External specialists are most likely to possess valuable and specialized component-level capabilities, but architectural knowledge is typically highly tacit and product-specific and therefore far from abundant. The strategy to position

[3] It has to be noted that systems integration as used in this thesis pertains to what could be called the narrow definition of the term (Hobday et al., 2006), referring to a specific coordination mechanism for the network of component suppliers based on a knowledge 'surplus' by the systems integrator firm. In a more broad sense the term systems integration is also used to describe and study the related trend that large product system firms increasingly outsource component development and manufacturing, and at the same time integrate forward by providing the end products together with advanced services, such as maintenance and other support activities, i.e. systems integrators are total solution providers, like IBM in the computer industry (e.g. Prencipe et al., 2003; Davies et al., 2007).

oneself as a systems integrator and to develop broad and deep systems knowledge is a lengthy, a costly, and a risky process (Adner, 2006), but given the scarcity of this knowledge and the difficulty to imitate systems integration capabilities, its potential pay-offs are significant, i.e. a strong and sustainable competitive advantage may result.

The notion of systems integration is closely related to concepts in other parts of the literature. Systems integration for instance refers to network organizational forms coordinated by leading firms. In the literature this principle is also referred to as ‘network orchestrators’ or ‘hub firms’ (e.g. Gomes-Casseres, 1996; Dhanaraj and Parkhe, 2007) that manage and coordinate ‘ecosystems’ (Adner, 2006) or ‘value constellations’ (Normann & Ramirez, 1993; Vanhaverbeke & Cloodt, 2006). Furthermore, systems integration is similar to the concept of absorptive capacity, which entails that firms are able to more effectively assimilate and integrate external knowledge if they already possess related knowledge (Cohen and Levinthal, 1990).

Systems integration also has close links with Open Innovation. For instance, it perfectly illustrates the importance and the changed role of internal R&D in the Open Innovation era, i.e. the firm’s R&D activities should no longer be mainly concerned with internal knowledge generation, but instead they should aim to integrate internal knowledge and external knowledge to come up with new product architectures (Chesbrough, 2003a). Below we explore and discuss these linkages in greater detail for two different but related types of systems integration: i.e. static (or synchronic) systems integration and dynamic (or diachronic) systems integration (Brusoni and Prencipe, 2001b; Prencipe, 2003). The former focuses on the coordination of component innovations within a firm’s current product architecture, whereas the latter plays a crucial role in renewing the product architecture itself.

### 3.3 Open Innovation and synchronic systems integration

Systems integrators are confronted with continuous technological change to the many components that constitute their products. Given their limited resources, system firms face difficult decisions regarding the extent that they should be involved in the design and development of these innovations. Brusoni et al. (2001) have shown that this is not simply a choice between make or buy, because system firms often maintain capabilities and knowledge related to components that are developed externally. Based on their study of technological change in the jet engine industry, Brusoni et al. (2001) propose a framework of appropriate coordination mechanisms for four different types of component innovation. These four types of technological innovation are defined in a two-by-two matrix based on the rate of component technology change and the predictability of interdependencies. The resulting four types of component innovation closely resemble the four types of innovation as put forward by Henderson and Clark (1990), i.e. incremental, modular, architectural, and radical innovation (see Figure 3.1). Below we discuss this model from the perspective of Open Innovation and we suggest how Open Innovation can be applied in each of the four types of innovation.

#### *Incremental component innovation*

Incremental component innovations are based on existing technology and for them it is known in advance how they can be implemented in the product system. Many elements of the PC architecture are for instance continuously being refined while staying within the limits of existing interface specifications (e.g. monitors, processors, software applications). In line with the reasoning of transaction cost economics (Williamson, 1975) and the literature about product modularity (Sanchez en Mahoney, 1996; Schilling, 2000), Brusoni et al. (2001) propose the market as the most appropriate organizational form to coordinate this type of innovation. In this approach, the system firm and component producers interact at arm's length. This is appropriate since there is no need for information exchange to (re)define interfaces and since it can be assumed that high-powered incentives exist that motivate external specialists to come up with (incrementally) new components.

In general, the market mechanism is not considered to be Open Innovation. Once components have been successfully developed externally, the system firm can simply decide to buy these components and integrate them in their product system or not. However, the invisible hand of the market mechanism is an extreme coordination mechanism and system firms can certainly play an active role for this type of innovation. System firms may for instance publish and spread interface specifications about how components have to be designed to fit with their products (e.g. 'cookbooks'). They may even want to more actively promote component development, such as for the development of complementary products. To the extent that external innovators come up with a wide variety of innovative components and complementary products, this of course benefits the system firm. In the mobile telecommunications industry for instance a wide variety of third parties (e.g. start-ups, banks, retail chains, entertainment and media companies, etc.) develops and commercializes advanced mobile data applications without any involvement of telecom operators. System firms may also implement several practices to tap into the creativity and complementary resources of external actors, such as organizing developer contests and issuing awards, promoting the generation of external ideas for specific certain components (i.e. focused and open idea generation).

In their study of the Japanese video game industry for instance, Aoyama and Izushi (2003) show that platform developers (i.e. system firms) rely on the flexibility, diversity, and creativity of hundreds of independent software publishers. To facilitate innovation by these software publishers, platform developers provide them with detailed architectural knowledge about for instance software development standards, new versions of operating systems, and quality inspections. Similarly, Funk (2003) illustrates that NTT DoCoMo shared detailed information about its open mobile telecommunications standard PDC with a set of intimate mobile phone suppliers. This early access to in-depth and standardized architectural knowledge provides certainty to suppliers and enables them to set the dominant design for mobile phones, whose technological core may well be straightforward (i.e. incremental component innovation). Furthermore, external entrepreneurial activity, although perhaps not technologically advanced, may result in promising components with respect to certain market needs, thus prompting the system firm to internalize them.

***Radical component innovation***

Radical component innovations are based on new technology and it is generally unknown how these innovations can best be implemented in the product system. Electric car engines for instance use a completely different technology than gasoline engines. Their implementation in cars requires substantial adjustments of many other car components and only after extensive experimenting and testing it is understood how other components have to be adjusted and how interfaces can best be defined. In line with transaction cost reasoning and in line with many studies on the organization of innovation (e.g. Chesbrough and Teece, 1996), Brusoni et al. (2001) propose vertical integration or ‘make’ as the most appropriate organizational form for this type of innovation.

For Brusoni et al. (2001) the most important reason to propose vertical integration is that the hierarchy of authority within the systems integrator can be expected to facilitate the required information exchange that is needed to discover and resolve the high level of interdependence for this type of innovation (e.g. Tushman and Nadler, 1978). In addition, vertical integration implies that the system firm finances and performs the development project (e.g. Robertson and Langlois, 1995; Gulati and Singh, 1998; Jaspers and Van den Ende, 2006). This can also be considered beneficial for this type of innovation, because it reduces concerns about knowledge spillovers and prevents the need to (contractually) safeguard this highly uncertain project. Furthermore, external component and technology developers might refrain from committing themselves to this highly uncertain type of innovation, which forces system firms to ‘go it alone’ (e.g. Van de Vrande et al., 2006).

It is increasingly being recognized however that Open Innovation can play an important role in processes of radical and highly uncertain innovation processes (e.g. O’Connor, 2006; Dittrich and Duysters, 2007). In this respect, a ‘learning dilemma’ exists (John et al., 2001). On the one hand, vertical integration might facilitate coordination and reduce appropriation concerns. On the other hand, the involvement of external actors in the project may help to reduce uncertainty, i.e. it means that different capabilities and different views are included in the innovation process. In addition, collaboration may help to spread risks and investments. It must also be noted that radical component innovations may demand technological change of other components, which makes it likely that system firms need to collaborate with external developers of interdependent components to integrate the system. Fujitsu for instance developed an entire new architecture of the hard disk drive following a technological breakthrough related to one of its components, i.e. the magneto-resistive head (Chesbrough and Kusunoki, 2001; Brusoni et al., 2007).

Should firms apply Open Innovation in the case of radical component innovation, then we suggest them to do this cautiously, e.g. by closely monitoring the knowledge generation at partners and the information flows across its boundaries (e.g. Brusoni et al., 2001). This may help to reduce appropriation concerns, but it also provides the firm with the knowledge to understand and act upon the technical and architectural implications of these innovations. Joint and collocated teams would for instance provide such monitoring. Furthermore, partner selection needs to be based on the likelihood that a partner is capable to help reduce the high degree of technological uncertainty of this type of innovation. In this respect, universities may be appropriate choices (e.g. Belderbos et al., 2004). Another, albeit rather ‘heavy’, option would be the creation of a joint venture. This allows risks to be spread, it increases a partner’s commitment, and it also allows for the establishment of formal safeguards. Finally, firms may stimulate creativity for the generation of radically new components by means of unfocused and out of the box idea generation mechanisms.

*Modular and architectural component innovation*
Modular component innovations involve technologically new components that can be implemented in product systems based on existing interfaces. The modular PC architecture is for instance well-known for its capability to accommodate entirely new components without requiring adjustments to other components. However, an uneven rate of technological change between components can easily result in ‘technical imbalances’ (Rosenberg, 1976) that reduce the performance of the product system as a whole (e.g. these innovations could result in new ‘bottleneck components’). In the case of PCs, new and advanced software applications may for instance require the development of faster computer chips to fully exploit the benefits of the software.

Architectural component innovations are the exact opposites of modular component innovations: these new components are based on mature technology, but their implementation requires the development of new interfaces. Consider the architecture of a mobile phone. The extension of these products with a digital camera module demands substantial adjustments to other components, such as the screen and the processor. Several redesigns are likely before this new but technologically straightforward component is optimally integrated in the product’s architecture.

For both types of innovation Brusoni et al. (2001) suggest ‘systems integration’ as the most appropriate coordination mechanism. Systems integration is a coordination mechanism in between the extremes of the market and the hierarchy. In this organizational form the systems integrator relies on external firms for the detailed design and development of the component, but it maintains internally the knowledge and capabilities about the basic design of the component and therefore also about this component’s relationships with other components, i.e. architectural knowledge (Henderson and Clark, 1990). This architectural understanding helps the system firm to effectively coordinate component changes and therefore to ensure the integrity of the product. Takeishi (2002) for instance found that car manufacturers were better able to integrate externally designed car components if they maintained internal coordinative capabilities related to these components.

Brusoni et al. (2001) define systems integration more precisely by referring to Weick’s (1976) concept of coupling. Different types of coupling can be viewed as distinct combinations of ‘distinctiveness’ and ‘responsiveness’ (Orton and Weick, 1990), or in the terms of Brusoni et al. (2001) as combinations of ‘specialization’ and ‘integration’ (see also Lawrence and Lorsch, 1967; Van de Ven, 1986; Sheremata, 2000). Coordination by means of market-based relationships can be considered a ‘decoupled’ organizational form. Component developers each pursue their own technological paths, go through their own learning processes, and innovate in parallel. At the same time, the systems integrator neither has the authority nor the required knowledge and information-processing capabilities to coordinate these dispersed activities at external suppliers. Put differently, this organizational form is characterized by high specialization and low integration. Conversely, vertical integration is a ‘tightly coupled’ organizational form that provides the system firm with strong capabilities to coordinate processes of component development, but this does not generate the specialization benefits of dispersed experimentation and learning.

The coordination mechanism of systems integration combines the organizational characteristics of specialization and integration in a 'loosely coupled' organizational form. Specialization results from the involvement of external actors that take on the responsibility for the detailed design and development of components. Integration (i.e. the capability to coordinate the dispersed innovation effort) results from the system firm's extensive knowledge about the system as a whole and from its basic knowledge about the components' core design concepts. In essence, systems integration therefore means that system firms 'know more than they make' (Brusoni et al., 2001). Brusoni et al. (2001) also explain *why* this is important: it enables systems integrators to identify and deal with interdependencies and technological imbalances so as to achieve unity of effort and to maintain a coherent product system. An important question is of course *how* system firms can expand their knowledge boundary beyond their production boundary to optimally accommodate modular and architectural component innovations. This is where Open Innovation comes in the picture.

Modular component innovations can be implemented in the product system based on existing interfaces, but their technological novelty might result in technical imbalances. To learn about possible imbalances and to understand what technological changes are required to other components, systems integrators need to closely monitor modular component innovations. Close links are therefore required with for instance specialized suppliers and universities. In addition, technological developments in other industries need to be monitored for their potential influence on the product system. This monitoring is likely to be effectively performed by system engineers, because these people will understand the system-wide implications of these innovations. There is no need for extensive communication with external innovators however, because modular innovations are based on existing interfaces. Some collaboration with external innovators, such as the facilitation of components tests, might however be an effective way to generate a better understanding of new component technologies and their implications for the product as a whole. Another way to come to understand a new component technology may be to (temporarily) hire an external specialist. Should the idea for a modular component innovation appear internally, seed-funding or creating a spin-off can be appropriate mechanisms. Furthermore, idea-generation systems might also be applied for modular innovations. Of course it is only in the actual design and development of an idea that it will be discovered or determined whether a technologically new component involves a modular or a radical component innovation.

Architectural component innovations cannot be readily implemented in the product system, because of the required interface changes (e.g. the size and shape of interrelated components has to change). As a result, an important responsibility of systems integrators is to identify interdependencies and to coordinate the specification of new interfaces. Intense exchange of coordinative information is therefore needed, for instance by means of establishing teams and working groups with representatives from interdependent component developers, by designing new interface specifications, by reviewing externally specified interfaces, or by facilitating tests.

In sum, our analysis above has indicated that Open Innovation serves the purpose of systems integration as it facilitates the development of knowledge about externally developed components. Furthermore, we have seen that Open Innovation plays an important role in the case of component innovation, but that the specific application of Open Innovation differs across the four types of innovation. In other words, our analysis proposes a tentative contingency model of Open Innovation (see Figure 3.1). Note that 'cautious collaboration' as suggested for radical innovation comes close to the concept of systems integration, because the 'excessive knowledge' as a result of monitoring not only serves a monitoring purpose (e.g. to prevent expropriation), but also a coordination purpose.

**Figure 3.1 Component innovation and a contingent Open Innovation model**

<table>
<tr><th></th><th></th><th colspan="2">Product Interdependencies</th></tr>
<tr><th></th><th></th><th>Predictable</th><th>Unpredictable</th></tr>
<tr><td rowspan="2">Rate of Change of Component Technologies</td><td>Even</td><td>Incremental component innovation:<br>coordination via market mechanisms<br><br>External innovation with limited or no need to exchange information or monitor<br><br>- Publish or license-out interface specs<br>- Stimulate innovation (e.g. contests; focused idea generation)<br>- Possibly internalize promising innovations</td><td>Architectural component innovation:<br>coordination via systems integration<br><br>Intense exchange of coordinative information with external specialists<br><br>- Participating in external teams<br>- Providing and reviewing interface specifications<br>- Facilitating component tests</td></tr>
<tr><td>Uneven</td><td>Modular component innovation:<br>coordination via systems integration<br><br>No need for active involvement or frequent information exchange<br><br>- Monitoring by system engineers<br>- Facilitate component testing.<br>- Hiring of specialists.<br>- Spin-offs/seed funding<br>- Open, unfocused/out of the box thinking</td><td>Radical component innovation:<br>coordination via vertical integration or systems integration<br><br>Cautious collaboration<br><br>- Teaming up with universities or other specialists<br>- Joint, collocated teams<br>- Joint ventures<br>- Open, unfocused/out of the box thinking</td></tr>
</table>

Source: Basic framework adapted from Brusoni et al., 2001, p.611.

## 3.4 Open Innovation and diachronic systems integration

Above we have seen that Open Innovation mechanisms provide system firms with knowledge about externally developed components and that they combine this knowledge to generate a detailed understanding of the product's architecture. In this way Open Innovation helps system firms to coordinate component-level technological change and to ensure the integrity of their current product systems (i.e. synchronic systems integration). In addition, system firms use their systems integration capabilities to design and to experiment with entirely new product architectures, i.e. dynamic, intergenerational or diachronic systems integration (Brusoni and Prencipe, 2001b; Prencipe, 2003; Hobday et al., 2005). This section first of all discusses two views about how product architectures and organizational forms evolve over time and about the difficulty to make the shift to next-generation product architectures and to start a new technological trajectory (e.g. Dosi, 1982). Subsequently, we discuss how diachronic systems integration relates to these two views and what its implications are for Open Innovation.

***The modularity trap of loosely coupled organizational forms***

The modularity literature typically assumes that coordination and control within vertically integrated firms is needed to design experimental and interdependent product architectures. Over time these architectures become increasingly modular as interdependencies are better understood and as interfaces are clearly specified (Chesbrough, 2003b). Architectural stability for instance results from the emergence of a 'dominant design' from a set of competing product architectures (Abernathy and Utterback, 1978; Murmann and Frenken, 2006). The stability of product interfaces contributes to component-level improvement as a result of focused and parallel innovation efforts from autonomous technology specialists (Dosi, 1982; Baldwin and Clark, 1997). The dominant view is therefore that product and organizational modularity are strongly linked, i.e. over time vertical integration is being replaced by market mechanisms (Sanchez and Mahoney, 1996). In this regard, Chesbrough (2003a) suggests that the application of Open Innovation changes over time (see also Christensen et al., 2005), i.e. Closed Innovation is needed in the early, highly interdependent stage of a product's life cycle, gradually giving way to Open Innovation for mature and modular product architectures (see also Maula et al., 2006).

As most industry participants focus on component improvement within the limits of the dominant product architecture, knowledge about how components interrelate and about how the system as a whole can be improved tends to erode. In this respect, Chesbrough and Kusunoki (2001) point to the danger of a 'modularity trap'. As the technical limits of a given product architecture are reached, loosely coupled organizational forms lack the capabilities to design and adopt new architectures (Chesbrough, 2003b). Similarly, Brusoni et al. (2007) point to the constraints of problem solving under conditions of modularity, i.e. modular search helps to reach a local optimum fast and efficiently, but it lacks the capabilities of broad and integral search for distant but higher peaks.

Given these limits of modularity at the end of a product's life cycle, Chesbrough (2003b) suggests that industries need to find ways to move back to an integrated state at the end of a product's life cycle to help them shift to the next technological paradigm. In a similar vein, Pisano (2006) argues that biotechnology has failed to live up to its expectations because of its disintegrated industry structure. He argues that more vertical integration, more network coordination, and more long-term relationships between large pharmaceuticals and small biotech entrepreneurs are needed to realize the systemic potential of biotechnology.

***The 'embeddedness trap' of vertical integration***

Whereas the modularity literature assumes that intermediate markets emerge for specific modules and activities (e.g. Jacobides, 2005), other literature exists that focuses on the opposite scenario, i.e. where incumbents remain responsible for and in control of the product architecture (Henderson and Clark, 1990). Interestingly, Henderson and Clark (1990) also point to a competency trap to introduce new product architectures at the end of a product's life cycle. They argue that architectural knowledge tends to become implicitly and tacitly embedded in the firm's structures and processes. Units responsible for interrelated components will for instance develop formal and informal communication channels between them to effectively coordinate their tasks (Von Hippel, 1990; Sanchez and Mahoney, 1996). In addition, units tend to develop information filters to respond only to new information that is relevant to the way that components currently interact. Other information gets filtered out. Furthermore, firms create routine problem-solving strategies (Nelson and Winter, 1982) that are specific to the dominant design and that reduce the need to communicate and negotiate in the case of interface problems.

This embeddedness of architectural knowledge in the processes and structures of incumbents is efficient as long as the current product architecture meets the demands of users and as long as improvements can still be realized, but it makes it difficult for incumbents to identify architectural opportunities, to unlearn existing architectural knowledge, and to come up with new architectural designs (Henderson and Clark, 1990). As a result of this 'blindness' (Dosi, 1982), or what we may call 'embeddedness trap', Henderson and Clark (1990) argue that new entrants (unencumbered by this embeddedness) may overtake incumbents with new product architectures.

***Systems integration: an intermediate position***

Systems integration is a coordination mechanism in between the market and the hierarchy (Brusoni et al., 2001). As a result, it deviates from the two abovementioned views. If complex products become more modular over time, systems integrators do tend to rely more and more on external actors, but it will not come to resemble a loosely-coupled, market-based organizational form. System firms maintain a coordinative role to integrate the dispersed activities of external actors (Brusoni and Prencipe, 2001b), i.e. product modularity will not result in a modular organizational form (see also Takeishi, 2002; Hoetker, 2006). Neither will systems integrators ever be vertically integrated. Even for highly interdependent designs, system firms will have to rely at least in part on external firms given the sheer complexity of their products.

Under all circumstances systems integrators therefore continuously need to monitor component-level dynamics and need to adapt their architectural knowledge accordingly. This continuous effort to monitor, absorb and integrate new technological developments not only allows systems integrators to ensure the integrity of their current product systems, it also provides them with the capability to design and experiment with entirely new product architectures, i.e. (system-level) architectural innovation (Henderson and Clark, 1990). Furthermore, to the extent that a completely new product architecture requires changes to be implemented by external developers and complementors, i.e. systemic innovation (Chesbrough and Teece, 1996; Maula et al., 2006), this same architectural knowledge helps system firms to coordinate these changes. In sum, system firms are able to simultaneously exploit their current product systems and to explore new ones (Prencipe, 2003).

The principle to design entirely new product architectures based on the integration of external ideas and technology is also applied outside the setting of complex products. Well-known is Procter & Gamble's innovation strategy dubbed 'Connect and Develop'. In this approach P&G searches for complementary products and ideas in a wide variety of disciplines. In addition, this open innovation approach is complemented by several organizational and technological mechanisms that promote the development of new and unobvious connections between internal and external knowledge (e.g. Dodgson et al., 2006; Huston and Sakkab, 2006). This for instance involves digital prototyping, which is able to integrate many different technologies that may be embodied in a new product (e.g. Dodgson et al., 2006). Similarly, Rigby and Zook (2002) stress the importance of complementing Open Innovation with a centralized and formalized internal organization to monitor, disseminate, and integrate knowledge of the various innovation activities that move into, out of, and around the firm.

By being open for external ideas and technology, and by developing deep systems knowledge, system firms are able to avoid the abovementioned competency traps (Prencipe, 2003; Brusoni et al., 2007). This complements prior literature (e.g. Henderson and Clark, 1990; Maula et al., 2006) by suggesting that systems integrators are less likely to be overtaken by new entrants. In fact, systems integrators tend to dominate successive generations of product architectures (e.g. Boeing and Airbus in aircraft manufacturing and Nokia and Ericsson in telecommunications technology). Incumbents sometimes increase their chances of survival and significantly reduce innovation risks by means of collaboration with other incumbents (e.g. Miller et al., 1995). For the design of a new DVD technology most incumbents for instance participated in one of two competing consortia (i.e. Blu Ray and HD DVD).

In the conventional view on the dynamics of industries, new entrants emerge in periods of discontinuous technological change, i.e. when the competencies of incumbents tend to be destroyed in a wave of 'creative destruction' (Schumpeter, 1942; Tushman and Anderson, 1986). In complex product industries few firms have the capabilities and the resources however to overcome entry barriers. New entrants for instance generally lack architectural knowledge to successfully develop a product architecture of their own as well the financial resources to build such a knowledge base (e.g. Hobday, 1998). Whereas specialized knowledge about individual component technologies tends to be abundant, this shows that architectural knowledge is typically a scarce resource that requires substantial specific investments. This scarcity and its associated sunk costs are strong entry deterrents providing competitive advantage to incumbent systems integrators.

In sum, systems integrators are able to design and coordinate new architectures based on the extensive knowledge and capabilities they maintain and integrate about components they do not develop in-house. The application of Open Innovation as discussed for the synchronic integration of component-level change is therefore also relevant for diachronic systems integration. Without up-to-date component knowledge there are no ingredients to explore system-level changes. In fact, close monitoring of component-level technological change may result in the recognition of new system-level opportunities (e.g. the design of a completely new hard disk drive by Fujitsu following strong technological improvements in one specific component).

### 3.5 An illustrative case: Open Innovation at Intel for reasons of systems integration

Intel's innovation strategy (Chesbrough, 2003a; Tennenhouse, 2004) is a well-known example of Open Innovation. It also provides a perfect illustration however of the conceptual linkages between Open Innovation and systems integration as discussed in this chapter. This brief case shows that Intel - to sustain its leading position as a computer chip provider - makes extensive use of external knowledge in order to generate rare and difficult to imitate architectural knowledge and systems integration capabilities. In other words, it is the *combination* of Open Innovation and systems integration that forms the basis of Intel's innovation strategy.

Illustrating the importance to create internally high-quality and proprietary architectural knowledge, Intel has set up three specialized labs (Chesbrough, 2003a) that each contribute to Intel's systems integration capability. First, Intel's Components Research Lab focuses on developments related to individual elements of microprocessors and their production processes. This for instance involves collaboration with suppliers to evaluate the impact of component innovations on other components and to learn about opportunities to combine them. Secondly, Intel Microprocessor Lab investigates future microprocessor architectures. Hence, this research facility focuses on a higher level of Intel's value chain by viewing microprocessors as systems created from a range of component and operations technologies. Thirdly, Intel's Architecture Lab operates at an even higher level of abstraction by adopting the perspective of entire computer architectures, in which microprocessors operate as a crucial subsystem.

Open Innovation and external knowledge plays a crucial role in each of these research labs. Intel especially views universities as an important source to learn about technological developments that might result in new businesses and disruptive innovations (Tennenhouse, 2004). To explore promising ideas, Intel adopts a combination of four research approaches: (1) university research grants; (2) research labs located near universities; (3) corporate venturing; and (4) internal projects for strategically important and proprietary research. Intel actively coordinates the research activities of these four research facilities to make sure that their research efforts concurrently address the same themes (Tennenhouse, 2004). Each unit has its own research focus, but sufficient overlap and knowledge transfer exists to pursue and explore opportunities for synthesis. This integrative approach is inspired by the innovation approach of DARPA (the US Defense Advanced Research Projects Agency), which typically deals with the development of complex product systems.

The underlying logic of Intel's innovation approach is based on the recognition that deep specialists operate in the firm's environment, such as in university labs. Intel aims to learn from these specialists, but its own innovation activities mainly focus on the establishment of linkages between specialists and the development of systems knowledge. In line with this logic Intel actively promotes the rotation of personnel, such as between universities and Intel labs (Tennenhouse, 2004), and requires researchers to spend some time in manufacturing (Chesbrough, 2003a). In this way, Intel aims to develop architects with the capacity to link knowledge domains rather than deep specialists. Such A-shapes skills (Madhavan and Grover, 1998) enable Intel to understand the interrelationships of diverse technologies and to actively control and influence the evolution of components and systems. In sum, this case illustrates that Open Innovation and systems integration are closely intertwined. The primary reason for Intel's Open Innovation model is to develop a unique stock of architectural knowledge, which enables Intel to further direct its internal as well as external innovation strategies, e.g. by investing selectively in component developers and start-ups. In other words, internal and closed innovation seems necessary to first of all integrate the knowledge that can be accessed by means of Open Innovation (e.g. as a result of monitoring) and subsequently it forms the basis for further Open Innovation to guide and direct external innovation.

### 3.6 Discussion and conclusions

Open innovation and systems integration are strong complements. Both need each other in order to be effective. First, systems integrator firms need to know more than they make in order to effectively integrate networks of component and technology developers for the coherence of existing products (i.e. static systems integration). In this regard, Open Innovation provides system firms with the mechanisms to expand their knowledge boundary. Secondly, in order to benefit from Open Innovation for the creation and development of new product architectures (i.e. dynamic systems integration), system firms need a strong systems integration capability to understand and create linkages between internal technology and the external ideas and technology that were acquired through Open Innovation.

Prior studies have indicated that an important opportunity to broaden the scope of Open Innovation is to take into account the complexity of the innovation process (e.g. West et al., 2006; Laursen and Salter, 2006). Our study meets this call by integrating the Open Innovation literature and the literature about the development of complex product systems. We contribute to these literatures by pointing out the strong complementarity that exists between the Open Innovation and systems integration. Whereas prior systems integration literature has outlined *why* firms know more than they make (Brusoni et al., 2001), our study has elaborated on this topic by outlining *how* firms may extend their knowledge boundary beyond their production boundary.

Another contribution in this regard, involves the framework that we proposed outlining the contingent nature of Open Innovation. We argue that the effective coordination of different types of component innovation requires the application of different types of Open Innovation mechanisms, i.e. in terms of their capability to stimulate, monitor, and coordinate the innovation. In this way we suggest a future avenue for research to explain how, why, and when Open Innovation is likely to contribute to the innovative performance of firms.

In our study we also touched upon one of the most fundamental assumptions underlying Open Innovation, i.e. the notion that firms operate in a 'landscape of abundant knowledge' (Chesbrough, 2003a). This chapter clearly points to a boundary of Open Innovation in this respect, because the systems integration literature stresses the strategic importance to generate internally high-quality architectural knowledge. Such knowledge is far from 'abundant' and requires a conscious and long-term internal development strategy. Open Innovation has an important role to play to continuously feed into this internal integration process. The case of Intel illustrates how close Open Innovation and systems integration are intertwined for the development of scarce and difficult to imitate architectural knowledge. Furthermore, the systems integration literature shows how the combination of Open Innovation and systems integration can result in strong and sustainable competitive advantage by surviving successive technological generations.

A final contribution involves the explicit distinction that we maintained throughout this chapter between system-level innovation and component-level innovation, i.e. synchronic versus diachronic systems integration. Both types of systems integration point to two completely different purposes of Open Innovation, i.e. the coordination of component developers for existing products and the generation of architectural knowledge for future products. Such an explicit distinction between component-level innovation and system-level innovation is often lacking in the innovation literature (Gatignon et al., 2002). Both types of systems integration are closely related however: whereas internal systems knowledge is required to generate new product systems, substantial parts of this proprietary knowledge may have to be made public (i.e. public interface standards) to stimulate and facilitate the development of components and complements.

Our study has several limitations. First, our study by no means aims to be comprehensive in its coverage of the Open Innovation literature and the systems integration literature. We did aim however to draw upon and to integrate some of the most fundamental underpinnings of both fields of literature. These were mainly related to knowledge-related characteristics of and prerequisites for systems integration, rather than issues related to persuading and getting the commitment from complementors, i.e. power-related issues (e.g. Maula et al., 2006).

Of course it has to be noted that our findings are derived from a conceptual analysis in the extreme setting of complex product systems. Many industries revolve around products that are significantly less complex, but given that many products consist of at least a few components and given the difficulty of many industries to design and implement substantial architectural innovations (e.g. PCs, biotech), we believe that the external validity of our findings is substantial. Of course future research is required in this regard, for instance to investigate the prominence of systems integration in a variety of industries. A promising line of research involves systems integration by small component developers. Although much of the systems integration literature takes the perspective of large system firms, its ideas also seem to apply to smaller-sized component developers.

Ethiraj and Puranam (2004) for instance studied the innovation activities of component developers and found that these firms benefit from building architectural knowledge themselves. As component suppliers understand better how their components fit into larger product systems, they can innovate more effectively at the component level. Similarly, we have seen that Intel established a research facility dedicated to computer architectures in an attempt to understand and influence the role of microprocessors in future computer systems. Hence, firms responsible for components or subsystems should strike a balance between the focus of their R&D activities on core component technologies and the scope of their R&D activities for the development of architectural knowledge (Ethiraj and Puranam, 2004). Ethiraj (2007) for instance shows that component developers attempt to increase the value of their own component innovations by targeting part of their R&D effort at bottleneck components.

Finally, future research is needed to further improve the contingent nature of Open Innovation. We proposed a tentative model for the application of Open Innovation in the context of component innovations, but more evidence is needed about which specific Open Innovation mechanisms fit the characteristics of the different types of innovation. In this regard it is clear that system firms need very extensive monitoring capabilities. This results in the question how firms realize this capability while keeping its costs within limits. In this regard it is interesting to observe the emergence of systems integration specialists. In the mobile telecommunications industry, mobile operators for instance increasingly focus on marketing and customer care, while tasks of systems integration for the development of complementary mobile applications are increasingly being performed by intermediary platform or middleware owners, such as firms with their own switches, text messaging centers and application platforms.

For managers this chapter presents several interesting insights. First, our study shows the importance of a balanced approach to Open Innovation, i.e. firms need to be open and closed at the same time: open with respect to new ideas and technological developments; closed with respect to developing and improving knowledge about how different technologies and components interrelate. This shows the important internal consequences of Open Innovation, i.e. Open Innovation provides the firm with knowledge the firm does not immediately need for its own production processes, but managers have to install mechanisms and processes to evaluate and integrate the knowledge they acquired externally with their own resources and capabilities. In this way, new avenues may be found to further exploit their proprietary technologies and their manufacturing and sales capabilities. Secondly, the model that we proposed for four different types of component innovation gives managers some preliminary clues on how to apply Open Innovation in a complex product context. Finally, our findings suggest that Open Innovation helps firms to experiment with entirely new product architectures. As firms develop a detailed understanding of technological interrelationships they are more likely to explore new connections and to identify architectural opportunities. In this way, proprietary and unique architectural knowledge may result in strong competitive advantage.

# PART 2.

# SYSTEMS INTEGRATION: A CONFIGURATIONAL APPROACH

# 4. Involvement of System Firms in the Development of Complementary Products: The Influence of Novelty

**Abstract**

This chapter focuses on the involvement of system firms (systems integrators) in the development of products that are complementary to these firms' product systems. The central question is: to what extent do the novelty of the system and the novelty of the complementary product affect the appropriate degree of involvement of system firms in the development of complementary products? A system firm has several options: it may develop the complementary product completely by itself, it can leave the development project completely to a specialized producer of complementary products, or it can apply different forms of collaboration with such specialized firms. As the first steps towards a configurational approach, we conceptualize the system firm's project involvement in terms of two dimensions: the firm's ownership of the project as a result of project investments and the firm's integration of the project in terms of coordination. More specifically, this chapter presents a (configurational) model for the most appropriate degree of involvement of the system firm, contingent upon the novelty of the system and the novelty of the complementary product. Basic to the model are two objectives of firms developing a new complementary product: the reduction of information and transaction costs in the development process, and the timely creation of installed base of the novel system and/or the complementary product. We performed a pilot test of the model using data on new service development projects in mobile telecommunications. The results show that the novelty of the system and complementary product indeed affect the performance effects of system firm involvement. Particularly when the system is mature and the complementary product new, the system firm could better leave complementary product development to a specialized external firm. In other cases, the system firm can choose its degree of involvement from low to either medium or high, depending on novelty conditions.

*This chapter is published as:* Van den Ende, J., Jaspers, F. and Gerwin, D. (2008). Involvement of system firms in the development of complementary products: The influence of novelty. *Technovation*, 28, 726-738.

## 4.1 Introduction

To an increasing extent products are complements to larger systems. Examples are cartridges that are complementary to printers, video games to video consoles, pads to coffee-machines, and, the example of this chapter, content services that are complementary to mobile telecommunication systems. The functioning and market acceptance of the complementary products depend on their alignment with the technical characteristics and market positioning of the larger system. For this purpose the developers of complementary products have to communicate with the producer of the larger system. Particularly for novel systems or complementary products, achieving alignment requires extensive information processing between the developer of a complementary product and the developer of the system. At the same time, users can often choose the different complementary products of a system independently, meaning that separate markets exist for a system as a whole and for its complementary products. Often, in both markets network externalities may be important (Arthur, 1988; Shapiro and Varian, 1999), which means that the timely creation of installed base is important for survival. Therefore the developer of a complementary product has two major concerns: the alignment of the complementary product with the rest of the system, and the creation of installed base for the complementary product itself.

This chapter addresses the degree that a system firm should be involved in the development of complementary products. It concerns the degree that system firms finance the development of complementary products, and the degree that they are involved in the execution of the complementary product's development process. We address the influence of the characteristics of the innovation on these decisions, particularly the novelty of the system and the complementary product, since these characteristics affect the need to create installed base for the system and complementary product.

The literature on the role of system firms in the development of complementary products, and on the effects of novelty conditions on that role, is scarce (Nambisan, 2002; Sengupta, 1998; Venkatraman and Lee, 2004). The literature on systemic innovation addresses the degree that system firms should be involved in component development in general, not for complementary products in particular (Brusoni and Prencipe, 2001b; Chesbrough and Teece, 1996; Teece, 1986, 1996). This literature focuses on the degree that system firm involvement facilitates the required alignment between system and component.

However, system firms and component manufacturers have a supplier-buyer relationship, which provides the system firm with a certain degree of control over suppliers in component development (Carson, 2007; Takeishi, 2002). We consider a complementary product to be an example of a component, but, whereas other components form part of the system and are delivered together with the rest of the system to the client, the complementary product is supplied separately from the rest of the product to the customer. As a consequence, system firms have less control over the development of complementary products, while the success of the system can still be highly dependent on these products. System firms will have to apply other methods to participate in complementary product development, such as financing the development or communicating intensively with the complementary product developer. Sengupta (1998) addresses the choices of system firms for participation in the development of complementary products, but he focuses on strategic considerations and does not investigate the effects of market conditions or the innovativeness of the system and complementary products on those choices, nor does he investigate the performance effects of those choices.

In this chapter we contribute to the literature by developing a model for the degree to which and the way in which system firms should be involved in complementary product development. The model takes into account both the required alignment between system and complementary product, and the need to align the complementary product with both the system market and its own market. Moreover, whereas most prior models were case-based (Chesbrough and Teece, 1996; Van den Ende, 2003), we performed a sample survey. The focus of our model on novelty conditions for the choice of system firm involvement in the development of complementary products does not mean that there are no other reasons that affect these decisions in system firms, such as considerations of resources and capacity available for innovation activities.

We draw from the neo-evolutionary economics literature (Arthur, 1989, 1996; Schilling, 2002) to develop our hypotheses on the influence of system firm involvement on the creation of installed base of complementary products (Shapiro and Varian, 1999). Our model also draws from the innovation management literature, particularly by including findings with respect to rapid creation of installed base in dynamic environments (Christensen, 1997; MacCormack et al., 2001; Wheelwright and Clark, 1992). The data concern development projects of mobile telecommunications services as complementary products of mobile telecommunications systems. We show that the novelty of the system and complementary product indeed affect the performance effects of system firm involvement. Particularly when the system is mature and the complementary product new, the system firm could better leave complementary product development to a specialized external firm. In other cases, the system firm can choose its degree of involvement from low to either medium or high, depending on novelty conditions. This result is particularly relevant for system firms which have to determine their degree of involvement in complementary product development.

This chapter is organized as follows. In the next section, we discuss the implication of the novelty of the system and complementary product for the organizational characteristics of the development project of the complementary product. Next, we develop hypotheses on the most appropriate degree of involvement of system firms, contingent on system and complementary product novelty. Subsequently, we describe our research methodology. Finally, we present our results and discuss the implications for theory and practice.

## 4.2 Theoretical background

***System and complementary product novelty***

A complementary product forms a component of a larger system. A system consists of a number of components, united in a common architecture (Henderson and Clark, 1990). We consider a complementary product to be an example of a component. However, whereas other components form part of the system and are delivered together with the rest of the system to the client, the complementary product is supplied separately from the rest of the product to the customer.

Like other components, complementary products are part of the architecture of the system, and are connected to the rest of the system by means of interfaces. The architecture and interfaces of systems are often subject to change in the early life of the system, until a dominant design emerges. In the early phase the interdependence between system and component is high, and the innovation on the component is truly systemic (Chesbrough and Teece, 1996). After the dominant design is set, developers of components and complementary products can conform to standard interfaces defined by the dominant design, and component innovation becomes largely autonomous (Abernathy, 1978; Utterback, 1994). Baldwin and Clark (1997) call the interfaces in such cases 'visible design rules' versus hidden design rules within the components. An important determinant of the novelty of the system is therefore the novelty of the architecture and interfaces (Table 4.1).

Components, including complementary products, may be developed anew for a new system, but they may also already exist as part of other systems or as stand-alone products. An important determinant of the novelty of a component is therefore the degree of similarity to existing products. We consider a component of a system new if it offers features to users previously unavailable from stand-alone products or components of other systems. We consider a component mature if customers can acquire it in a similar form from other systems or channels. In terms of the product life cycle, we consider a system or component new when it is in the fluid phase of the life cycle, and mature when it is in the transitional or specific phase (Cusumano et al., 1992; Utterback, 1994). So, for a new component in general no dominant design will yet exist in the market.

**Table 4.1 Important criteria for novelties of system and complementary product**

| | **Novel / Fluid phase** | **Mature phase** |
|---|---|---|
| **System** | Novel architecture and interfaces | Standard architecture and interfaces ('Visible design rules') |
| **Complementary product** | New features for users | Features similar to existing products |

The novelties of the system and of the components influence the degree of uncertainty in development projects of components. High system novelty creates technological uncertainty for the interfaces with the component (interdependence). A highly novel component creates technological uncertainty for the hidden design rules of the component itself, and can also require changes of the interfaces. Moreover, the novelty of the system creates market uncertainty with respect to the behavior of competitors, the type and number of prospective users of the system, user preferences, and any substitutes that may appear for the system. Similarly, the novelty of a complementary product also creates uncertainty in the market of the complementary product.

***Integration and ownership***

Two types of firms may be involved in the development of complementary products: system firms and specialized producers of the complementary products. System firms are responsible for the architecture and the interfaces of a system as a whole (Bonaccorsi et al., 1999; Gann and Salter, 2000; Hobday, 2000), whereas specialized producers of complementary products may be responsible for their specific complement.

We distinguish two dimensions of organizational forms for the development of complementary products: the degree of integration and the degree of ownership by the system firm (Robertson and Langlois, 1995. See also Gerwin, 2004; Gerwin and Ferris, 2004). The literature on vertical integration uses the concept of 'integration' with respect to the structure of firms (Robertson and Langlois, 1995; Williamson, 1985), whereas organization theory and innovation management literature use it on a process level, with respect to the actual coordination that takes place between subunits or firms (Grant, 1996; Kahn, 1996; Tatikonda and Montoya-Weiss, 2001). We use the concept on the first, structural level, but we relate it to the second level. We define integration as the extent to which the organizational form for the development project of the complementary product facilitates coordination and information exchange between the developers of the complementary product and the system. Internal development of a complementary product by the system firm of course means that the degree of integration is high, and even more so if system and complementary product development take place in one subunit. Integration is lower when a system firm and a complementary product firm collaborate on the development of the complementary product, for instance in the form of an alliance. Integration is least when the system firm leaves the development of the complementary product completely to a specialized complementary product firm.

The degree of ownership by the system firm refers to the extent that the system firm finances the development activities of the complementary product. If the system firm fully finances these activities, a situation of common ownership of system and complementary product occurs (Mohr et al., 1996). At the other extreme, one or more specialized producers of complementary products finance the development activities, without any ownership by a system firm. In between these extremes the system firm shares ownership over the innovation project with one or more specialized producers of complementary products. It has to be noted that ownership and integration are different aspects of the involvement of the system firm, but they are not completely independent, since a high degree of ownership of the complementary product's development activities by the system firm facilitates information exchange between the development activities for the system and complementary product, and thus supports integration as defined above (Robertson and Langlois, 1995). But ownership does not necessarily involve integration, since system firms can financially participate in the development of complementary products, but leave all development activities to a supplier.

**4.3 Hypotheses**

We hypothesize that the novelty of the system and complementary product affect the two dimensions of the involvement of the system firm, but in different ways. First, we assume that both the novelty of the system and complementary product affect the optimal degree of integration between the system's development activities and the complementary product's development activities (Gulati et al., 2005). As noted above, when the system and complementary product are both new, interface uncertainty will be high. In line with transaction cost theory we assume that in that case a low degree of integration between the system's and complement's development activities creates high transaction and information costs, and that a high degree of integration will reduce these costs (Grover and Malhotra, 2003; Gulati and Singh, 1998; Hoetker, 2005). In this case a high degree of integration will reduce the costs and duration of the complementary product's development. Integration will also improve the quality of the output of the project, since the system and complementary product can be better aligned to each other (Chesbrough and Teece, 1996). When either the system or complementary product, or both, are mature, interface uncertainty will be lower, and integration is less needed. In this situation, superfluous integration may even create unnecessary coordination costs and delays. We therefore argue that *the appropriate degree of integration between the development activities of the system and the complementary product increases with the novelty of the system and the complementary product.*

We define integration misfit as the difference between the actual degree of integration between the system's and complementary product's development activities and the appropriate degree of integration. In line with contingency theory, we hypothesize that the degree of misfit negatively affects the performance of the complementary product development project (Burton et al., 2002; Donaldson, 2001; Gresov, 1989; Naman and Slevin, 1993). We make a distinction between the performance of the development project (in terms of project duration, project cost efficiency and the quality of the development process) and the performance of the innovation in the market (e.g. number of customers and the financial return). As indicated above, we expect that project performance will be higher as the degree of integration between the development of the system and the development of the complementary product is more appropriately aligned with the novelty of the system and the complementary product. We also expect that the project's duration and its quality will affect the market performance of the complementary product (Tatikonda and Montoya-Weiss, 2001). We therefore hypothesize:

> Hypothesis 1. *The degree of misfit between the actual and the appropriate degree of integration between the development of the system and the complementary product, where the appropriate level increases with the novelty of the system and the novelty of the complementary product, negatively affects the project and the market performance of the complementary product development project.*

Second, we assume that the novelty of the system and the complementary product affect the appropriate degree of ownership by the system firm. Neo-evolutionary theory shows that in network markets installed base is important, particularly in the early phase of a new market (Arthur, 1988, 1989, 1996; Shapiro and Varian, 1999). Network markets are characterized by follower behavior amongst producers and consumers, since installed base creates benefits for both existing and new producers and users, for instance because of the higher availability of information about the product, decreased prices for the product or the availability of complementary products. To create installed base, firms have to align the product closely to the market, by introducing it within the 'window of opportunity'. This requires equipping it with attractive features, adapting those features actively in response to customer feedback and spreading knowledge about the features through marketing communication (Christensen et al., 1998; MacCormack et al., 2001; Dew and Read, 2007; Schilling, 2002).

Its will be clear that the markets of both systems and complementary products often have network characteristics. Network effects involve that a high installed base of a complementary product that is offered in addition to a specific system may be a reason for other system firms to use the same or a slightly adapted version of the complementary product for their system (Van den Ende and Wijnberg, 2003). For instance, once a computer program is popular on MS-DOS computers, Apple will be inclined to support the development of an adapted version of this program for its own computers.

This means that for the producer of a complementary product the installed base of both the system and complementary product itself are important. Which of these markets is most important depends on the novelty of both markets. The installed base of the system market is especially important when the system is new, and when the complementary product is mature. In that situation the success of the complementary product stems primarily from its alignment to the system market (Teece, 1986). Examples are complementary products that form 'killer products' or 'killer applications' for new systems. In such cases, alignment of the complementary product to the systems market will create the best chances for success of both the system and the complementary product. The installed base in the market of the complementary product is especially important if the complementary product is new and the system mature. In that case the complementary product has to create installed base for itself, and thus has primarily to be aligned to the requirements of its own market. When both the system and the complementary product are new, the two markets are equally important, and the complementary product can best be aligned as much as possible to both markets. When both markets are mature, innovation for the complementary product is incremental in all respects, and market alignment is not a major issue since the product already has a sufficient installed base. Summarizing, we assume that the complementary product can best be aligned to the requirements of the newest market, the one of the system or the complementary product.

We furthermore assume that ownership by a firm that has the most knowledge of the relevant market creates the best conditions for managing the aligning process (Cooper, 2001; Danneels, 2002). Firms with knowledge of the market can better judge which time-to-market is most appropriate for the system or product and which adaptations have to be made to the product to meet customer requirements. Ownership puts a firm in a position to decide on time-to-market and to make such adaptations, since it provides control over resources and design decisions in the development of the complementary product (Lewis et al, 2002).

Since we explained above that the complementary product can best be aligned to the most novel market, the relative novelties of the system's and complementary product's markets determine the most appropriate party to have ownership of the development of the complementary product. Moreover, the firm addressing the most novel market will feel the highest urgency to introduce the complementary product and to create an installed base (Lambe and Spekman, 1997). This also means that ownership of the complementary product's development can best be with the firm that addresses the market that is most novel. When the novelties of both markets are about equal, shared ownership of the development project of the complementary product seems the most appropriate solution.

To summarize, we argue that *the appropriate degree of ownership by the system firm of complementary product development activities increases with system novelty and decreases with the novelty of the complementary product.* We define ownership misfit as the difference between the actual degree of ownership and the appropriate degree of ownership. Since our considerations are primarily based on market performance, we expect ownership misfit to affect market performance.

> Hypothesis 2. *The degree of misfit between the system firm's actual and appropriate degree of ownership of the complementary product's development activities, where the appropriate level increases with the novelty of the system and decreases with the novelty of the complementary product, negatively affects the market performance of the complementary product.*

Finally we hypothesize that a misfit on one organizational dimension will reinforce a misfit on the other dimension. Misfit with respect to integration will mean that the alignment of the complementary product with the system is inappropriate. Misfit with respect to ownership will mean that the complementary product is not well aligned to the most novel and relevant market (system or complementary product market). We expect that the combined effect of the two misfits will be greater than the sum of their separate effects. The development of the component will wander off completely from the perspectives of both the system and the most relevant market.

> Hypothesis 3. *Integration misfit and ownership misfit interact in their negative effects on the market performance of the complementary product.*

Figure 4.1 illustrates the most appropriate organizational forms for complementary product development activities under different conditions for the novelty of the system and complementary product. In each quadrant we present the degree of integration and ownership by the system firm according to the hypotheses (see also Van den Ende, 2003). The newer the system and complementary product, the higher will be the integration. As a result, integration is highest in Quadrant III, lowest in Quadrant II, and intermediate in the other two quadrants.

**Figure 4.1. Appropriate organizational forms for system firms to develop complementary products**

| Complementary product | System: Novel | System: Mature |
|---|---|---|
| **Mature** | I<br>Intermediate integration;<br>High degree of ownership<br>by system firm<br><br>*System firm develops system and finances complementary product development. Specialized producer of complementary product performs the development activities under contract with the system firm* | II<br>Low integration;<br>Intermediate degree of ownership<br>by system firm<br><br>*System firm provides system. Complementary product firm performs complementary product development tasks within functional departments. System and complementary product firms share the costs and benefits* |
| **Novel** | III<br>High integration;<br>Intermediate degree of ownership<br>by system firm<br><br>*Internal development by system firm with external funding by complementary product firm, or independent organization in which system and complementary product firm co-finance complementary product development* | IV<br>Intermediate integration;<br>Low degree of ownership<br>by system firm<br><br>*System firm and complementary product firm co-develop complementary product. Complementary product firm finances complementary product development* |

The newer the system, the higher will be the ownership by the system firm, and the newer the complementary product, the lower the ownership by the system firm. Ownership by the system firm is therefore highest in Quadrant I, lowest in Quadrant IV, and intermediate in the other two quadrants. In each quadrant we illustrate the degree of involvement of the system firm that meets these conditions.

## 4.4 Methodology

***Sample and data collection***

We tested the hypotheses in the Dutch mobile telecommunications industry. The mobile telecommunications industry is particularly suitable for this purpose since the technology develops at high speed, and thus a relatively high number of examples of completely new systems are available. Moreover, mobile services are complementary products of telecommunication systems with markets of their own, and thus are appropriate examples of complementary products for the purpose of this study. Mobile telecommunications systems consist of a physical transmission network such as GSM, GPRS or UMTS[4],

[4] GSM: Global System for Mobile Communications; GPRS: General Packet Radio Service; UMTS: Universal Mobile Telecommunications System.

middleware, and complementary products such as handsets and services. ‘Middleware’ refers to the software and protocols that facilitate the operations of the network and that specify interfaces between the network and the other complementary products. Usually, newly introduced networks provide tailor-made middleware, whereas over time telecom operators introduce standard so-called platforms for the connection of services such as I-Mode and Vodafone live!

Mobile services refer to the user applications available on mobile networks. Examples are location-based services, mobile games, ringtones and mobile office applications. We consider the physical network and the middleware to be the system, and mobile services to be the complementary products. Telecom operators develop or implement networks and middleware, and thus are system firms. Both telecom operators and specialized service firms, for instance ringtone providers or banks, can develop the services.

Our sample consisted of thirty mobile service development projects that were executed in the Netherlands in 2001 and 2002, and for which data were collected in 2002/2003. The dataset included projects covering a wide range of both services and network and middleware technologies. Furthermore, the projects covered all five Dutch mobile telecom operators and numerous service firms, ranging from those dedicated to mobile applications to those with core activities in other markets, such as a retail bank. The projects ranged in size from fewer than five people to two hundred people, and in duration from less than a month to well over a year.

We studied each project in a structured interview with the project manager(s). For each project performed in a single firm the project manager completed a questionnaire. If a project was executed by two or more firms, we interviewed the project manager of the most important telecom operator and the most important service firm. If two project managers were interviewed, we took the mean of the results. During the interview, the respondent first completed the questionnaire in the presence of the interviewer. Next, we discussed the project with the respondent to make up a case report, which served as additional backup qualitative data.

***Measurement of variables***

We measured the variables in our hypotheses using four-point and five-point scales. System novelty and complementary product novelty were each measured by a single item. To capture system novelty we asked for the degree of standardization of the platform to which the mobile service was connected. Platforms define the interfaces which connect the network and the services, and, as indicated in the theory section, the novelty of these interfaces is the most important aspect of system novelty. The platform standardization scale ranged from ‘no standardization’ to ‘a very high degree of standardization’. Complementary product novelty was measured by asking for the novelty of the service features to consumers. This scale ranged from ‘no new service features’ to ‘very new service features’. The absence of new service features indicated that the mobile service was a close copy of a service that was already being offered either in the mobile market or in other markets, and hence provided no new functionality.

The level of integration between the development activities for the system and complementary product was measured on a five-point scale. A score of 1 indicated the lowest level of integration, which represented internal development of the mobile service by a service firm, independently of the telecom operator's network development activities. A score of 2 indicated that a telecom operator and a service firm had an alliance to develop the service, with each of the partners performing their tasks internally. Consequently, this involves only a minor degree of integration between the service firm and the telecom operator. An alliance between a service firm and a telecom operator was characterized by a score of 3 when a dedicated service development unit included personnel from both partners. A score of 4 represented internal service development by a telecom operator, but in such a way that the service development tasks were performed independently of the system development tasks. The highest level of integration - indicated by a score of 5 - referred to the situation in which the telecom operator developed the service internally in such a way that personnel from the network department and the service development task worked together. Ownership by the system firm was measured by the relative amount of investment made by the telecom operator in the service development project. This variable ranged from 'no investment' to 'all the investment'.

To measure governance misfits, our framework defined that the appropriate level of integration (Appropriate I) in complementary product development projects increased with the novelty of both the system and the complementary product. Hence, we calculated Appropriate I as the sum of system novelty and complementary product novelty (Equation 1 below). Furthermore, we stated that the appropriate degree of ownership by the system firm in complementary product development projects (Appropriate O) should increase with system novelty and decrease with the novelty of the complementary product. Hence we calculated Appropriate O as system novelty minus complementary product novelty (Equation 2 below).

In line with Naman and Slevin (1993) we defined integration misfit (Misfit I) as the absolute difference between the actual and the appropriate levels of integration (Equation 3 below). Similarly, ownership misfit (Misfit O) was the absolute difference between the actual and the appropriate levels of ownership (Equation 4 below). Also following those authors, we used the standardized values of the appropriate and actual levels of integration and ownership. Several authors have applied more simple binary scales for fit or misfit (e.g. Burton et al., 2002), but at the expense of a loss of information. Since we assume that the performance implications of the two types of misfit reinforce each other, we included the interaction term (Misfit I * Misfit O) in the analysis. Our treatment of misfits is summarized as follows:

$$\text{(1)} \quad \text{Appropriate I} = \text{System Novelty} + \text{Complementary Product Novelty}$$
$$\text{(2)} \quad \text{Appropriate O} = \text{System Novelty} - \text{Complementary Product Novelty}$$
$$\text{(3)} \quad \text{Misfit I} = |\,\text{Actual I} - \text{Appropriate I}\,|$$
$$\text{(4)} \quad \text{Misfit O} = |\,\text{Actual O} - \text{Appropriate O}\,|$$

The dependent variables in our hypotheses are project and market performance. Informed by previous studies (e.g. Griffin, 1997; Kessler and Bierly III, 2001; Tatikonda and Montoya-Weiss, 2001), we measured each variable by five items, each of which was on a five point scale. Each item reflected actual performance relative to expectations as perceived by the respondent. This use of subjective performance evaluations is in line with the literature (Blindenbach-Driessen et al., forthcoming). The lowest score represented very disappointing performance, a medium score meant that the performance lived up to expectations, and the highest score indicated performance level well beyond expectations.

The five items that we used to measure different attributes of project performance were (1) cost efficiency, (2) budget performance, (3) quality of execution, (4) time-to-market, and (5) adherence to interim deadlines. Varimax rotated principal axis factoring revealed two factors with eigenvalues greater than 1. These two factors accounted for over seventy percent of the total variance. To increase reliability and to reduce the number of dependent variables, we aggregated the items into these two factors. The first factor clearly referred to the financial performance of the development project (Items 1 and 2). We therefore labeled this factor *project efficiency* (Cronbach's alpha = 0.6). The second factor contained the non-financial criteria for project performance (Items 3, 4 and 5). We labeled this factor *project timeliness* (Cronbach's alpha = 0.7), since two of the items (time-to-market and adherence to project deadlines) are clearly related to the speed of the development project, and the third item, quality of the project's execution, also affects project speed since it facilitates decision-making and communication. Table 4.2 presents the factor loadings.

**Table 4.2 Factor Loadings for Performance Indicators**

| Items | Project Performance | | Items | Market Performance | |
|---|---|---|---|---|---|
| | 1 | 2 | | 1 | 2 |
| Efficiency | | .645 | User satisfaction | | .808 |
| Budget | | .687 | Reliability | .482 | |
| Quality | .604 | | Number of users | .731 | |
| Time-to-market | .737 | | Revenues | .715 | |
| Deadline | .681 | | Growth | .902 | |

Loadings below 0.35 are excluded. Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization. Rotations converged in 3 iterations.

The market performance items asked for the degree to which the service could meet expectations regarding: (1) number of users for the service, (2) revenues, (3) growth of the service, (4) user satisfaction, and (5) reliability of the service. A varimax rotated principal factor analysis revealed two common factors with eigenvalues greater than 1. These factors explained over seventy percent of the total variance. The first factor, Item 4 or user satisfaction, had a factor loading of 0.8. This factor was therefore simply labeled as *user satisfaction*. We aggregated three of the remaining four items into a second factor. Because the item concerning reliability showed a relatively low factor loading (lower than 0.5), we decided to remove it from further analysis. This significantly improved the internal consistency of the factor and increased the level of explained variance to over eighty percent. Furthermore, the three remaining items (Items 1, 2, 3) clearly pointed toward the commercial performance of the service. Therefore, we labeled this factor *commercial performance* (Cronbach's alpha = 0.8).

**Table 4.3 Descriptive statistics and correlations**

| Variable | Mean | S.D. | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|---|---|
| 1. System Novelty | 2.10 | 0.96 | | | | | | | |
| 2. Comp Product Novelty | 2.87 | 0.87 | - 0.05 | | | | | | |
| 3. Integration | 2.13 | 1.14 | 0.15 | - 0.30 | | | | | |
| 4. Ownership | 2.13 | 1.40 | - 0.13 | - 0.10 | 0.49*** | | | | |
| 5. Project Efficiency | 2.92 | 0.71 | 0.08 | - 0.31* | - 0.16 | - 0.54*** | | | |
| 6. Project Timeliness | 2.97 | 0.79 | 0.14 | 0.06 | - 0.33* | - 0.40** | 0.35* | | |
| 7. Commercial Performance | 2.78 | 0.94 | 0.24 | 0.14 | - 0.20 | - 0.33* | 0.15 | 0.32 | |
| 8. User Satisfaction | 3.55 | 0.85 | - 0.07 | 0.17 | - 0.14 | 0.11 | - 0.11 | - 0.11 | 0.13 |

Pearson, * p < 0.10, ** p < 0.05, *** p < 0.01, N=30 (N=28 for correlations with 7. CP and 8. US).

## 4.5 Results

Descriptive statistics and correlations are reported in Table 4.3. The table shows a high correlation (r=0.49) between the two dimensions of organizational form (integration and ownership), but each variable still reflects considerable unique information. The sample varied with respect to novelty. Taking the middle of the novelty scales as the demarcation between novel and mature, we had 11 projects for new and 19 for mature telecommunication markets, and we had 19 projects developing services in new service markets, and 11 projects developing services for mature service markets. The sample also varied regarding the degree of ownership by the telecom operator (system firm). Fifteen projects were financed and executed by service firms (complementary product firms) without any involvement of a telecom operator. Twelve projects were financed and performed by a telecom operator in an alliance with a service firm. Three projects were completely financed by a telecom operator.

To test our hypotheses we performed a stepwise regression analysis. For each of the four dependent variables we studied three models (see Table 4.4). Model 1 includes integration and ownership to investigate their direct effects. In Model 2 we added the misfit measures related to these two organizational dimensions to test whether they negatively influence performance (Hypotheses 1 and 2). Model 3 adds the interaction term of the two types of misfit to test whether they reinforce each other (Hypothesis 3). To mitigate the multicollinearity problem for this interaction term we mean-centered the Misfit I and Misfit O variables. The resulting variance inflation factors were well below the acceptable value of 2.5. For each regression analysis we ran an additional model that incorporated project duration as a control variable. This variable failed to reach significance and is therefore not included in the models presented below.

Table 4.4 presents the results of the regression analyses. Model 1 significantly explains *project timeliness* and indicates that ownership by the telecom operator has a direct negative effect on project timeliness ($p<0.10$). This is a consistent finding as it also appears in Model 2 and Model 3. The misfit variables fail to explain project timeliness. Ownership is also negatively related to *project efficiency* ($p<0.01$) Adding the misfit variables and their interaction term does not significantly improve the explanation of project efficiency.

Model 1 has only weak explanatory power with regard to *commercial performance* ($R^2$=0.11). Again we find a direct negative effect of ownership on the dependent variable ($p<0.10$). The explanatory power is strongly improved by adding the misfit variables. Ownership misfit is significantly and negatively associated with commercial performance ($p<0.10$), which supports Hypothesis 2. Supporting Hypothesis 3, we find a significant and negative interaction term ($p<0.10$). Finally, the explanatory power for the regression analysis explaining *user satisfaction* is limited, and the misfit variables are insignificant.
In sum, the results show partial support for our hypotheses. We do not find support for Hypothesis 1, which stated that integration misfit has a negative effect on project performance. Hypothesis 2 stated that ownership misfit negatively affects market performance. Our results indicate that ownership misfit is negatively and significantly associated with commercial performance. We therefore consider Hypothesis 2 to be supported. Finally, Hypothesis 3, regarding the effect of the interaction between integration and ownership fit on project and market performance, is also supported for commercial performance.

**Table 4.4 The performance effects of organizational forms and misfit**

| | PROJECT TIMELINESS[a] | | | PROJECT EFFICIENCY[a] | | | COMMERCIAL PERFORMANCE[b] | | | USER SATISFACTION[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| CONSTANT | 3.61*** | 3.60*** | 3.47*** | 3.39*** | 3.40*** | 3.49*** | 3.31*** | 3.42*** | 3.12*** | 3.66*** | 3.74*** | 3.52*** |
| INTEGRATION | -0.12 | -0.13 | -0.07 | 0.09 | 0.09 | 0.04 | -0.04 | 0.15 | 0.29 | -0.19 | -0.06 | 0.05 |
| OWNERSHIP | -0.17* | -0.18* | -0.20* | -0.31*** | -0.32*** | -0.31*** | -0.21* | -0.19* | -0.24* | 0.15 | 0.16 | 0.13 |
| MISFIT I | | -0.02 | 0.00 | | -0.14 | -0.15 | | -0.20 | -0.17 | | -0.12 | -0.10 |
| MISFIT O | | 0.05 | 0.10 | | 0.17 | 0.13 | | -0.29* | -0.19 | | -0.24 | -0.17 |
| MISFIT I * MISFIT O | | | -0.14 | | | 0.10 | | | -0.31* | | | -0.23 |
| F CHANGE | | 0.04 | 0.66 | | 1.16 | 0.50 | | 1.41 | 2.40 | | 0.95 | 1.41 |
| F | 3.00* | 1.41 | 1.25 | 6.03*** | 3.63** | 2.95** | 1.59 | 1.53 | 1.78 | 0.85 | 0.90 | 1.01 |
| $R^2$ | 0.18 | 0.18 | 0.21 | 0.31 | 0.37 | 0.38 | 0.11 | 0.21 | 0.29 | 0.06 | 0.14 | 0.19 |

*p<0.10, **p<0.05, ***p<0.01, a N=30, b N=28, probabilities for the misfit variables are 1-sided.
Unstandardized coefficients are presented.

## 4.6 Discussion

In this chapter, we developed a framework for the most appropriate degree of involvement of system firms in complementary product development, based on life cycle considerations for the system and its complementary products. We postulated that, because of information and transaction costs, integration between development activities of the system and the complementary product has a positive effect on performance under higher degrees of novelty of both the system and complementary product. Moreover, we postulated that when a system is novel relative to the complementary product, ownership by the system firm has a positive effect on performance since it creates better conditions to create installed base. In the opposite situation, when the complementary product was new relative to the system, we expected that ownership by a complementary product firm has a positive on performance. We defined measures of misfit in terms of the deviation between the actual degree of involvement of the system firm in the complementary product's development and the postulated degree of involvement, based on novelties of the system and complementary product.

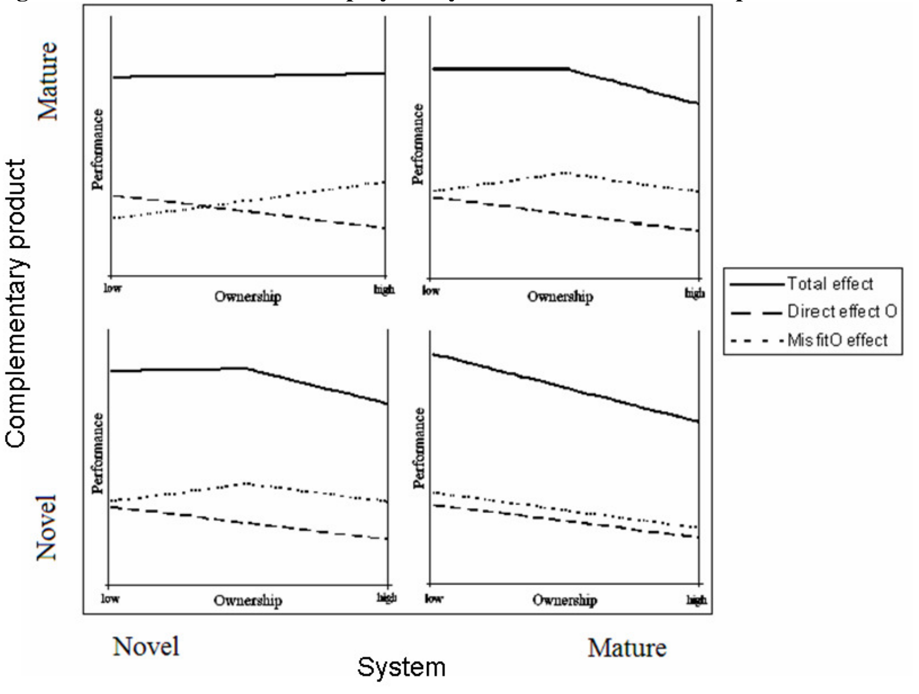
We find some significant effects of misfit on performance. In line with our assumptions, ownership misfit appears to have a significant and negative effect on commercial performance (Model 2). We also find support for the expected interaction between integration and ownership misfit (Model 3). We find no significant effects of misfit with respect to integration. However, almost all the results concerning integration misfit provide directional support for our hypotheses.

While integration does not show a clear direct effect on performance, we find a significant direct negative effect of ownership on project and commercial performance. The financial involvement of the system firm consistently deteriorates performance, irrespective of novelty conditions. A possible explanation refers to the size of system firms. The literature shows that employees of large firms often do not have the proper incentives to pursue innovations on products that have low revenue potential compared to the existing product (Chandy and Tellis, 2000; Christensen, 1997). This is clearly the case for system firms, for which complementary products have lower revenue potential than the systems that they exploit. Moreover, Ahuja and Lampert (2001) have pointed to the rigidities of a large organization in exploring new technologies as a consequence of its learning concerning past technologies (a form of path dependence). These rigidities will be reflected in slow decision-making and low commitment in radical innovation activities. The financial participation of the large system firm in complementary product development will be accompanied by participation in decision-making and control of the project, which will be adversely affected by such rigidities. Thus, the size of system firms may explain why their financial participation negatively affects the performance of complementary product's development instead of helping it.

A question of course is how the misfit effect and direct effect of ownership integration relate to each other. The misfit effect indicates that ownership should be chosen contingent on the novelty of the system and complementary product. The direct effect indicates that there is a 'one best way' of low system firm ownership, irrespective of novelty. In Figure 4.2 we show the total effect of ownership and ownership misfit on commercial performance for different situations of novelty of the system and complementary product. The figures are based on Model 2, assuming that the value of the integration variable in each quadrant conforms to our model.

We find a clear negative total effect in the lower right quadrant (Quadrant IV), in which low ownership by the system firm has the best performance effects. This confirms our assumption that for the development of a new complementary product for a mature system, ownership by the system firm should be low. In the upper left quadrant (Quadrant I) the direct effect and the misfit effect cancel each other out. In other words, the novelty of the system requires a high degree of ownership by the system firm, particularly to create an installed base for the new complementary product, but the inherent disadvantages of these large firms cancel out the advantages of high ownership. In the other two quadrants, where we had expected an intermediate degree of ownership by the system firm, results indicate that ownership should be between low and intermediate. Within this range, ownership has no effect on performance.

**Figure 4.2 The effect of ownership by the system firm on commercial performance**




Our results with respect to direct effects and misfit effects put the contingency view that is behind our model into perspective. The partial confirmation of our hypotheses is in line with a contingency view, but there is also some support for a ‘one best way’ approach, according to which specific elements of an organizational form have a specific effect on performance (in our case the negative effect of ownership by large system firms) irrespective of the novelty of the system and complementary product. The best solution so far is a combination of the two perspectives, which is illustrated by our interpretation of the results in Figure 4.2.

This chapter makes some important contributions. The study takes market dynamics into account for the choice of organizational forms for complementary product development. So far, the literature has mainly considered organizational forms for the choice of components (Chesbrough and Teece, 1996; Gulati and Singh, 1998), whereas we developed a model for the choice of organizational form for the development of complementary products. Our approach considers the required alignment between system and complementary product, but adds considerations of the market alignment of the complementary product to both the system market and its own market. In this respect, we build on the literature on network markets in our assumption that the creation of an installed base in novel markets is an important requirement to be met in the choice of organizational form for the development of complementary products, and that accordingly the type of firm that is in control of the innovation project should be based on these relative novelties. The importance of this aspect is emphasized by the fact that we do not find support for our hypothesis regarding the required alignment between system and complementary product (Hypothesis 1), but that we do find support for the hypotheses based on considerations of market alignment (Hypothesis 2 and 3).

Our results have several implications for the practice of system and complementary product development. Our results show that system firms should take the novelty of the system and complementary product into account in their decisions on their degree of involvement in the development of complementary products. Particularly when the system is mature and the complementary product new, the system firm could better leave complementary product development to specialized external firms, which are in that case better positioned to create installed base for the complementary product. In other cases, the system firm can choose its degree of involvement between low and either medium or high, dependent on novelty conditions.

The implications for mobile telecom operators include that they should seriously consider more participation in service development than is usual at this moment. Today at least, most European telecom operators prefer to rely on the market for the development of services, since they themselves lack the required resources and capabilities. Our results show that under conditions of network novelty, telecom operators should participate in the development of services. Recently, some European telecom operators have changed their strategy, internalizing service development to some extent.[5]

Although mobile telecom operators often create a 'walled garden' for service providers and users, we expect that these implications also hold for other types of system firms in which these walled garden may exist to a less pronounced extent. Examples include video game console manufacturers that may financially support the creation of dedicated games for their new consoles, developers of web applications that can provide early users with incentives to contribute to their sites6, and supermarket chains introducing new product scanning technologies that provide incentives to suppliers to include this complementary technology in their products. Also in such industries and cases the success of the system and complementary product are mutually dependent. Consequently we may assume that the reasons for the influence of novelty conditions on the appropriate degree of system firm involvement equally hold.

Our study faces certain limitations. First, the two measures of organizational form are rather close to each other. For future research it would be useful to develop more detailed and distinct multidimensional measures for organizational characteristics (Jaspers and Van

[5] Today, France Telecom develops the majority of its mobile services internally.
[6] For instance, the open innovation website Fellowforce provided financial compensation in its early period to people who recruited new members.

den Ende, 2006). Moreover, and despite the fact that most of the single-item scales measure fairly concrete objects and attributes (Rossiter, 2002), in future research the use of multi-item scales and multiple respondents would provide more valid and reliable results and prevent common method bias, although we expect that it is unlikely that the ratings of our respondents were structured by implicit theories concerning our rather complex misfit expectations (Podsakoff et al., 2003). To increase the validity of our data collection, we did personal interviews at the location of the interviewees. Moreover, since this study aimed to do a pilot, the number of cases was limited, but in a future full-scale study we intend to collect a larger sample, increasing the reliability of the measures.

Second, in the case of mobile telecommunications, we considered the system to comprise the physical network and the middleware, and to be developed by telecom operators. Since new middleware is sometimes developed for an existing network and existing middleware can operate on new networks, the network and the middleware can better be considered as two parts of the system. In our case studies, it appeared that independent IT firms involved in middleware development had participated in the service development project. These firms can be included as a second category of system firms.

Finally, while we focused on novelty, other factors such as resources, experience of R&D management, capacity, size of the system firm and market demand may also influence a system firm's involvement in complementary product development. Resources may be influential due to the relatively poor financial situation of Dutch mobile telecommunications firms when we collected our data. Most cases in this study referred to periods in which the UMTS biddings in the telecom industry had just taken place in the Netherlands. These biddings have severely deteriorated the cash position of telecom operators, leading to a decreasing ability of telecom operators to participate in service development projects. The lack of resources may have increased the degree of misfit in our sample and at the same time have strengthened the negative direct effect of ownership by the telecom operator on performance. When used as controls in a future full scale study with a larger number of cases, these variables may increase the significance of the findings.

## 4.7 Conclusions

In this study, we tested a model for the most appropriate degree of involvement of system firms in the development of complementary products, based on the novelties of the system and complementary product. In particular, we tested whether misfits between the appropriate and actual degree of involvement had negative performance implications, where appropriateness depended on novelty. We distinguished two elements of involvement: the degree of integration and the degree of ownership by the system firm of development activities for complementary products. We tested the framework on a dataset of service development projects in the Dutch mobile telecommunications industry.

We found partial support for our hypotheses that the novelty of the system and complementary product are determinants of the degree of involvement by system firms in the development of complementary products. We particularly found support for our assumption that the degree of ownership by the system firm should depend on novelty conditions. Moreover, we found a negative direct effect of ownership by the system firm on performance. These results support a combination of the contingency approach reflected in our model, according to which the degree of involvement of system firms has to be adapted to the specific phases in the life cycles of both system and complementary product, and a one best way approach, according to which the involvement of system firms should not be too high. The combination of the two approaches is reflected in Figure 4.2.

This study implies for practitioners that performance requires a choice of involvement by system firms in accordance with novelty. The often chosen solution by telecom operators to outsource service development as much as possible is not necessarily always the best one. From the perspective of market performance, the system firm should not be involved too much when the complementary product is new and the system mature. In other situations the system firm may be involved to some extent, particularly when the system is new relative to the complementary product. Taking these novelty contingencies into account may improve performance in one of the most difficult environments for innovation, that of larger systems.

# 5. How Systems Integrators Organize Component Development Projects: Toward a Configurational Theory

**Abstract**

Systems integrators - firms responsible for the design and development of complex products - can not develop all components themselves. This chapter addresses the question how and when systems integrators need to be involved in component development projects themselves and how and when they can rely on external component developers. In this chapter we conceptualize the organizational form of component development projects as a configuration of four dimensions: (1) the extent that the firm finances the project, e.g. internal, collaborative, or external projects; (2) the extent that the firm performs project tasks itself or relies on other firms; (3) the extent that the firm coordinates the project to align it with other components; and (4) the extent that the firm possesses and absorbs the technological knowledge that is used and generated in the project. Based on existing literature we build a configurational model that proposes an ideal-typical configuration for each of six types of component innovations. To increase our confidence in this tentative theory and to refine it, we study thirty development projects of mobile telecommunications applications. The results partially support our model and also suggest several adjustments.

## 5.1 Introduction

Systems integrators - firms responsible for the design and integration of multi-component, multi-technology products - are continuously confronted with processes of component innovation (e.g. Brusoni et al., 2001). For these firms it is an important question how they should be involved in these many different development projects and how and when they can rely on external component developers. On the one hand, they have to control and coordinate component innovation to ensure the integrity of their products, but on the one hand they have to rely on external actors, because they do not have the capabilities to perform all innovations themselves (Hobday et al., 2005). To deal with this simultaneous need for specialization and integration, Brusoni et al. (2001) found that jet engine manufacturers 'know more than they make'. By maintaining and developing deep knowledge about externally performed innovations (e.g. by developing the basic design of components) these firms were able to coordinate and integrate processes of component-level change.

Hence, by making a distinction between a system firm's production boundary and its knowledge boundary, and by studying their interplay, Brusoni et al. (2001) were able to develop a better understanding of the way these firms manage component innovation. This chapter builds on and extends this approach by simultaneously taking into account multiple dimensions of the system firm's organizational form of component development projects. More specifically, we draw on several fields of literature, such as transaction cost economics (e.g. Williamson, 1985), the resource-based view of the firm (Barney, 1991), and organization theory (e.g. Tushman and Nadler, 1978; Thompson, 1967), to conceptualize the organizational form of development projects as a configuration of four 'dimensions of integration' (see also Jaspers and Van den Ende, 2006).

First, *ownership integration* (Robertson and Langlois, 1995) refers to the extent that a system firm finances a project and therefore owns its output and is able to control it (e.g. Pisano, 1990). This dimension is based on the legal and the transaction cost perspective of firm boundaries (e.g. Williamson, 1985; Grossman and Hart, 1986), which is the dominant approach to the study of vertical firm boundaries (Santos and Eisenhardt, 2005; Holmström and Roberts, 1998). Subsequently, as becomes apparent from the literature about supplier involvement in NPD, a distinction can be made between the extent that a firm finances a project and the extent that a firm performs project tasks (*task integration*). For instance, a firm that fully finances a project might rely more or less extensively on suppliers for the execution of project tasks, e.g. 'black box sourcing' versus 'white box sourcing' (Petersen et al., 2005). *Knowledge integration* refers to abovementioned knowledge boundary of the firm. It reflects the extent that a firm possesses and absorbs the technological knowledge that is used and generated in a development project. As indicated above, a firm might know more than it makes (Brusoni et al., 2001), i.e. the level of knowledge integration can exceed the level of task integration. Finally, the dimension of *coordination integration* refers to the degree of information-processing by the systems integrator to achieve unity of effort with the development project (e.g. Tushman and Nadler, 1978) Coordination integration is independent from the degree of ownership integration (Robertson and Langlois, 1995). Internally financed projects might for instance operate very autonomously, whereas the exchange of coordinative information with external development projects might be very intense.

Different organizational forms of component development projects arise if systems integrators integrate projects to a greater or lesser extent in terms of these four dimensions. To illustrate, in between the extreme configurations of fully integrated projects (high levels of integration on all four dimensions) and fully disintegrated projects (low levels of integration on all four dimensions), a configuration could for instance be a component development project that a system firm partly finances (medium ownership integration), in which it performs only a few tasks (limited task integration), about which it develops a detailed understanding (high knowledge integration), and with which it exchanges a considerable amount of coordinative information to make sure that the component fits into the larger product (medium coordination integration).

By considering the four dimensions of integration as basic building blocks, our objective in this chapter is to develop a normative configurational theory of organizational forms of development projects. A first contribution of this study involves that it extends and integrates literature about the multiple boundaries of the firm (e.g. Robertson and Langlois, 1995; Brusoni et al., 2001; Santos and Eisenhardt, 2005; Araujo et al., 2003). Although the dimensions of integration are based upon existing literature, to our knowledge no prior studies exist that have incorporated all four dimensions of integration in one comprehensive model. In the context of new product development projects, we aim to do so by adopting a configurational approach.

This configurational approach in itself can be seen as a second contribution of this chapter. Only few configurational theories exist in the field of innovation management, even though these theories can result in valuable insights about synergistic effects between concepts (see Chapter 2). These insights have both theoretical and practical value. Theoretically, these insights pertain to the interrelationships between concepts that are usually treated as factors with independent, linear effects. In our case we are for instance able to integrate the fields of literature from which the four dimensions of integration originate (e.g. transaction costs economics, the resource-based view, and organization theory). In terms of practical relevance, the insights from this study come closer to the reality of practitioners, who have to consider multiple organizational dimensions simultaneously rather than in isolation (George and Bennett, 2005). As illustrated above, the configurational approach allows us to conceptualize in great detail the richness of organizational forms as they occur in practice.

A third contribution of this study involves that our unit of analysis is the development project. Assisted by the availability of data at this level of analysis, many studies on the boundary of the firm for innovation take a firm-level perspective. These studies for instance consider the extent that a firm applies make, buy, or ally in order to get hold of innovations. However, theory and data at the project level are likely to provide richer insights (Veugelers and Casssiman, 1999), because this is where innovation actually occurs. Coupled with our configurational approach, this study is uniquely designed to conceptualize the organizational form of NPD projects and to investigate its performance implications.

To achieve our theory-building objective, this chapter takes two steps in the iterative cycle of moving between theory and data (Eisenhardt, 1989). First of all, we build a tentative model that – from the perspective of a systems integrator – proposes an ideal-typical organizational configuration for six different types of component development projects. Following configurational logic, we expect that fit between the type of innovation and its organizational ideal type contributes to project performance. We develop our configurational model theoretically, which means that our model does not suffer from sample dependence (Miller, 1996, Doty and Glick, 1994; Das et al., 2006).

Secondly, to increase our confidence in the theory and to refine it, we confront our tentative model with qualitative data about thirty cases of component development projects in the mobile telecommunications industry. Our analysis is based on the principle of analytical generalization (e.g. Yin, 2003; Firestone, 1993). To increase the strength of this analysis we employ tactics of pattern matching and of theoretical and literal replication (e.g. Yin, 2003). Furthermore, we perform within-case analyses to increase the internal validity of our findings (e.g. Yin, 2003; Van de Ven, 2007). Our results partly support the theoretically developed model as well as suggest several adjustments, such as the identification of equifinal organizational forms. This chapter is structured in the following way. First of all it introduces the four dimensions of integration. Secondly, existing theoretical insights are used to construct an ideal-typical configuration for six different types of component development projects. Next, the methodology is discussed, which is followed by the case study results. The chapter ends with a discussion and conclusions.

## 5.2 Theoretical background: four dimensions of integration

### *Ownership integration*

This section introduces four organizational dimensions of component development projects. We position them in existing literature and touch upon their interrelationships. These dimensions constitute the basic building blocks of the ideal-typical organizational configurations that we will construct in the next section. The first dimension, ownership integration (Robertson and Langlois, 1995), refers to the extent that two stages of production are under common ownership. This legal-administrative perspective on firm boundaries (e.g. Williamson, 1985; Grossman and Hart, 1986; Novak and Eppinger, 2001) plays an important role in many studies on the organization of innovation (e.g. Chesbrough and Teece, 1996; Pisano, 1990; Veugelers and Cassiman, 1999). In this chapter we define ownership integration as the extent that the system firm finances a component development project. Full ownership typically means that the firm has hierarchical control over the project and possesses the exclusive rights to the output of the project. Transaction cost economics indicates that external component developers might refrain from investments in component development projects if the innovation is highly asset specific, i.e. if investments have limited value in other applications because the new component is highly customized and adapted to the product system (Williamson, 1985). The system firm might thus be forced to finance such development projects internally.

The level of ownership integration for a development project is minimal if it is completely financed by one or more other firms. As pointed out in the product modularity literature (e.g. Sanchez and Mahoney, 1996; Schilling, 2000), low ownership integration allows the system firm to benefit from the high-powered incentives of the market, which induces rapid and parallel innovation by external specialists (Robertson and Langlois, 1995; Brusoni et al., 2001). After the successful completion of an external project, the system firm might purchase the component and integrate it in its product. In between the extremes of high and low ownership integration, medium ownership integration refers to projects where the firm shares investments to a greater or lesser extent with one or more partners, i.e. in a new product development alliance (e.g. Gerwin, 2004).

***Task integration***

Secondly, task integration refers to the extent that the system firm performs the tasks in a component development project. This is distinct from the project's ownership structure (Von Hippel, 1990; Ulrich and Ellison, 2005; Sinha and Van de Ven, 2005). When the firm for instance fully finances a project, it has several options with respect to task integration. At one extreme, a completely integrated project results if the firm also performs all the development tasks (high task integration). This has the advantage that appropriation concerns are minimal, because external actors have no direct opportunity to absorb critical information. In addition, integrated projects can be controlled and coordinated based on authority (Mintzberg, 1979; Gulati and Singh, 1998).

At the other extreme, all development tasks are sourced from external actors if the investing system firm adopts a low degree of task integration, i.e. commissioned/contracted projects or black box sourcing. In between these extremes the firm might rely on external actors for only part of the project's workload, e.g. white or grey box sourcing (Petersen et al., 2005). Supplier involvement in NPD has the advantage that the specialized competencies and the incentives of these firms might increase the speed and efficiency of the development process (e.g. Brown and Eisenhardt, 1995; Robertson and Langlois, 1995; Sheremata, 2000).

***Coordination integration***

Robertson and Langlois (1995) used the term coordination integration, our third dimension of integration, to refer to the extent of information exchange between two stages of production to achieve 'unity of effort' (Lawrence and Lorsch, 1967). In our context, we define it as the extent of information exchange between the system firm and the component development project to make sure that the component fits into the product system. A high degree of coordination integration is needed when the component is highly interdependent with other components (Thompson, 1967). In this situation of systemic innovation (Chesbrough and Teece, 1996), intense information-processing is needed, for instance by means of mutual adjustment and team coordination (Van de Ven et al., 1976; Tushman and Nadler, 1978), to make the component compatible with the rest of the product (Daft and Lengel, 1986; Bensaou and Venkatraman, 1995).

In contrast, a project can be performed without any information-processing (low coordination integration) when the new component operates within the limits of existing interfaces (Schilling, 2000; Brusoni et al., 2001). Finally, it is important to note that coordination integration and ownership integration are two related, but distinct dimensions (Robertson and Langlois, 1995). Information processing occurs within the system firm if an internal project is involved, but information processing takes place across firm boundaries when external projects have to be coordinated. The extent of information-processing between the system firm and the component development project reflects the strength of the tie between the two (Granovetter, 1985). In this respect coordination integration considers issues of embeddedness and integration beyond the distinction between market and hierarchy (Stevenson, 2000).

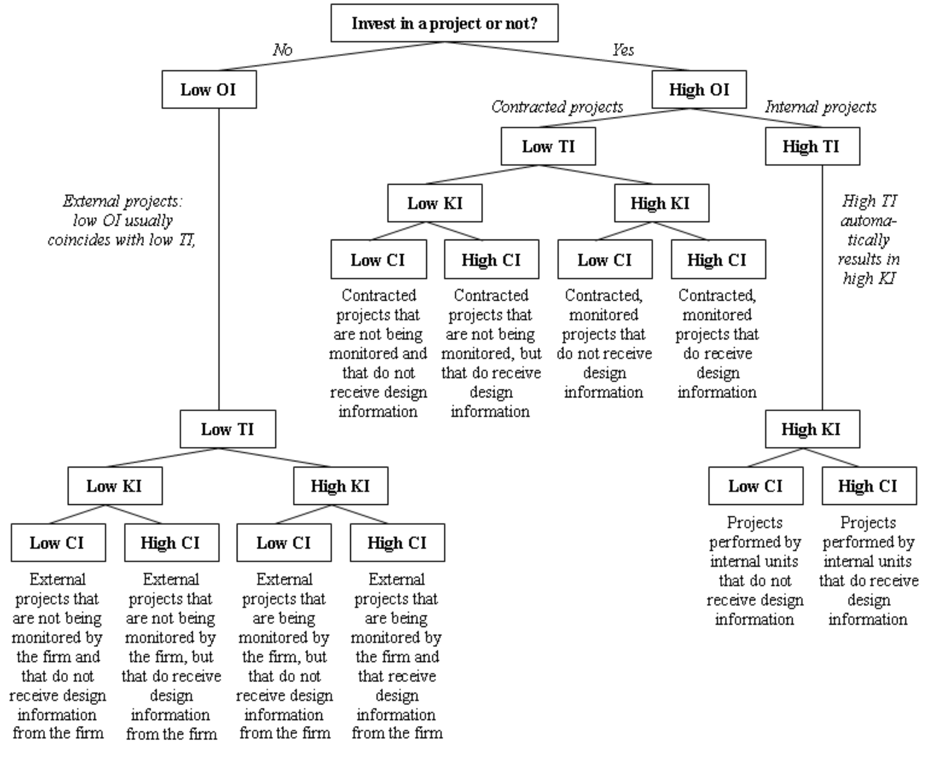
***Knowledge integration***

Fourth, knowledge integration refers to the extent that the system firm possesses and absorbs the knowledge that is used and generated in a component development project. For internally performed tasks the system firm automatically absorbs knowledge as a result of learning by doing. The system firm does not automatically learn from projects if task integration is low, i.e. if component design and development are performed externally (Venkatesan, 1992). Whereas the resource-based view advises firms to focus on its core competences and to leave all other activities to external actors (Prahalad and Hamel, 1990), Brusoni et al. (2001) have shown that system firms might 'know more than they make', i.e. knowledge integration can exceed task integration.

In a similar vein, Takeishi (2002) indicates that a distinction should be made between task partitioning and knowledge partitioning in inter-firm relationships. Firms can for instance expand their knowledge boundary by monitoring external component innovations or by specifying the basic design of components that are developed externally. The resulting internal knowledge of external capabilities helps system firms to access, coordinate, and control these capabilities (e.g. Cohen and Levinthal, 1990; Araujo et al., 2003; Tiwana and Keil, 2007). For instance, in the absence of formal control over a partner, it might help to specify and enforce project outcome controls (Tiwana and Keil, 2007). Brusoni et al. (2001) show how systems firms use knowledge about external component innovations to ensure the coherence of the product system over time.

Figure 5.1 presents some illustrative configurations of component development projects by combining extreme values of the four dimensions. This figure shows some hybrid forms in between the extremes of 'make or buy', i.e. high values on all four dimensions versus low values on all four dimensions, and illustrates some of the interdependencies between the four dimensions. For instance, low ownership integration usually means that such externally financed projects are also being performed by external actors (the left-hand side of Figure 5.1). It is of course possible that the system firm does perform some tasks in externally financed projects, such as component testing or assisting in the design of the component. In addition, the right-hand side of Figure 5.1 indicates that high task integration automatically results in high knowledge integration. This reflects learning by doing.

**Figure 5.1 Illustrative extreme configurations of the four dimensions of integration**




OI=Ownership Integration; TI=Task Integration; KI=Knowledge Integration; CI=Coordination Integration.

## 5.3 A configurational theory

In this chapter we conceptualize the organizational form of component development projects as a configuration of the four dimensions of integration. In this section we distinguish six types of component innovation (see Figure 5.2). Based on existing literature we propose an ideal-typical configuration for each of these types. Given that the resources of system firms are limited (e.g. Hobday et al., 2005), the guiding principle for the development of the ideal types is that these firms should only 'integrate' a development project if this is likely to provide benefits to the development project (e.g. in terms of quality, cost and speed) and/or to the product as a whole that can not be realized by external innovation.

The six types of component innovation that we address in this chapter are primarily determined by the degree of change of the component's technological basis and the degree of change of interfaces between the component innovation and other components (Henderson and Clark, 1990; Chesbrough and Teece, 1996). In addition, as far as components are based on existing technology, we make a distinction between core components and peripheral components (e.g. Teece, 1996; Gatignon et al., 2002). Below we discuss the six innovations in greater detail as we use existing literature to propose ideal-typical configurations. Of course it is impossible to include an exhaustive amount of theory in this process (e.g. Das et al., 2006). In addition, it is difficult to theorize about equifinal organizational forms (e.g. Gresov and Drazin, 1997), especially given the scarcity of theory about high-performing configurations (Grandori and Furnari, 2008). Given that "*(o)ne cannot possibly expect to be comprehensive in developing a taxonomy of innovations and organizational archetypes*" (Teece, 1996, p.216), our approach is to develop only one ideal type for each type of innovation.

**Figure 5.2 Six types of component innovation**

| | **Incremental Change of a peripheral Component** | **Incremental Change of a Core Component** | **Radically New Component Technology** |
|---|---|---|---|
| **Incremental Interface Change** | 1. Incremental innovation of a peripheral component | 3. Incremental innovation of a core component | 5. Modular component innovation |
| **Radical Interface Change** | 2. Architectural innovation of a peripheral component | 4. Architectural innovation of a core component | 6. Radical component innovation |

***Incremental innovation of peripheral and core components***

Incremental component innovations have two basic characteristics (e.g. Henderson and Clark, 1990; Teece, 1996). First of all, they connect to the product system based on existing interfaces. This type of innovation therefore can be implemented without the need to adjust other components, i.e. the level of interdependence for this type of innovation is low. This means that the system firm does not need to exchange information with other component developers to accommodate the integration of the new component. Coordination integration for these 'autonomous innovations' (Chesbrough and Teece, 1996) can therefore be low (Robertson and Langlois, 1995). High coordination integration would result in higher costs and in the loss of time due to an excessive flow of information. Secondly, incremental component innovations are based on existing technology, i.e. the degree of technological change is low. This either means that existing technology is used to create a new component or that a minor adjustment is made to an existing component. The use of existing technology means that technological uncertainty in these development projects is low (Chesbrough and Teece, 1996).

For components based on existing technology, Gatignon et al. (2002) make a distinction between core components and peripheral components. Core components are strategically important to the performance of the product. They are generally based on scarce capabilities and tightly coupled to the product, i.e. specificity tends to be high for these components, because they tend to be interconnected with other components by means of customized interfaces (Teece, 1996; Gatignon et al., 2002). In contrast, peripheral components are of limited strategic importance, because they tend to be based on generic, readily available technologies and tend to be loosely coupled to the product system through only a few standard interfaces (e.g. Venkatesan, 1992; Teece, 1996; Gatignon et al., 2002). Typically, components that are based on new technology are strategically important to system firms, because customized interfaces are required to integrate these components and because it will not yet be clear how they affect other components. Over time technologies mature and interfaces become standardized, thus decreasing the importance of the component. This was for instance the case for the digital control systems of jet engines (Brusoni et al., 2001).

Based on the abovementioned characteristics, system firms are likely to benefit from the high-powered incentives of the market for the development of *incremental innovations of peripheral components* (Type 1 in Figure 5.2). Many external firms will possess the required technological capabilities (or have easy access to them) and are likely to feel the pressure to exploit these capabilities by developing new components (Robertson and Langlois, 1995; Teece, 1996). The system firm therefore does not need to finance and perform such projects, i.e. ownership integration and task integration can in general be low. In addition, the limited strategic importance of peripheral components means that system firms do not need to acquire deep knowledge about these innovations to ensure the coherence of their products, i.e. knowledge integration can be low as well.

In sum, we suggest that the ideal-typical organizational configuration for incremental innovations of peripheral components consists of low integration on all four dimensions, i.e. external projects or '*outsource everything and anything*' (Teece 1996, p.218). For this type of innovation we do not expect that the absence of a system firm negatively influences its outcomes, i.e. external specialists do not need the system firm to perform this type of innovation fast, cheap, and with high quality. Furthermore, this configuration allows the system firm to focus its resources on more important projects. Figure 5.3 indicates for each type of innovation the ideal type that results from the theory-building process. Like in Figure 5.2, the top-left cell represents incremental innovations of peripheral components.

**Figure 5.3 A configurational theory of component development projects**

| | **Incremental Change of a Peripheral Component** | **Incremental Change of a Core Component** | **Radically New Component Technology** |
|---|---|---|---|
| **Incremental Interface Change** | Ownership Integration: L<br>Task Integration: L<br>Knowledge Integration: L<br>Coordination Integration: L<br>***1. External projects*** | Ownership Integration: H<br>Task Integration: H<br>Knowledge Integration: H<br>Coordination Integration: L<br>***3. Autonomous internal projects*** | Ownership Integration: L<br>Task Integration: L<br>Knowledge Integration: H<br>Coordination Integration: L<br>***5. Monitored external projects*** |
| **Radical Interface Change** | Ownership Integration: L<br>Task Integration: L<br>Knowledge Integration: H<br>Coordination Integration: H<br>***2. Monitored & coordinated external projects*** | Ownership Integration: H<br>Task Integration: H<br>Knowledge Integration: H<br>Coordination Integration: H<br>***4. Coordinated internal projects*** | Ownership Integration: H<br>Task Integration: M<br>Knowledge Integration: H<br>Coordination Integration: H<br>***6. Coordinated and partly contracted internal projects*** |

L = Low; M = Medium; H = High

Just as for incremental innovations of peripheral components, we expect that the level of coordination integration can be low in the case of *incremental innovations of core components* (Type 3 in Figure 5.2). On the other three organizational dimensions we suggest high levels of integration. High ownership integration gives the system firm full control over the design and development of these important components. When the firm decides to share project investments with other firms this might result in compromises that are not in the best interest of the product as a whole. Typically, control over core components provides the basis of a firm's position as a systems orchestrator (Adner, 2006). Furthermore, collaboration and contracting with external firms might be difficult for this type of innovation, because strategically important and tacit knowledge is likely to be involved and because investments tend to be highly specific (Teece, 1996).

In addition, it is likely that the system firm already possesses the strategically important capabilities at the start of the development project (Teece, 1996). A combination of high ownership integration and high task integration therefore seems appropriate, because this provides full control and prevents hold-ups and knowledge spill-overs. Furthermore, high task integration means that the system firm is able to exploit these capabilities and that it can maintain and improve its knowledge about these important components through learning by doing, i.e. high knowledge integration. In sum, the ideal-typical configuration for incremental innovations of core components combines low coordination integration with high ownership, task, and knowledge integration. A configuration that resembles this ideal type would be a unit or team that operates autonomously within a system firm.

***Architectural innovation of peripheral and core components***

Architectural innovations are reconfigurations of existing product systems (Henderson and Clark, 1990). In terms of *component* innovation, this means that the technological basis of a component remains the same, but that new or radically different interfaces are required to connect this component to the rest of the product, for instance because significant changes are required to the size and shape of other components. Hence, the implementation of these 'systemic innovations' (Teece, 1996) means that design information has to be exchanged extensively between those responsible for interdependent components (Berggren and Bengtsson, 2004; Brusoni et al., 2001). In our case, where a systems integrator exists that overlooks the coherence of the product as a whole, we assume that this firm takes on the responsibility to identify and resolve interdependencies. In line with information-processing theory we therefore suggest a high degree of coordination integration for this type of innovation, e.g. as a result of mutual adjustment or team coordination (Tushman and Nadler, 1978; Van de Ven et al, 1976; Barki and Pinsonneault, 2005). Low coordination integration would mean that component developers have insufficient information about how to align their components with the rest of the product, which might result in component malfunctions or even in a product failure.

For *architectural innovations of peripheral components* (Type 2 in Figure 5.2) we propose that ownership integration and task integration can in general be limited. Just as for incremental innovations of peripheral components, the system firm can rely on specialized external firms to finance and perform this type of innovation without any substantial risk. However, to understand the consequences of these innovations, system firms need to adjust their knowledge about the affected interfaces. To keep this architectural knowledge (Henderson and Clark, 1990) up to date, Brusoni et al. (2001) suggest that system firms need to 'know more than they make,' i.e. knowledge integration should be high although task integration can be low. This knowledge of external activities can help to improve the effectiveness of coordination integration (e.g. Argote et al., 2003).

In sum, for the development of architectural innovations of peripheral components we suggest a configuration of high levels of coordination integration and knowledge integration, coupled with low levels of ownership integration and task integration. This means that the system firm relies on external innovation, but at the same time - for instance by closely monitoring these external innovation processes - the firm is 'cautious' (Chesbrough and Teece, 1996) regarding the coherence of its product. Hence, the firm is able to coordinate component changes if needed.

*Architectural innovations of core components* (Type 4 in Figure 5.2) involve components that are based on existing technology, but that interconnect with the product system by means of new or significantly altered interfaces. Furthermore, these innovations are strategically important to the performance of the larger product. System firms are therefore likely to possess a detailed understanding of these components and how they relate to other components, and they are likely to feel the need to control the development of these components (Teece, 1996). By performing these innovations internally, i.e. high task and ownership integration, the firm can exploit its capabilities and at the same time maintain full control over the component and how it interconnects with other components.

This integrated approach also has the advantage that it prevents spillovers of strategically important knowledge, and it also results in the automatic absorption of the newly created architectural knowledge. This architectural knowledge enables the firm to effectively coordinate systemic changes with internal or external actors responsible for interdependent components (Brusoni et al., 2001). The ideal-typical configuration that fits best with the characteristics of this type of innovation thus consists of high levels of integration on all four dimensions. An example could be an internal unit that performs the incremental adjustment of the core component and that extensively coordinates interface changes with internal and/or external units responsible for interrelated components.

***Modular component innovation***

Modular innovations are based on new technology, but they comply with existing interfaces (Henderson and Clark, 1990). A modular component innovation (Type 5 in Figure 5.2) either replaces an existing component or adds an entirely new element to the product. Like incremental innovations, modular innovations operate within the limits of existing interfaces and can therefore be integrated into the product with limited or no coordinative effort from the system firm. Coordination integration can therefore be low. The development of technologically new components is a highly uncertain task. To solve technical problems efficiently and fast, the modularity literature stresses the benefits of external organization and specialization for this type of innovation (Baldwin and Clark, 1997; Sanchez and Mahoney, 1996; Schilling, 2000). Facilitated by established interfaces, firms can seek flexibility by letting others take the risks in these highly uncertain development activities (Sanchez, 1995; Lambe and Spekman, 1995). This allows a system firm to benefit from trial and error and idiosyncratic learning at specialized component developers without having to internalize the technology (Robertson and Langlois, 1995; Geyskens et al., 2006). This division of labor, which is commonplace in for example biotechnology and aerospace networks (e.g. Arora and Gambardella, 1990; Brusoni et al., 2001), results in economies of specialization that system firms can not realize on their own.

Although external projects bring specialization benefits, system firms need to closely monitor these dispersed innovation efforts (Brusoni et al., 2001). Uneven rates of progress at the component level might result in technical imbalances that could influence the performance of the product as a whole (Rosenberg, 1976). Brusoni et al. (2001) therefore suggest that firms need to know more than they make for this type of innovation in order to understand its system-wide implications and to be able to coordinate changes of other components if needed. Hence, for the purpose of systems integration the level of knowledge integration needs to be high. In sum, the configuration that seems to fit best with the characteristics of modular component innovation consists of low integration in terms of coordination, task execution, and ownership, but of high knowledge integration. In other words, this configuration requires the system firm to install mechanisms to monitor external projects.

***Radical component innovation***

Radical component innovations (Type 6 in Figure 5.2) involve the development of new interfaces and of components that are technologically new. First of all, high coordination integration is of course needed to accommodate this systemic innovation. Secondly, we suggest a high degree of ownership integration for radical component development projects. External firms might not be willing to commit themselves to these highly uncertain projects, because they are characterized by both high technological uncertainty and high asset specificity (e.g. Geyskens et al., 2006).

In terms of task integration, system firms are faced with a ‘learning dilemma’ (John et al., 2001). On the one hand, firms may want to perform radical innovations themselves to fully control and understand their design and development. On the other hand, they could benefit from external sources to solve technical problems faster, cheaper, and better (Robertson and Langlois, 1995; Sheremata, 2000). As a compromise, we propose a medium level of task integration. This allows the firm to perform the most crucial tasks internally, such as the design of the component, and at the same time it allows the firm to benefit from external expertise and creativity. Although collaboration may be difficult for uncertain projects such as these, for instance because of honest differences of opinion (Gulati and Singh, 1998), a high degree of ownership integration provides the firm with the authority to - if needed - prevent and resolve costly and time-consuming disputes ‘by fiat’ (Tadelis, 2002). At the same time, coordination can be achieved by means of direct supervision (Radner, 1992; Hoetker, 2005).

Finally, the system firm is likely to acquire in-depth knowledge of radical component innovations, because they can have important consequences for the system as a whole. For the tasks the system firm performs itself, high knowledge integration automatically results. For the tasks performed externally, the firm’s hierarchical control as a result of high ownership integration enables it to closely monitor them. In combination with the firms existing architectural understanding, this newly generated knowledge about this innovation also facilitates the extensive coordination that is needed to effectively align the component with the rest of the system. In sum, we propose a highly integrated organizational form for radical component innovations, with a medium degree of task integration. This indicates internal projects (as a result of high ownership integration), that are strongly coordinated and monitored, and that are partly performed by external specialists.

## 5.4 Method

***Analytical generalization***

Above we have followed a theoretical approach to propose a configurational theory of organizational forms for component development projects. As part of the further theory-building process, it is our objective to increase our confidence in this tentative theory and to further refine it using case study research (e.g. Eisenhardt, 1989). For this purpose, our application of case study research is based on the principle of analytical generalization (Yin, 2003; Eisenhardt, 1989; Firestone, 1993). To increase our confidence in the validity of a theory this approach entails that "*a previously developed theory is used as a template with which to compare the empirical results of the case study*" (Yin, 2003, p.32-33). When comparing expectations with case study findings it has to be recognized that cases differ in their potential to provide evidence that supports a theory.

In principle, a single case provides support for a theory (but not definitely proves it!) if this case has an outcome that would be predicted by the theory. This support would be particularly strong if such a case is at the same characterized by values on other explanatory variables that would predict a completely different outcome, i.e. a least-likely case (Gerring, 2007; George and Bennett, 2005; Jaspers, 2007). In contrast, most-likely cases can only provide weak support for the validity of a theory because they are from the outset most likely to corroborate the theory, i.e. confirmation here merely means that the theory has survived a 'plausibility probe' (King et al., 1996). However, a failure to observe the expected outcome for most-likely cases would seriously damage our confidence in the theory (Markus, 1989; Gerring, 2007). For deterministic and precisely formulated theories, which are very rare in the social sciences (Mohr, 1982), a single (crucial) case can even decisively falsify the theory (Gerring, 2007). In sum, findings from individual cases can increase our confidence in a theory to the extent that they are more or less likely to show the predicted outcome, i.e. to the extent that they are difficult tests. When a case supports the theory, analytical generalization - at the very least - means that we can expect the theory to hold in cases that are (almost) similar (Yin, 2003; Firestone, 1993).

Of course our confidence in the validity of a theory grows stronger if we are able to replicate findings in multiple cases (Yin, 2003; Dul and Hak, 2008; Jaspers et al., 2008). In addition to replication with very similar cases, another tactic to increase our confidence in the validity of a theory is to analyze cases that are completely different and for which we would therefore expect different outcomes, i.e. theoretical replication (Yin, 2003). Hence, it is of great importance for replication logic to select cases on theoretical grounds (Eisenhardt and Graebner, 2007). To the extent that multiple cases also support the theory under different scope conditions, the generalizability of the theory increases as it can be expected to hold in a wider domain (Firestone, 1993; Dul and Hak, 2008). It is important to stress that analytical generalizability also applies to other research methods, such as surveys and experiments. The results from surveys for instance need to be replicated in surveys on other populations to increase our confidence in the validity of the theory in its theoretical domain (Dul and Hak, 2008).

The abovementioned ideas about analytical generalization are based on the principle of 'pattern matching' (Yin, 2003). This means that cases are compared with a theoretical expectation in terms of (a pattern of) scores on the independent and the dependent variable. In addition to this approach, another tactic to increase the analytical insights that can be gained from case studies is to perform within-case analyses. These are able to provide evidence about the causal mechanisms that contribute to a certain outcome. This evidence from a lower level of aggregation (King et al., 1994) has the potential to increase our confidence in the causality that is assumed by the theory (Van de Ven, 2007). Such within-case analyses allow us to 'trace the causal process' (George and Bennett, 2005) and to 'elucidate the causal mechanisms' (Gerring, 2007), i.e. it facilitates 'explanation building' for the benefit of internal validity (Yin, 2003).

In this chapter, detailed analyses of individual cases provide an excellent opportunity to increase our understanding of the inner-workings of configurations. Although this can be considered as theory-building 'at a lower level of aggregation' (King et al., 1994), our main interest is to use within-case analysis to refine our theory at its current level of analysis (i.e. configurations of the four organizational dimensions) and to increase our confidence in it (see also Chapter 2). More specifically, we compare in this chapter the six ideal types with a convenience set of thirty component development projects (these cases were analyzed quantitatively in Chapter 4). First of all, we classified these cases as one of the six types of innovation. For each type of innovation, the configuration as presented in Figure 5.3 shows the organizational configuration that we expect to find for each individual case. For each case we compare its observed organizational configuration with its expected configuration and for each case we perform a within-case analysis.

Based on configurational logic (Doty et al., 1993; Doty and Glick, 1994), we expect that a situation of perfect fit (i.e. when an observed instance perfectly resembles its respective ideal profile) contributes positively to project performance. Given the large number of factors that possibly influences project performance, we do not propose that perfect fit is sufficient for high project performance, but we do propose that it makes high project performance more likely. Obviously, case study research is unsuitable to determine the extent that fit contributes to performance, i.e. the size and strength of its causal effect, but within-case analysis does make it possible to show how fit contributes to performance, i.e. it can show that the ideal type 'works' (George and Bennett, 2005). Besides pattern-matching and a within-case analysis, we perform a cross-case analysis for all the cases that classify as the same type of innovation. To the extent that more cases confirm the ideal type (replication) we are able to increase our confidence in the theory.

In principle, we can expect that deviation from the ideal type has a negative effect on project performance. However, given the possibility of equifinality, cases that deviate from the proposed ideal type might also point to an alternative high-performing organizational form (without reducing our confidence in the viability and the appropriateness of the original ideal type). All in all, the case study research that we are proposing can be seen as a step in the iterative cycle of moving between theory and data (Eisenhardt, 1989) in the development of a configurational theory.

***Data and measurement***

The unit of analysis in each of the thirty cases is the organizational form adopted by a Dutch mobile telecommunications operator for the development of a value-added mobile application. Examples of such applications are mobile games, mobile office applications, and mobile payment services. These software products can be considered (complementary) components of the larger mobile telecommunications product system, which for instance also consists of mobile handsets, various content platforms and protocols (SMS, MMS, i-mode, etc.), and the mobile telecommunications network itself (switches, base stations, etc.). This context is very suitable for our study. First, mobile operators can be considered systems integrators for mobile applications. These firms own and operate the networks that enable mobile applications and because of their need to recoup investments in licenses and infrastructure, they have a great interest in the generation of a wide variety of value-added applications. Because of rapid changes in network technologies and protocols, these firms play a central role in the coordination and integration of mobile applications.

Secondly, we are able to keep many factors constant by focusing on one type of component and on one specific product system and industry. In addition, mobile applications are not typical physical components that are sold as integral parts of a larger product (such as car parts). Instead, mobile applications have a market of their own, because mobile users typically have the option to use or to subscribe to specific value-added services or not, i.e. these applications are complementary (software) components of the mobile telecommunications system. For this type of component we might expect that additional factors play a role in determining the organizational form of mobile operators. Chapter 4, for instance, argues that the involvement of operators depends on the need to create an installed base for the network as well as for the application itself. This makes it more likely that our case study analysis provides rich insights, because we focus on an empirical setting that might be considered closer to the boundary of the theoretical domain of our configurational model than regular component development projects, i.e. our setting is less-likely to corroborate the theory.

Third, the mobile industry is very innovative, which allowed us to select projects that differ considerably in terms of the type of innovation. In addition, the projects vary significantly in terms of their organizational forms. They range from fully integrated by mobile operators to fully disintegrated, i.e. external innovation by independent third parties, such as financial institutions, game developers, and news agencies. In addition, our set of cases includes projects from all five mobile network operators that were active in the Dutch mobile market at the time of data collection (2002-2004). The projects range in size from fewer than five people to 200 people, and in duration from less than a month to over a year. Table 5.1 gives a short overview of the projects.

For each case the project manager acted as the key informant. At the time of the interview, each project was completed less than a year before. For several projects we interviewed project managers from the different participating firms. In a semi-structured interview each respondent was interviewed during at least one hour. Right after the interviews the field notes were converted into case reports. For some cases additional information was collected in follow-up telephone interviews. To increase the richness of the data we promised respondents not to disclose the names of firms or applications.

**Table 5.1 Brief description of the thirty applications and their organizational form**

| | Mobile application | Brief description of the organizational form |
|---|---|---|
| **Case 1** | A text-messaging service for groups | Internal development by an IT firm with its own platform |
| **Case 2** | An SMS-based dating application | Internal by a start-up firm with its own SMS platform |
| **Case 3** | An MMS greeting card service | Internal development by a start-up |
| **Case 4** | A voice-response service to remotely control a web page | Internal by an operator-independent IT firm |
| **Case 5** | A mobile payment terminal | Internal by an electronic payment service provider |
| **Case 6** | A MMS communication service | Internal by a start-up firm with its own text messaging platform |
| **Case 7** | An location-based game using GPS and WAP | External development by a start-up and a platform owner |
| **Case 8** | An SMS-based multiplayer game | External development by a start-up |
| **Case 9** | A WAP-based directory service | Internal by the directory company |
| **Case 10** | A text-messaging service for groups | An autonomous unit of a mobile network operator |
| **Case 11** | An on-line photo management application | Internal by an operator together with its platform supplier |
| **Case 12** | An SMS-based lottery service | An alliance between an operator and a lottery firm |
| **Case 13** | A mobile Internet chat application | Collaboration between an operator and a broadcasting organization |
| **Case 14** | A mobile e-mail application facilitating attachments | Collaboration between an operator and an external developer |
| **Case 15** | SMS content messages | Internal by a mobile network operator |
| **Case 16** | A mobile office application based on GPRS | An alliance of an operator, a PDA developer, and a software firm |
| **Case 17** | An SMS application to report the status of security personnel | An alliance between an operator and an security system provider |
| **Case 18** | Mobile Internet route planner | Collaboration between an operator and a route planner developer |
| **Case 19** | A mobile office application based on GPRS | Internal by an IT service provider |
| **Case 20** | Mobile video on demand | Internal by a small and operator-independent IT firm |
| **Case 21** | A mobile ticketing application | An alliance between an IT firm and a train company |
| **Case 22** | A mobile parking application | External development by a start-up |
| **Case 23** | A mobile banking application | External development by a start-up |
| **Case 24** | Car navigation based upon real-time traffic information | IT firm Internal by a motorists' association |
| **Case 25** | A track-and-trace application | An alliance of an operator, a security agency, and a software firm |
| **Case 26** | A mobile personal assistant service | An alliance by an operator and its spin-off |
| **Case 27** | A network-specific notification service | A spin-off from a mobile operator |
| **Case 28** | A mobile patient management system | Collaboration between a mobile operator and an ASP |
| **Case 29** | A mobile banking application | An alliance between an operator and a retail bank |
| **Case 30** | A content SMS application based on a new platform | Internal by a hardware and systems integrating company |

During the semi-structured interviews we addressed the organization of the development project (i.e. the four dimensions of integration), the characteristics of the innovation itself (e.g. technical novelty, interface change), and project performance. Based on the qualitative data that we obtained we rated our variables of interest ourselves. For some variables we could validate our ratings using the quantitative data that we obtained at the start of each interview using a self-completion questionnaire (see Chapter 4 of this thesis). *Ownership integration* and *task integration* were for instance measured on a five-point scale ranging from a score of 1 (the operator did not invest in the project/performed no project tasks) to a score of 5 (the operator made all investments itself/performed all project tasks). A score of 3 referred to the equal division of investments and project work load between the operator and its partner firm(s).

We rated ownership integration and task integration as low when the operator did not invest in the project or did not perform any project tasks (these ratings corresponded to scores of 1). Both variables were rated as medium to indicate that the operator performed or financed at least some part of the project up to half of the project (these ratings corresponded to scores of 2 and 3). We rated ownership integration and task integration as high when the operator financed or performed considerably more than half of the project or the entire project (corresponding to scores of 4 and 5). In 6 out of the 60 ratings the quantitative data were not in line with our qualitative ratings. For these instances we had clear qualitative evidence to deviate from the quantitative score as indicated by the respondent. In two cases (Case 2 and Case 8) the respondent for instance indicated that an operator financed part of the project (scores of 2). However, these investments involved the costs for the first commercial implementation of wholesale applications. The actual development of these applications was however financed completely by external application developers (i.e. low ownership integration).

In principle, *knowledge integration* was assigned the same rating as task integration because of learning by doing. However, for nine projects we found qualitative evidence that the operator developed a detailed understanding of the application although it did not perform all project tasks, i.e. high knowledge integration. This evidence, for instance, involved the operator asking (ex ante) if it were possible to get access to the insights and the lessons learned from the (external) project (Case 19), but in most cases the operators 'knew more than they made' because of their involvement in the basic design of the application, in application testing, and/or because of project monitoring.

In terms of *coordination integration* we rated twenty-two projects as low. In fifteen of these projects no operator was actively involved and there was as a result no coordination between the project and an operator. In the remaining seven projects an operator was at least to some extent involved in terms of ownership integration and/or task integration, but this involvement did not pertain to the exchange of coordinative information. In these seven projects the interface specifications were clear from the outset in these projects. In five cases coordination integration was rated as high, because an operator was heavily involved in establishing interface specifications and in making sure that the network would accommodate the application. In three of these cases interfaces were established in close collaboration with external application developers (Case 17, Case 18 and Case 28), and in two cases (Case 15 and Case 27) the application was developed within a mobile operator, i.e. coordination integration involved frequent communication between different internal units. Finally, in the three remaining cases coordination integration to accommodate the implementation of the application was medium. In Case 16 and Case 29 the managers from the operator indicated that information exchange with external actors was limited and far from extensive. In the third case, Case 30, the project manager from an external developer stated that there had been some, but limited contact with operators for the implementation of the application.

Figure 5.4 presents how the thirty projects are allocated to the six types of innovation. This figure also shows the ideal profile for each type of innovation (taken from Figure 5.3) and for each case this figure reports its observed profile in terms of the four dimensions of integration. As can be seen from Figure 5.4 our set of cases contains eight incremental peripheral component innovations, only one architectural peripheral component innovation, five incremental core component innovations, four architectural core component innovations, eight modular component innovations, and four radical component innovations. Below we outline the measures that we used to classify the thirty cases into the different types of innovation.

In total, twelve projects were concerned with the development of applications that were technologically new, i.e. modular component innovations and radical component innovations. These applications involved new pieces of hardware (e.g. a GPS tracking device that included a data only SIM card), new pieces of software (e.g. a technology to transform live television streams into a mobile format), and/or technologically new interfaces *within* the application itself (e.g. a mobile banking application that integrated a customized mobile handset and a banking system).

**Figure 5.4. An overview of ideal and observed configurations**

| | Incremental Change of a Peripheral Mobile Application | | | | | Incremental Change Of a Core Mobile Application | | | | | Radically New Mobile Application | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | OI | TI | KI | CI | | OI | TI | KI | CI | | OI | TI | KI | CI |
| **Incremental Interface Change** | **1. Ideal Profile** | **L** | **L** | **L** | **L** | **3. Ideal Profile** | **H** | **H** | **H** | **L** | **5. Ideal Profile** | **L** | **L** | **H** | **L** |
| | Case 1 | L | L | L | L | Case 10 | H | H | H | L | Case 19 | L | L | H | L |
| | Case 2 | L | L | L | L | Case 11 | H | M | H | L | Case 20 | L | L | L | L |
| | Case 3 | L | L | L | L | Case 12 | M | M | H | L | Case 21 | L | L | L | L |
| | Case 4 | L | L | L | L | Case 13 | L | M | H | L | Case 22 | L | L | L | L |
| | Case 5 | L | L | L | L | Case 14 | L | M | H | L | Case 23 | L | L | L | L |
| | Case 6 | L | L | L | L | | | | | | Case 24 | L | L | L | L |
| | Case 7 | L | L | L | L | | | | | | Case 25 | M | M | M | L |
| | Case 8 | L | L | L | L | | | | | | Case 26 | M | H | H | L |
| **Radical Interface Change** | **2. Ideal Profile** | **L** | **L** | **H** | **H** | **4. Ideal Profile** | **H** | **H** | **H** | **H** | **6. Ideal Profile** | **H** | **M** | **H** | **H** |
| | Case 9 | L | L | H | L | Case 15 | H | H | H | H | Case 27 | H | H | H | H |
| | | | | | | Case 16 | H | H | H | M | Case 28 | M | M | H | H |
| | | | | | | Case 17 | M | M | H | H | Case 29 | M | M | M | M |
| | | | | | | Case 18 | L | M | H | H | Case 30 | L | L | L | M |

OI=Ownership Integration; TI=Task Integration; KI=Knowledge Integration; CI=Coordination Integration;
L = Low; M = Medium; H = High.

The remaining eighteen projects involved incremental and architectural innovations. These innovations were incremental adjustments of existing applications or new applications that were based on technological capabilities that were familiar to the project team. Nine of these applications can be considered core applications and the other nine can be considered peripheral applications. Core applications are tightly coupled to the mobile network and/or strategically important to the operator (e.g. Gatignon et al., 2002). Tightly coupled applications involve applications that interface directly with multiple mobile network elements, such as switches and billing systems, by means of customized interconnections. Case 15, Case 16, Case 17, and Case 18 involved the creation of new and tailor-made interfaces. Case 18 for instance involved a specific interface with the operator's billing system and Case 17 involved customized SIM cards. In addition, Case 13 and Case 14 were tailored to one specific mobile network using the operator's proprietary standard. These integral applications could therefore not be readily implemented on other networks. Furthermore, in our set of cases several projects were regarded as highly important by the operator. These projects for instance served to increase the operator's innovative image (Case 12), to generate additional revenues (Case 10 and Case 15), to attract users for a new network technology (Case 11, Case 13, Case 14, and Case 18), or to build a footprint in a new user segment (Case 16). In contrast, eight cases (Case 1 - Case 8) use standard and open communication protocols and are of limited strategic importance to the operators. Mostly, these peripheral applications interconnect with application platforms using only a single interface). Case 9 is neither strategically important nor customized, yet it does involve radical change to network interfaces.

In the questionnaire we also asked respondents about the novelty of the interface(s) *between* the application and the mobile network. This allowed us to determine the degree of interface change, i.e. the vertical axis of Figure 5.4. Nine projects involved new interfaces or the radical adjustment of existing interfaces, i.e. the architectural and the radical innovations. The remaining twenty-one projects operated within the limits of existing interfaces, such as those specified in protocols like SMS, WAP, MMS, and i-mode, and in network technologies like GSM and GPRS. These projects involve incremental and the modular innovations.

Finally, we discussed several dimensions of project performance with our informants, such as the speed of the development project, the project's adherence to budget goals and interim deadlines, and the quality of the application. We could complement these qualitative insights with quantitative data from the questionnaire about the extent that performance in terms of each dimension was below, in line with, or beyond expectations.

## 5.5 Results

In this section we report the findings for each type of innovation. Given space limitations we focus on the most insightful within-case findings and on the results from cross-case analysis. Figure 5.5 on the next page illustrates the results as it shows whether - and if so how - the findings cause adjustments to the theoretically developed configurational theory (as displayed in Figure 5.3).

### *Type 1. Incremental innovation of peripheral mobile applications*

Eight cases fit this type of innovation and they all perfectly resemble the ideal profile of low values on all four dimensions, i.e. development projects without any involvement of a mobile operator. In line with our expectation these 'perfect fits' generally performed very well. Given the generic technologies and the standard interfaces involved, the innovators could successfully develop and implement the applications without the support of mobile operators. As far as performance was somewhat disappointing, this was not due to the absence of a mobile operator. One project manager for instance indicated that project efficiency was somewhat disappointing, because project members communicated too frequently (Case 2). Another manager was disappointed with project speed as a result of a slow regulatory certification process (Case 5). Collectively, these eight replications increase our confidence in external innovation as a viable configuration for the development of incremental innovations of peripheral components. Hence, there is no need to adjust the original ideal profile (see Figure 5.5).

### *Type 2. Architectural innovation of peripheral mobile applications*

Only one case involved the development of an architectural innovation of a peripheral mobile application (Case 9). In this project a mobile Internet version was developed of an already existing directory service. The alignment of the application with the mobile network was an uncertain task however, because the application had to be adapted to the specific requirements of each new mobile handset that supported the WAP (Wireless Application Protocol) mobile Internet technology. At the time of this project, WAP was still a very new technology. In line with the ideal profile, this project was financed and performed without the involvement of a mobile operator (low ownership integration and low task integration). And in line with what we might expect, the application developer (a directory firm) was able to successfully develop this straightforward application.

The development of the interfaces was another story though. The directory firm had designed the application with limited specificity in order to make the application available through multiple mobile networks. However, at the request of a pioneering operator the application was initially included in the new mobile Internet portal of this operator. This operator collected the specifications of new mobile phones itself (high knowledge integration), but it did not communicate this architectural knowledge to external developers (low coordination integration). The operator was of the opinion that developers had to acquire handset specifications themselves. However, the directory firm decided not to invest in the collection of information about how to connect new mobile phones. As a result, the application worked on just a few handsets and malfunctioned on many others.

In line with what we might expect, this case shows that the absence of coordination integration reduced the quality of the application (and therefore also the quality of the operator’s portal). The project manager from the directory firm indicated that the application would have been regularly updated should the directory firm have had easy access to the right information. In sum, the operator could have prevented the limited performance of this project by communicating the architectural knowledge it possessed anyway, i.e. by taking on a more active role as a systems integrator. The required high degree of knowledge integration was present, but without a high degree of coordination integration this does not contribute to project performance. On the contrary, this deviation from the ideal profile shows exactly the type of interface problems that we would expect. This case therefore supports the originally proposed ideal profile.

**Figure 5.5 The refined configurational theory of component development projects**

| | **Incremental Change of a Peripheral Component** | **Incremental Change of a Core Component** | **Radically New Component Technology** |
|---|---|---|---|
| **Incremental Interface Change** | Ownership Integration: L<br>Task Integration: L<br>Knowledge Integration: L<br>Coordination Integration: L<br>***1. External projects*** | Ownership Integration: H H/M/L<br>Task Integration: H M<br>Knowledge Integration: H H<br>Coordination Integration: L L<br>***3. Autonomous internal projects or monitored collaborative projects*** | Ownership Integration: L M<br>Task Integration: L H/M<br>Knowledge Integration: L H/M<br>Coordination Integration: L L<br>***5. External projects or collaborative projects*** |
| **Radical Interface Change** | Ownership Integration: L<br>Task Integration: L<br>Knowledge Integration: H<br>Coordination Integration: H<br>***2. Monitored and coordinated external projects*** | Ownership Integration: H H/M/L<br>Task Integration: H M<br>Knowledge Integration: H H<br>Coordination Integration: H H<br>***4. Coordinated internal projects or monitored and coordinated collaborative projects*** | Ownership Integration: H H/M L<br>Task Integration: H M L<br>Knowledge Integration: H H L<br>Coordination Integration: H H M<br>***6. Coordinated internal projects, monitored and coordinated collaborative projects, or intermediate systems integration*** |

L = Low; M = Medium; H = High.

### *Type 3. Incremental innovation of core mobile applications*

Five cases fit into this category of technologically straightforward, yet strategically important (all five) and network-specific (Case 11, Case 13, and Case 14) innovations. One of them (Case 10) perfectly resembles the ideal profile of low coordination integration and high levels of ownership integration, task integration, and knowledge integration. This project was performed by a team within the R&D unit of a mobile operator. This operator considered this application strategically important because of its strong potential to increase the operator’s revenues by allowing groups of people to exchange text messages. The application used straightforward SMS interfaces, which meant that the team could easily implement the application without any communication with units responsible for other network elements. In line with our expectations for this ‘perfect fit’ the project manager indicated that the project was performed successfully and that it resulted in a high-quality application.

The other four projects all deviate from the ideal profile, but still performed in line with expectations. Next we discuss these four cases in some greater detail to investigate why these deviations occurred and why they did not coincide with disappointing performance. First of all, we expected to observe high task integration for these projects, but in all four projects the operator performed only part of the project workload (medium task integration). In Case 11 the operator collaborated with an IT platform supplier with whom the operator had a long and a strong relationship. Considerable trust therefore existed between both firms and the supplier could effectively contribute to the project because of its detailed understanding of the operator’s application platform. Case 12 and Case 13 involved applications that the operators considered strategically important, but these applications heavily relied on complementary assets owned by external actors, i.e. a lottery firm and a broadcasting organization. The active involvement of these firms was therefore more efficient and effective than full task integration (and duplication) by the operator. In Case 14 the operator attempted to develop the application internally, but because of technical problems it approached a web agency to continue the project. In sum, in all four projects an external actor was involved to some extent because of the operators’ expectation that this would contribute to the project’s performance.

In addition, in all four projects the operators performed only those tasks that enabled them to develop a detailed understanding of the project. These tasks for instance involved the basic design of the application and application testing. In addition to this selective type of task integration, in each project the operator closely monitored the detailed design and programming work that was performed by their partners. In Case 13 the operator for instance communicated with its partner on a daily basis and in Case 14 the operator tested and discussed the latest version of the application once a week. Hence, despite only a medium level of task integration, knowledge integration in all four projects was high. Note that communication between the operator and its partners did not serve the purpose of coordination integration, because in each project the network interfaces already existed and remained stable. Instead, the high degree of knowledge integration contributed to the operators’ ability to control these projects in the absence of high task integration.

For three projects this ability to exercise control was especially important given the absence of the expected high degree ownership integration. The operator in Case 11 did finance the project itself, but in Case 12 the operator financed the project only in part (medium ownership integration), and in Case 13 and Case 14 the external actors even financed the entire project (low ownership integration by the operator). In Case 13 and Case 14 the operator allowed these external actors to finance the entire project, because these projects used the operator’s proprietary mobile Internet standard. In combination with their high degree of knowledge integration, this allowed the operators to strongly control these projects. In Case 12 the application was not specifically tailored to the operator’s network, which might explain why the operator at least in part invested in this project.

Then the question remains why the operators' partners were willing to participate and invest in these projects even though these projects were heavily controlled by the operators. In Case 12 and Case 13 the operators' partners were willing to invest in the project because they wanted to exploit their complementary brand names and their customer base in the mobile market. In Case 14 the application developer met the request of the mobile operator to finance the entire project, because it hoped to perform projects for this operator in the future. In this regard, this firm took for granted that it would not make a fair return on this project,

All in all, whereas Case 10 illustrates that the ideal type of autonomous internal projects provides an appropriate organizational setting to execute this type of innovation, four replications suggest that monitored collaborative projects (i.e. high knowledge integration coupled with medium task integration and possibly even with low ownership integration) constitute a suitable alternative. This alternative allows operators to benefit from the expertise, the (complementary) resources, and the incentives of external actors, while they are still able to strongly control the development process. We can therefore extend our model for this type of innovation with an equifinal organizational configuration of low coordination integration, medium task integration, and high knowledge integration that can be coupled with various degrees of ownership integration (see Figure 5.5).

***Type 4. Architectural innovation of core mobile applications***

Four projects classified as architectural innovations of core components. The ideal profile for these projects is high integration on al four dimensions. Case 15 perfectly resembles this ideal profile of fully integrated projects. In this case an operator financed and performed the creation of new and specific interfaces between several of its network elements to make it possible for mobile users to send and receive content text messages, such as news alerts and ringtones. Ownership integration and task integration are therefore high. There was also considerable information exchange between the different internal units that were responsible for the network elements that were affected by this project (high coordination integration). Because the operator already possessed the relevant technologies itself, and because it performed and coordinated all project tasks, the degree of knowledge integration can be considered high as well. The team for instance developed detailed knowledge about how to adjust the network elements as a result of the intensive internal coordination effort.

However, despite this perfect fit, Case 15 experienced severe problems with the development of the interfaces for this network-specific application. According to the project manager, external specialists should have been involved in the project, such as a developer of SMS centers. Although the operator did possess all the relevant network elements, the operator lacked a detailed understanding of these pieces of equipment at the start of the project. The operator managed to develop internally the necessary architectural knowledge, but this required much more investments than expected and the quality of the resulting interfaces was disappointing. According to the project manager the quality of the interfaces would have been better should one or more external component specialists have performed part of the development project. In other words, ex post there was a high degree of knowledge integration, but at the start of the project the degree of knowledge integration was limited. In this situation, a medium degree of task integration, i.e. cooperation with external specialists, seems appropriate, because this would have increased the degree of knowledge integration at the beginning of the project.

The other three cases seem to corroborate this view. In Case 16 an operator developed a mobile office application that consisted of several off-the-shelve hardware and software components, such as PDAs and synchronization software. A substantial part of the project involved adjusting these components to tailor them to the operator's network. The operator performed these interface tasks all by itself (high task integration) based on only limited information exchange with its suppliers (medium coordination integration). The operator managed to develop the required interfaces, but according to the project manager the project performed below expectations. The operator lacked the detailed expertise of its component suppliers that could have helped to develop the interfaces fast and efficiently. A medium degree of task integration therefore, coupled with a high degree of coordination integration with the suppliers, is likely to have resulted in better project performance. This would have been in line with the original plan for this project, which was to arrange an alliance between the operator and its suppliers. In the end, the operator's (large-sized) suppliers were hardly committed to this project, which forced the operator to go it alone.

Unlike Case 15 and Case 16, Case 17 and Case 18 did involve the active participation of external specialists in the application development project. In each project an external actor applied its specific expertise to successfully perform a part of the development project (medium task integration). Hence, these cases show that external specialists, in the absence of a knowledgeable operator, can help to prevent disappointing project performance. In addition, we find that these external actors financed respectively part of the project (medium ownership integration) and the entire project (low ownership integration). In line with our findings for incremental innovations of core components, we find that the operators in both Case 17 and Case 18 aimed to control these collaborative projects by performing tasks selectively, for instance by designing and developing the interfaces, in order to build a detailed understanding of the project (high knowledge integration). In addition, the operators had further possibilities to control these projects because they of course owned the networks to which the applications had to be customized. In Case 18, progress by the application developer was for instance fully dependent on operator approvals.

In sum, the four cases suggest an organizational form that is different from the original highly integrated organizational form. The cases indicate that monitored and coordinated collaborative projects, i.e. high knowledge integration, high coordination integration, medium task integration, and possibly medium or low ownership integration, provide the ingredients for an organizational form that contributes to project performance. This new configuration assumes however that the operator lacks a detailed ex ante understanding of the technologies involved. This is why the involvement of external specialists can be beneficial. The assumption for the original ideal profile was that the operator does possess a detailed understanding of the technologies involved. In this regard, Case 15 perfectly fits the original ideal profile, but it does not meet the assumption of high ex ante knowledge integration. Hence, this case can not be considered to disconfirm the original ideal profile. Instead, we consider this case as support for the new profile. Because of the different assumptions for the original and the new organizational configuration, we depict them both in Figure 5.5. In our dataset we have no cases that allow us to qualify the appropriateness of the original ideal profile.

***Type 5. Modular mobile application innovation***

Eight projects were technologically new and could be implemented using existing interfaces. One of these cases (Case 19) perfectly resembled the ideal profile of monitored external projects, i.e. low degrees of ownership integration, task integration, and coordination integration, and a high degree of knowledge integration. The operator in this case realized a high degree of knowledge integration because it got access to the lessons learned in this external development project. The operator wanted to use this expertise in the future development of its own mobile office application. Hence, the high degree of knowledge integration did not contribute to the performance of this specific project of Case 19. Given that Case 19 lived up to its expectations, this suggests that the ideal-typical organizational form for modular component development projects can be adjusted to a configuration of full disintegration on all four dimensions of integration.

Five of the remaining seven projects in fact resemble such a completely disintegrated organizational form. Three of these projects (Case 20, Case 21, and Case 22) performed very well and therefore support the idea that it is perfectly possible for external innovators to develop a modular component innovation without a high degree of knowledge integration from the side of an operator. The other two fully disintegrated projects (Case 23 and Case 24) performed very badly, because both projects required significantly more time and financial resources than expected. However, supporting the configuration of full disintegration, the within-case analyses for these two cases did not reveal that the disappointing performance was due to a lack of operator involvement and knowledge. Arguably, both cases were technically the most ambitious projects of the five ‘perfect fits’ and at the same time they were initiated by firms with the least capabilities, i.e. a small start-up and a motorists’ association without any IT-related NPD experience. It can therefore be no surprise that these projects failed.

In sum, from the perspective of operators, external innovation appears a viable and an attractive organizational form, because external firms appear to be willing to take substantial risks to realize this technologically ambitious type of innovation and they can succeed without any operator involvement. The originally proposed high degree of knowledge integration by a mobile operator does not appear to be important to successfully complete this type of innovation project. In line with these findings we can adjust the configuration to low values on all four dimensions (see Figure 5.5). However, as shown by Case 19, a high degree of knowledge integration might still have important long-term benefits for operators.

Unlike the six prior projects, Case 25 and Case 26 actively involved mobile operators in terms of ownership integration and task integration. These projects therefore substantially deviate from the adapted ideal profile of full disintegration. Both cases are different from the six cases above however, in that the operators actively participated in these projects for its learning and long-term benefits. The operators did not have a great interest in the performance of these two projects themselves and for the completion of these projects they relied as much as possible on external actors. This is in line with the rationale for the ideal type of full disintegration.

In Case 25 the operator performed part of the project's tasks and was responsible for part of the required investments (medium levels of task integration and ownership integration). This involvement from the operator mainly pertained to the development of an innovative component of this mobile application (a data only SIM card). In future projects other application developers could use this component to develop many other applications without the active involvement of the operator. The operator therefore participated in this specific project for its long-term effects. In a similar vein, the operator in Case 26 developed a technologically uncertain application within its research division, but externalized the new technology as soon as it got patented. Hence, besides the configuration of disintegration on all four dimensions we also find evidence for a configuration with substantial operator involvement. We have included this possibility in Figure 5.5, but we have to take into account that this configuration serves to promote the operator's learning and long-term interests, rather than project performance. In this respect, this additional organizational configuration is not really an equifinal organizational form.

Finally, we would like to elaborate on an additional insight from the within-case analysis of Case 26. The operator financed and performed the initial development of this innovative application, and once this was completed, an autonomous spin-off was created that invested in the further development of the application. Ownership integration for the project as a whole was therefore medium. The operator performed almost all development tasks however (high task integration), because the spin-off contracted the additional development work to finalize and further improve the application from the operator's research division. In fact, the spin-off had no other choice, because it was highly dependent on the knowledge and the expertise of operator's technicians. These specialists still operated within the operator however, and once they had initially designed the application and externalized it, they had much less incentives to optimize the application. According to a director from the start-up, the resulting lack of commitment and responsibility from the operator's technicians - as they gave priority to internal projects - meant that the platform malfunctioned for a long time because essential redesigns were not completed in time. This provides a fine illustration of the operator's long-term focus for these projects.

***Type 6. Radical mobile application innovation***

Four projects classify as radical component innovations. None of the four projects that classified as a radical component innovation match its ideal profile of high levels of integration in terms of ownership, knowledge and coordination integration and medium task integration. The medium degree of task integration was proposed as a compromise between the need for high task integration (to fully control proprietary and tacit know-how) and the possibility to benefit from external resources to reduce the significant uncertainties in this type of innovation. The organizational form of Case 27 almost matches this ideal profile as it consists of high levels of integration on all four dimensions. This application was developed internally by the research division of a mobile operator. The fact that this application was developed by a research division and that the operator wanted to patent the underlying application platform might explain the full internalization of the project, i.e. the desire to learn and the need to prevent knowledge leakage was high. The application that resulted from this project performed as intended, but we can not exclude the possibility of course that the involvement of external actors could have reduced for instance the project's costs. As soon as the application's technology was patented, an independent start-up licensed the operator's platform to commercialize it.

Case 30 deviates substantially from the ideal-typical configuration, since operator involvement in this project was very limited, i.e. it was financed and performed without any substantial operator involvement (low ownership integration and low task integration). The project involved the first application of a completely new text messaging platform. This platform made it possible to exchange content messages, whereas text messages used to involve only person-to-person messages. The platform and the application were developed mainly by a technology company that used to produce SMS centers and that used to consult operators with the implementation of this equipment. Hence, this company labels many of its activities as 'systems integration'. By developing this platform it wanted to become a service company that takes an intermediary role in between operators and content providers. At the time - according to the project manager - operators were hardly aware of the opportunity to generate revenues with content messages.

The operators did communicate with this technology company to interconnect the platform, but this was very limited since the technology company - as a systems integrator - understood in great detail the needs of the operators (medium coordination integration). Neither did the operators develop any detailed understanding of the service platform (low knowledge integration), as they felt no urgency to introduce this type of application. The development of the first pilot application for this platform was very costly, but in terms of quality it performed very well. Hence, this case indicates that radically new applications can be successfully developed in the presence of systems integration intermediaries, thus reducing the need for operators to become involved in these projects and to coordinate them. This challenges our assumption that mobile operators take on the responsibility to act as a systems integrator. We elaborate upon this finding below in the discussion section. This finding of 'downstream systems integration' is included in Figure 5.5 by suggesting an ideal type of 'external, lightly coordinated projects' (a configuration of low task integration, low ownership integration, low knowledge integration, and medium coordination integration).

Case 28 and Case 29 were both performed only in part by mobile operators themselves (medium task integration). This is in line with our expectation that external actors should be used to assist in the successful completion of this complex type of innovation. Both projects also involve external investments however, which reduces the control of operators over these projects (medium ownership integration). Next we discuss these two projects in some greater detail. Like Case 30, Case 28 involves the development of an application as an integral part of a new platform development project. The majority of the detailed development work was performed by an IT company that wanted to become a wireless application service provider. The platform was connected to one mobile network, and its operator was also involved in the project, i.e. it financed part of the project (medium ownership integration), it participated in the design of the application and in project tests (medium task integration), and it was closely involved in its coordination (high coordination integration). Because of its coordinating role (e.g. integrating for instance the activities of several hardware providers) and its involvement in application tests, the operator also obtained a detailed understanding of the application (high knowledge integration). The project performed very well. It was for instance completed much faster than expected.

Case 29 involves an alliance between a mobile operator and a retail bank for the development of a mobile banking application (medium ownership integration and medium task integration). For the operator it would not have been possible to develop this application on its own because it lacked any detailed banking expertise and capabilities. The operator was not involved in the design phase and during the detailed development phase sub teams from both firms often operated autonomously. Furthermore, cultural differences between the two firms resulted in substantial communication barriers. Hence the level of coordination integration was medium and also knowledge integration was restricted (medium knowledge integration). As we might expect for this type of innovation, the project was confronted with significant interface problems in the absence of intense coordination integration. The interdependencies between the banking systems and the telecommunications network were for instance completely underestimated and large uncertainty existed about whether and how the activities of both actors would be aligned.

The project required much more financial resources than expected and the project also failed to meet most project milestones. To improve the security of the interfaces between the mobile network and the banking system it was for instance necessary to develop a customized SIM card. During the process the bank took on more and more responsibilities from the operator, because the bank had an important deadline to make (it wanted to use the application as a summer gift to its users) and because it did not want to damage its strong image with a malfunctioning application. The operator also felt the urgency to realize this application, but substantially less than the bank. The operator’s main objective was to attract new users with this application. Coupled with the differences between the telecommunications industry and the highly regulated financial services industry, which strongly emphasizes security, this meant that the operator was less concerned than the bank about the quality and the security of the application and its network interfaces.

In sum, Case 28, Case 29 and Case 30 show that external actors possess relevant skills and resources to help perform development projects of radically new components. In addition, Case 28 shows that a combination of high knowledge integration and coordination integration can help to prevent architectural problems and provides the operator with control over these projects, thus partly substituting the loss of formal control based on project investments. In this respect, Case 29 shows that insufficient coordination integration causes interface problems. We adjusted our ideal type accordingly (see Figure 5.5) by including an organizational form of monitored and coordinated collaborative projects (high knowledge integration and coordination integration, coupled with medium ownership integration and task integration).

## 5.6 Discussion and conclusions

This chapter deals with the decisions of systems integrators (i.e. firms responsible for the development and the integration of product systems) regarding their involvement in the development of components for their products. Whereas most studies on the organization of innovation consider the extent that a firm sources its technology and innovations internally, externally, or through alliances, we extend the literature that focuses on the organizational form of specific innovation projects (e.g. Pisano, 1990; Veugelers and Cassiman, 1999). Furthermore, we move beyond the dominant focus on the decision between make, buy, or ally (ownership integration) by also considering: the actual integration of project tasks by the system firm (task integration); the project's integration by the system firm in terms of coordination (coordination integration); and the extent that the system firm possesses and develops a detailed technological understanding of the project (knowledge integration).

By considering the organizational form of component development projects as configurations of these four dimensions of integration, we extend the existing multi-dimensional conceptualization of organizational forms in the systems integration literature (Brusoni et al., 2001). Our configurational approach materialized as we proposed an ideal-typical configuration for each of six different types of component innovation. In spite of the tentative nature of this configurational model, which we developed based on existing theoretical insights, our case study analysis was largely unable to disconfirm the claim that the ideal types are suitable to deal with the challenges and the characteristics of their respective component development projects. Overall our case study analysis provided no grounds to change four of the six initially formulated ideal types. The other two ideal types were adjusted only slightly based on the case study findings. In addition, our case study analysis identified several equifinal organizational forms.

The resulting refined configurational model (Figure 5.5) suggests that organizational forms for component development projects need to be tailored to the project's characteristics and that multiple ways exist to achieve this objective. This supports prior contingency models (e.g. Chesbrough and Teece, 1996; Teece, 1996; Brusoni et al., 2001), adds project-level empirical substance to this field, and indicates the existence of internally consistent configurations. We for instance found that operators for several types of innovation complement collaborative projects with selective task involvement and with high knowledge integration. This adds to existing literature about how 'excessive' knowledge plays a role in the innovation process (e.g. Brusoni et al., 2001; Takeishi, 2001; Tiwana and Keil, 2007). Below we discuss our findings in greater detail. We start with the ideal types that were left unchanged and then move on to the ideal types that we slightly adapted and finally we address the new equifinal configurations. After that we reflect on our methodology, pinpoint limitations, and suggest opportunities for future research. We end with managerial implications.

***Unchanged ideal types***

In terms of the unchanged ideal types we found first of all that the ideal types for the development of incremental innovations of peripheral components (Cases 1-8) and core components (Case 10) constituted organizational forms that are appropriate for the execution of these projects. They contributed to project performance and/or they were beneficial to the interests of the systems integrator in general. All nine cases were perfectly in line with the ideal type. Individually, these cases therefore have limited potential to increase our confidence in the ideal types.

However, coupled with the within-case evidence, the eight replications for *incremental* *innovations of peripheral components* strongly increase our confidence in this ideal profile as an appropriate organizational configuration. All eight cases show that external actors are able to successfully complete this type of component development project. Of course this is a very straightforward type of innovation, which suggests that also operators themselves (in highly integrated organizational forms) are able to perform this type of innovation. However, the fact that our set of cases did not include any projects with operator involvement is in line with our expectation that operators focus their activities on more important and more difficult innovations that are less likely to be generated externally. In fact, external developers might well perform projects of this kind better than operators because the existence of a separate market for value-added mobile applications provides them with strong incentives to develop new applications. In addition, as shown by our cases, this external innovation by very different firms (e.g. start-ups, IT companies, a payment service provider) benefits mobile operators by generating a wide range of mobile applications for their networks (e.g. a multi-player game, a location-based service, a dating application, a mobile payment application, and a greeting card service). In sum, the findings for incremental innovations of peripheral components provide a first and a strong indication of the validity of the ideal type and they provide no basis for adjustments.

Supporting the ideal type, we found for *architectural innovations of peripheral components* that deviation from the ideal type contributed to disappointing performance (Case 9). More specifically, we found that low coordination integration in the face of radical interface change resulted in interoperability problems. More in general, these negative effects of insufficient coordination integration appear to be a strong finding, since replications in Case 16 and in Case 29 also report interface problems when we observed only medium coordination integration. Furthermore, architectural problems were absent in the five cases that showed high coordination integration to deal with radical interface change (Case 30 involves an exception that will be discussed below). Finally, the four cases of *architectural innovations of core components* were unable to assess the originally proposed ideal type. Rather - and as will be discussed below - these four project point to a new, equifinal organizational form. As a result, the originally proposed ideal type remains unchanged for now.

***Adapted ideal types***

Based on our case study results we slightly adjusted the ideal types for modular and radical component innovations. For *modular component innovations* we concluded that low integration on all four dimensions is an appropriate organizational form for this type of innovation. Case 19 indicates that the originally proposed high level of knowledge integration does not appear to contribute to project performance. Instead it appeared to serve a long-term learning objective. This suggests an adjustment of the ideal profile to low values on all four dimensions. Supporting this view, three projects that perfectly fit this adapted ideal profile report high project performance and show no signs of any negative effects from having only a low level of knowledge integration. Two other projects with low values on all four dimensions performed badly, but for these projects we did not find that this was the result of any organizational misfit. Instead, we found rival explanations for the failure of these high-risk projects.

We also find support in the literature for this adjustment of the ideal type. A closer look at the systems integration literature reveals that a distinction can be made between static (or synchronic) systems integration and dynamic (or diachronic) systems integration (Brusoni and Prencipe, 2001b; Prencipe, 2003). Static systems integration focuses on the short-term challenge to integrate interdependent components and to maintain a coherent product. Hence, a high degree of knowledge integration seems especially relevant for the performance of development projects for architectural innovations. On the other hand, dynamic systems integration means that knowledge integration should be high to monitor technological developments in order to support the design of future component innovations and product architectures. This seems especially relevant for modular innovations. Hence, a low level of knowledge integration can not be expected to negatively influence the performance of modular component development projects, but it could well deteriorate the firm's long term capability to coordinate and to innovate (e.g. Danneels, 2002).

We find that our original ideal type for *radical component innovations* needs adjustments. We initially proposed a highly integrated organizational form with a medium level of task integration as a *compromise* between on the one hand the need to fully integrate tasks to prevent knowledge spillovers and to learn and on the other hand the need to reduce uncertainty and solve problems by benefiting from the variety provided by collaborating with one or more external actors. Not surprisingly we found that a completely integrated project performed very well (Case 27). In line with what we might expect we find that Case 27 involves the development of a proprietary application for which spillovers have to be prevented. Hence, it seems best to split the original ideal type into two ideal types: the completely integrated organizational form (Case 27) and a highly integrated organizational form with some involvement of one or more external actors. This latter possibility is discussed below.

***New, equifinal ideal types***

Rather than confirming or disconfirming the original ideal type, several cases suggested the existence of alternative organizational forms to deal with the characteristics of their respective development projects, i.e. equifinal organizational forms. First of all, an important trend across *incremental innovations of core components* (Case 11 – Case 14), *architectural innovations of core components* (Case 17 and Case 18), and *radical component innovations* (Case 28) involves that operators not always opt for the full integration of project investments and project tasks. Instead these seven cases report the successful involvement of third parties that executed project tasks and that possibly also invested in the project. For operators this first of all reduces their own project investments of course. This is of considerable importance to operators, because they tend to have huge debts as a result of investments in network licenses and in the deployment of new network technologies. In addition, collaboration enabled operators to benefit from the (complementary) resources and capabilities possessed by third parties.

At the same time, the operators in these seven cases collaborated very carefully as they aimed to extensively control these collaborative projects. We can understand this need for control as it is a principle that also underlies the original, highly integrated ideal types to protect strategic interests and to reduce appropriation concerns. More specifically, in all seven cases the operators aimed to control the projects by maintaining and developing substantial knowledge about them. On the one hand, they generated this knowledge by monitoring the project and by communicating intensively with their partners. On the other hand, they also achieve a high level of knowledge integration by performing their own tasks (medium task integration) very selectively. For instance, they were typically heavily involved in or responsible for the basic design of the component and for testing the component, i.e. tasks that contribute strongly to understanding and controlling the project as a whole.

In sum, systems integrators can successfully seek specialized input from external actors for these three types of innovation by substituting for the loss of formal control by applying non-ownership mechanisms (e.g. Santos and Eisenhardt, 2005; Mohr et al., 1996). This finding complements prior literature (e.g. Brusoni et al., 2001; Tiwana and Keil, 2007) as it shows - at the level of individual projects - that operators apply knowledge integration to balance the need for specialization and integration and to protect their interests. These cases therefore suggest equifinal organizational forms for incremental and architectural innovations of core components and for radical component innovations that consist of medium task integration and high knowledge integration, possibly combined with medium or low ownership integration. In other words, these projects are essentially monitored collaborative projects.

Case 29 provides additional support for this new configuration in the case of radical component innovation. This case did involve collaboration with an external actor, but without a high degree of knowledge integration. This misfit (i.e. medium rather than high knowledge integration) made effective coordination and collaboration more difficult and therefore reduced performance. Similarly, Case 15 and Case 16 show how highly integrated organizational forms fail to work for architectural innovations of core components (i.e. high rather than medium task integration). The project managers of these highly integrated and disappointing projects both indicated the need for external expertise, because the operators themselves lacked a detailed understanding of the (existing) technologies that were involved in these projects. This indication that medium task integration would have been more appropriate provides further support for the new ideal type.

Case 15 and Case 16 can not be said to disconfirm the original (fully integrated) organizational form. The original ideal type for architectural (and incremental) innovations of core components rests on the assumption that systems integrators possess and understand the technologies involved, which they exploit and protect by performing these projects themselves. In Case 15 and Case 16 this assumption of high ex ante knowledge integration did not appear to be true and high integration by the operators therefore resulted in disappointing performance because it would have been better (as for instance in Case 11 – Case 14) to collaborate with external specialists. We therefore maintain the original highly integrated organizational form, which we can expect to be especially beneficial if the systems integrator is already highly knowledgeable. Otherwise, i.e. if the operator lacks the relevant knowledge and capabilities, collaboration in line with the new organizational configuration seems more appropriate.

As an additional conclusion related to the cases that resulted in the monitored, collaborative ideal type (Case 11 – Case 14, Case 17, Case 18, and Case 28), we find that transaction costs played only a limited role in these cases. In general, these projects were highly specific because the applications involved were tailored to the operator's network. However, instead of highly integrated projects, we found projects with medium task integration and possibly even with low ownership integration. For incremental innovations of core components we found several explanations for collaboration and for the willingness of external actors to become involved in these projects. In Case 11 strong trust for instance already existed between the operator and its partner and Case 12, Case 13 and Case 14 point to several strategic reasons for the collaboration (see also Sengupta, 1998), such as external actors that wanted to exploit complementary products and that hoped to gain future business from the operator.

From the perspective of operators, a factor that delimits appropriation concerns is that they own the networks to which core applications are tailored. As a result, the operator and its partner are both committed to the development project, which reduces hold-up fears. However, especially if its core technologies are involved, operators might be hesitant to collaborate (i.e. Case 17). Finally, it is especially the combination of uncertainty and specificity that can be expected to result in vertical integration (Geyskens et al., 2006), which refers to radical component innovations. Again, Case 29 indicates that transaction costs were not decisive in the chosen organizational form. Other factors, such as the urgency of the operator and its partner resulted in their joint commitment.

For *modular component innovation* we also found an alternative ideal type. In Case 25 and Case 26 network operators partially financed modular component development projects and also performed these projects at least in part. In both cases the involvement of the operator involved the development of an innovative technology that could be applied as an input in future application development projects of external actors, such as a spin-off or licensees. Hence, a collaborative (i.e. partly integrated) organizational form for modular innovations seems to be especially appropriate if the project involves a technology that the operator can use to facilitate further application development by external developers. Otherwise, i.e. if the project is limited to only one application only, external innovation (i.e. the original, slightly adjusted ideal type) seems more appropriate.

Finally, Case 30 suggests that *radical component innovations* can be performed successfully without any significant operator involvement at all. In this case the systems integrator's role was performed by a knowledgeable IT-firm that positioned itself in between mobile operators and third party application developers. This IT-firm did not own a mobile network itself, but it did possess an application platform that was interconnected to multiple networks. In this way this 'middleware' platform became the relevant interface for application developers. It can therefore be expected that this organizational form of intermediary/downstream systems integration also works for other innovation projects and not only for radical component innovation.

The emergence of intermediary systems integrators can be considered a logical move in the life cycle of system industries. On the one hand, mobile networks - like many other product systems - become more modular over time, which makes such intermediary platforms possible in the first place. On the other hand, the sheer number of mobile applications, which has exploded in the last decade or so, has made it almost impossible for operators to coordinate them all on their own. Of course standardized and open interfaces facilitate autonomous external innovation (e.g. Case 1- Case 8), but our cases also illustrate that a large number of innovations still require intense coordination in the face of interface changes. Hence, it might be no surprise that the operator in Case 9 for instance aimed to delegate systems integration tasks (i.e. monitoring interface changes) to application developers. In sum, intermediary systems integration involves an attractive opportunity for operators to economize on their systems integration efforts with respect to mobile applications. In Case 29 intermediary systems integration refers to low ownership integration, low task integration, low knowledge integration, and medium task integration. Because the IT firm was itself a very knowledgeable firm, it required only very limited coordination integration between this firm and operators to successfully align the application (and in this project also the platform itself) to the mobile network in the face of new interfaces.

***Reflection on the case study methodology***

This study must be seen as the first step in the process to build a configurational theory about organizational forms of component development projects. It was neither the objective of this study to generate insights about the strength of the association between the degree of fit with an ideal profile and project performance nor to provide details about the frequency with which different organizational forms occur in practice. Instead, our multiple case study provided insights about viable and appropriate organizational forms, i.e. it showed how and why different organizational configurations deal with the characteristics of different types of innovation and contribute to project performance.

Put differently, the major strength of our case study approach involves its internal validity. Space limitations preclude the reporting of detailed within-case analyses, but for each case we were able to pinpoint in quite some detail how and why its organizational form contributed to project performance. Furthermore, our approach explicitly aimed to increase our confidence in the validity of the ideal types by means of replication. For some ideal types we were able to substantially increase our confidence in its underlying (middle-range) theory because we found multiple replications (e.g. Case 1 - Case 8). At the same time we explicitly recognized that different cases have different implications for the theory. Some cases were for instance perfectly in line with the theory and these cases are most-likely to result in high performance (e.g. Case 1 - Case 8). Individually these cases therefore add little to our confidence in the theory. In contrast, cases that deviate strongly from the ideal type can strongly challenge our confidence in the theory. Our dataset did not include extreme misfits however, which means that we were unable to investigate their performance implications. It might be that the inconsistency and negative effects of these organizational forms prevent them from occurring in practice.

Because we investigated each case in detail we also developed an understanding of the specific circumstances in which these projects were performed and of the factors that influenced their eventual organizational set-up. In this way we are able to specify scope conditions that delimit the boundaries of our configurational theory as such (Firestone, 1993; Dul and Hak, 2008). This is related to the external validity of our findings. First of all, it is important to recognize that our initial and theoretically formulated configurational theory is very generic in nature, i.e. it can be said to ambitiously apply to most types of components, products, and systems integrators, across the globe and in any time-period. As a general principle, considerable replications in many different parts of the entire theoretical domain are required to ever reach such a universal external validity. However, given the particular empirical scope of our case studies we must be careful in judging the external validity of the refined configurational theory. Below we discuss several important delimiting scope conditions.

First and foremost, we must recognize that our findings come from one particular empirical setting (application/software development), in one particular industry (the Dutch mobile telecommunications industry), and in one particular stage of its life cycle (the emergence of mobile data applications, which is a radical shift from traditional voice services). Unlike typical physical components that are assembled into products before they are shipped to consumers, mobile applications are complementary software parts of the mobile telecommunications system. Hence, several collaborative projects involved external actors originating from other industries that aimed to exploit their existing capabilities and resources by developing a mobile application. For these complementary applications a separate market exists, as a result of which the incentives for external actors are likely to be greater than for developers of regular components.

Projects with medium or low ownership integration and task integration might be more prominent in this setting than in others. For instance, the strategic need for external developers to create an installed user base might outweigh appropriation concerns as a result of asset specificity. Furthermore, the fact that valuable already exist at various external actors makes it more attractive for operators to involve them in application development. In other words, resource-based arguments in favor of collaboration for component development projects (e.g. Hoetker, 2005) are particularly strong in this setting. The fact that mobile applications are complementary products also means that fully disintegrated projects (e.g. incremental innovations of peripheral components and modular component innovations) typically means that the external innovators commercialize these applications themselves in the end user market rather than operators purchasing them.

Another factor that might have influenced our findings is the particular timing of our projects. At the time of their execution, most mobile operators were in a state of flux. They were in the process of investing huge amounts of money in the deployment of new technologies to facilitate higher-capacity mobile data transmission, e.g. GPRS, UMTS, MMS, and i-mode. At the same time, they typically had huge debts because of their investments in new network licenses (UMTS). This can be argued to promote joint investments and task execution in development projects, because operators lacked financial resources.

As argued above, this collaboration also allowed operators to benefit from the complementary resources and capabilities possessed by third parties. This is important because operators were traditionally not involved in application development at all. They simply operated telecommunications networks to facilitate voice services only. With the introduction of new technologies operators therefore had to master these new technologies and to learn how to stimulate and coordinate the development of applications as well as their adoption in the market place. In other words, their systems integration capabilities were fairly new and underdeveloped at the time of our study. This explains why we find in several cases (e.g. Case 15, Case 16, and Case 29) that operators were not all-round knowledgeable firms as they required input from external technology specialists to effectively realize interface changes. Hence, this increases the likelihood to find collaborative projects. At the same time, the lack of detailed systems integration capabilities might explain why we observed extensive knowledge integration in many collaborative projects. This helped operators to learn about these projects and to improve their systems integration capabilities.

Finally, our cases studies pointed to several other scope conditions and factors that influenced whether and how we refined the ideal types. For instance, trust was not explicitly included in the initial development of the configurational mode. Trust can be expected to reduce appropriation concerns and also makes it less costly to manage collaborative projects (Gulati, 1995). This is also what we found in Case 11. For very uncertain and specific projects we might expect that operators prefer fully integrated projects and that trust plays less of a role (Hoetker, 2005). This is also suggested by our case findings for radical component innovation. Another scope conditions identified in the above discussion of the ideal types is for instance the involvement of operators in the development of modular components if these projects facilitate future external component innovations.

***Limitations and future research***

Besides the abovementioned limitations in terms of our study's external validity, there are other limitations that should be kept in mind when interpreting our results. First of all, our dependent variable mainly focused on short-term performance implications of a project's organizational form, e.g. project performance and the consistency of the larger product system. Performance can also be considered from a long-term perspective however. The operator's goal in Case 29 was for instance to increase its customer base rather than to make sure that the application was optimally aligned. Several projects were in fact strategically important to the operator, which indicates a long-term objective rather than the operator's desire to optimize the development project itself. Case 26 was for instance performed in the research division of the operator. Arguable, learning played a more important role in this project than the need to develop an application within time. To fully understand the appropriateness of organizational forms, long-term objectives therefore also have to be considered. Hoetker (2005) for instance indicates that the anticipated uncertainty of future component development projects should influence the firm's decisions about which organizational forms to pursue, i.e. integrating projects now results in better capabilities in the future and therefore in a higher chance to innovate successfully in an uncertain future.

Our measures for the four the four dimensions of integration were mainly concerned with the extent that they were present or absent, i.e. their quantity. Our case studies also allowed us to assess in some detail the quality of for instance the degree of task integration. We for instance found that selective task integration, such as basic design and product testing, has important implications for the degree of knowledge integration. This indicates that it is important to investigate the quality of different organizational forms to fully understand the interrelationships among the organizational dimensions. The extent of coordination integration is one thing for instance, but the type and quality of the information that is being exchanged is another. We might argue that for instance the degree of knowledge integration influences the quality and the level of detail in the exchange of coordinative information. To further improve our understanding of the internal consistency of ideal types, future research should take this into account.

Future research is needed to increase our confidence in our ideal types. As indicated above, this study only provides two first steps in the theory-building process (the theoretical process to build the tentative configuration and a first-case study investigation). In this first phase it is important to identify equifinal ideal types and to come to understand their inner workings in detail. Informed by our study additional cases can be selected on theoretical grounds (e.g. Eisenhardt and Graebner, 2007; Yin, 2003; Pettigrew, 1999), for instance by searching for instance cases that deviate greatly from an ideal type and to investigate their performance implications. Also perfect fits can be analyzed in depth, which are likely to increase our understanding of their internal consistency. In addition, future case studies are needed to investigate configurations in other empirical settings. This helps to further establish the scope of the theory (Bacharach, 1989; Firestone, 1993).

Eventually we not only want to understand how and why organizational forms contribute to project performance. To come to a parsimonious model of recurrent and effective organizational forms we also want quantitative information about the prevalence of the different ideal types and about the strength of their effects on performance. Of course the entire theory building and testing process should be highly iterative. New findings change the direction of research and suggest which research design is needed to find the most pressing questions. In addition, quantitative analysis of data on a large number of projects can be used as an alternative theory-building process. It could complement our approach in identifying new ideal-typical organizational forms.

Finally, future research could try to extend the configurational model with findings from Chapter 4. Whereas a direct comparison with Chapter 4 is difficult, because the model in Chapter 4 is more linear in nature than the current configurational model, both models seem to complement each other and seem to indicate that project performance and commercial performance might be achieved with similar organizational forms. Figure 4.2 shows that commercial performance for modular complementary product innovations (cell bottom right) is highest for low ownership integration. Likewise, we find in the current chapter that low ownership integration is part of an appropriate configuration (in terms of project performance) for modular innovation (cell top right). Furthermore, the commercial performance of incremental innovations (top right in Figure 4.2) seems to benefit from limited or medium ownership integration. With respect to (peripheral and core) incremental innovations we find in this chapter that low and medium ownership integration can certainly facilitate high project performance.

Other findings from the current chapter also seem to fit with the findings of Chapter 4. In Chapter 4 we found for instance no support for the claim that more novel applications should coincide with higher operator integration for reasons of coordination. An explanation might be our finding from Chapter 5 that this integration can be limited if interfaces remain stable, i.e. if networks are mature, regardless of the novelty of the application. In addition, we found in Chapter 4 that projects generally performed worse (as perceived by their managers) if operators financed a larger part of these projects. We can explain this finding based on the qualitative analysis of the underlying data in the current chapter. As can be seen from Figure 5.4, a large number of relatively simple incremental projects was performed without the involvement of operators. In contrast, operators were more heavily involved in the more difficult projects. On average, the relatively simple projects were more successful than the relatively difficult projects, i.e. project managers of these latter projects were less satisfied.

***Managerial relevance***

Albeit tentative in nature, our study provides a framework that guides managers in their decisions how to organize component development projects. This is a strategically important topic that is relevant for any firm that produces a multi-component product. We show how integrative decisions can be made regarding multiple organizational dimensions and how this is contingent on the specific characteristics of a variety of component innovations. For instance, we show the importance of providing a sufficient amount of coordinative information to component development teams if interfaces change substantially. Furthermore, we show that firms are able to control alliance projects if they maintain and develop detailed knowledge about these projects. In addition, for some types of component innovation we indicate multiple organizational forms that might serve as alternative organizational solutions depending on a firm's specific needs and preferences.

# 6. How to Organize the Development of Inter-Industry Architectural Innovations?

**Abstract**
This study considers the development of new products that are created by combining technologies from different industries. Numerous firms will be specialized in the individual technologies of these inter-industry architectural innovations, but none of them will possess detailed knowledge about how to integrate these previously unconnected technologies. In other words, there are no incumbent systems integrators with existing architectural knowledge to design the new product architecture and to coordinate component providers. In the absence of knowledge overlap between the firms from the different industries, and assuming that they will have different structures and cultures, we investigate how development projects of inter-industry architectural innovations can be organized to increase the likelihood of project success. Based on a comparative case study we propose that this type of project benefits from a configuration that includes specialists from the different industries (to obtain high-quality component input), that results in high information-exchange between them (to generate a detailed architectural understanding), and that facilitates timely and effective decision-making to prevent and resolve conflicts. We discuss how our inductive findings contribute to the literature on for instance the organization of innovation, systems integration, and strategic alliances. We also propose various organizational forms that meet our proposition.

*This chapter is co-authored with Jan van den Ende and Andrea Prencipe. We thank Geerten van de Kaa for his useful comments and suggestions.*

## 6.1 Introduction

In today's economy, technologies from different industries are increasingly being combined to create new products and services. Mobile payment solutions for instance integrate mobile telecommunications technology (e.g. mobile networks, mobile handsets, billing systems) with technologies from the financial services industry (e.g. ATMs, credit card systems). In another example, nanotechnology creates advanced materials by manipulating atoms based on insights from biology and chemistry (Kodama, 1992; *Business Week, 2005*). These products and services can be considered a special type of architectural innovation. Whereas architectural innovations are traditionally seen as reconfigurations of *existing* product systems *within* a single industry (Henderson and Clark, 1990), this study focuses on *new* combinations of technologies from *different* industries. We label this type of innovation 'inter-industry architectural innovation'. These innovations generate additional revenues by exploiting and combining distinct and previously unconnected technologies, and in the process they cause industries to converge (e.g. Kodama, 1992; Duysters and Hagedoorn, 1998). Before these innovations can be brought to the market, they first have to be developed however. Based on theoretical grounds we expect this development process to be very challenging. This chapter therefore addresses the question how development projects of inter-industry architectural innovations can be organized to increase the likelihood of project success.

Why do we expect the development of inter-industry architectural innovations to be so challenging? This seems surprising given that the building blocks of the new product architecture already exist (e.g. Henderson and Clark, 1990). We focus on three characteristics that are likely to make it difficult for the innovating firm(s) to successfully develop this type of innovation. First, no knowledge exists about how the previously unconnected technologies can best be combined to create a new product. This lack of prior architectural knowledge (Henderson and Clark, 1990) means that component interdependencies will be highly unpredictable (Brusoni et al., 2001). As a result, innovators need to find out how the different technologies interrelate and whether and how they have to be adjusted. In other words, a key objective for development projects involves the generation of architectural knowledge in order to understand and resolve component interdependencies. Given that multiple diverse and interdependent technologies are involved, this learning process is likely to involve many problems, such as product redesigns and difficult design trade-offs (e.g. Sheremata, 2000).

Secondly, the generation of architectural knowledge is complicated by the fact that the various component technologies originate from different industries. Given that the technological breadth of firms is inherently limited (Kodama, 1992; Davies et al., 2006) and given that many firms tend to focus on their core competencies (Prahalad and Hamel, 1999), individual firms are unlikely to be specialized in all the technologies underlying the new product architecture. Development projects therefore first of all need to duplicate missing technologies or need to include specialists from the different industries (such as incumbents or technology vendors) to acquire access to their technologies and capabilities.

The absence of prior architectural knowledge and the absence of firms that possess all relevant technologies implies that the design and development of inter-industry architectural innovations takes place in the absence of an incumbent 'systems integrator' (Brusoni et al., 2001). For the design and development of many product systems, systems integrators exist that possess a detailed understanding of a product's architecture (Brusoni et al., 2001). Based on this expertise these firms coordinate the actions of individual component providers (Brusoni et al., 2001; Prencipe et al., 2003). Such an orchestrating actor does not exist for the development of inter-industry architectural innovations, since no firm will possess a detailed understanding of the various technologies and their interrelationships. In contrast, specialists from the different industries will have to integrate their respective technologies and need to discover interdependencies without any knowledge overlap or joint routines. This is likely to reduce the effectiveness of inter-firm knowledge transfer and coordination (e.g. Argote et al., 1998; Darr et al. 1995; Baum and Ingram, 1998).

Thirdly, if firms from different industries collaborate to develop an inter-industry architectural innovation, these partners will have no prior ties and their organizational structures, routines, and cultures will be adapted to their respective technology-base and competitive environments (Henderson and Clark, 1990; Gulati and Singh, 1998). As a result of these differences, a strong fault line is likely to exist between team members from the different collaborating firms (Lau and Murnighan, 1998). This fault line between factions from the different firms is likely to result in poor project performance because of an increased likelihood of conflicts between them, e.g. due to personal differences and different frames of reference with respect to execution of tasks and the resolution of problems (Li and Hambrick, 2005; Madhavan and Grover, 1998). Although partners come from different industries and although they are no direct competitors, they could be reluctant to share information and resources. It might for instance be unclear how partners will behave in the new market for the architectural innovation. In sum, we expect that it will be difficult to develop a high-quality inter-industry architectural innovation, let alone to realize this fast and efficiently.

Based on the principle of contingency theory that different types of innovation require different organizational approaches (Chesbrough and Teece, 1996; Tidd and Bodley, 2001), the objective of this chapter is to explore how development projects of inter-industry architectural innovations can be organized to increase the likelihood of project success. The theoretical relevance of this study is first of all that it extends the literature about architectural innovation. This literature traditionally emphasizes the reconfiguration of existing architectures (Henderson and Clark, 1990; Galunic and Eisenhardt, 2001) rather than the creation of new architectures from already existing components. Secondly, our study complements the systems integration literature (e.g. Brusoni et al., 2001; Prencipe et al., 2003; Hobday et al., 2005) by showing how product systems and architectural knowledge are created in the absence of an incumbent system firm.

Thirdly, by studying how development projects of this very specific type of innovation can best be organized we contribute to the literature about the organization of innovation (e.g. Robertson and Langlois, 1995; Chesbrough and Teece, 1996) and to the literature about (organizational) success factors for NPD projects (e.g. Brown and Eisenhardt, 1995; Henard and Szymanski, 2001). To achieve our theory-building objective we studied and compared three differently organized development projects of inter-industry architectural innovations. The next section discusses the methodology in greater detail. This is followed by the results from the case study analysis. We end with a discussion of the theoretical and managerial implications of our findings.

## 6.2 Methods

Our analysis is based on a comparative study of three cases. The unit of analysis in each case is a development project of an inter-industry architectural innovation. Within each case the objective is to find evidence about how and why the organizational set-up of the project contributes to project performance. Case studies are particularly suitable for this purpose (Yin, 2003), i.e. to trace causal processes and mechanisms (George and Bennett, 2005). Insights about such causal mechanisms help to increase our confidence in the causal effects between concepts (Van de Ven, 2007). In addition to the within-case analyses, a cross-case analysis is performed with the objective to generate one or more propositions (Eisenhardt, 1989). The three cases that we studied involve projects that were performed in the Netherlands for the development of innovative mobile telecommunications applications. In the last decade mobile telecommunications has evolved from an analogue into a digital system and from a voice-based service offering into a proposition that includes packet-switched data services (Jaspers et al., 2007). These developments spurred the fusion of the mobile industry with other industries, such as the financial services industry and the broadcasting industry.

The three projects involve the development of (1) a mobile payment application, (2) a mobile banking application, and (3) a mobile television solution. The mobile payment application made it possible to transfer funds between users and to purchase products and services from web stores that adopted this payment method. With this service debit payments could be made on-line or using the mobile phone (based on text messaging). In both cases users are called on their mobile phones to authorize transactions with a unique identification code. In the second case, a mobile banking application was integrated in pre-configured mobile phones. This application enabled users to pay bills, transfer funds, check account balances, and top-up prepaid airtime. These services could be performed real-time, using the direct link between the mobile Internet application and the user's bank account. Finally, the mobile television solution makes it possible to broadcast mobile video calls live on television, thus turning mobile users into cameramen.

All three projects involve the development of a software application that is partly based on mobile telecommunications technology. As a result, the empirical variety of our cases is limited. This reduces the external validity of this study, but at the same time it facilitates the cross-case analysis by keeping many factors constant. To increase the likelihood to generate theoretical insights from the cross-case analysis, the three projects were selected because of their different organizational set-ups (Pettigrew, 1999; Eisenhardt and Graebner, 2007). The mobile payment application was developed by an independent start-up, the mobile banking application was developed in a contractual alliance between the Dutch subsidiary of an international mobile network operator and a Dutch retail bank (which is part of a large international financial corporation), and the mobile television solution was developed in an informal alliance of a small Dutch IT firm, an international television producer, and a large producer of telecommunications equipment. Table 6.1 lists several additional project details.

For each project we collected primary data through on-site interviews with key informants. In addition, we analyzed publicly available information, such as press releases, company information, on-line news articles, and articles in business magazines. The interviews typically lasted between one and two hours. In the case of the mobile television application we interviewed the four persons who were most knowledgeable of the development process: a founder of the IT firm, the solution architect from the IT firm, the project manager from the telecom firm, and a sales representative from the telecom firm who was involved in the project from the beginning (these interviews took place in 2007). In the case of the start-up we interviewed one of the founders (in 2002). The case study of the mobile banking alliance is based on interviews with five project members (conducted in 2003 and 2004): three employees from the bank (one of the project initiators, the bank's project manager, and a project member who was involved in the design of the application and who was responsible for the alignment of processes with the operator) and two employees from the operator (a business development manager and the manager responsible for the security of the application). To gain full cooperation we promised the interviewees to keep the names of companies and applications anonymous.

**Table 6.1 Description of cases**

| | The mobile television alliance | The mobile payment start-up | The mobile banking alliance |
|---|---|---|---|
| **The application** | (Live) video calls to television shows | Person-to-person fund transfer and on-line purchases (a debit service) | Real-time person-to-person and bank transactions |
| **Organizational set-up** | An informal alliance between a telecom firm, a television producer, and a small IT firm | A start-up company | A contractual alliance between a bank and a mobile operator |
| **Firm size (approximately)** | Telecom firm: >60,000 worldwide<br>Television firm: >5,000 worldwide<br>IT firm: 23 | <10 | Bank: >100,000 worldwide<br>Operator: 750 |
| **Prior relationships** | None | - | None |
| **Project size (persons at its peak)** | 10-15 | 5-10 | >250 |
| **Project duration (until launch of first version)** | 2005 (Q4) – 2007 (Q2) | 2001 (Q4) – 2002 (Q4) | 2000 (Q3) – 2001 (Q2) |
| **Project objectives** | Main focus was to develop a high-quality and a very reliable application | Main focus was cost efficiency | Very high time pressure; Especially for the bank: a high-quality and a very secure application |
| **Project Performance** | High: a high-quality application that resulted from a smooth development process. | Low: quality problems and disappointing project costs and project speed. | Low: much higher costs than expected and slow project progress. Collaboration problems. |

The topics covered in the semi-structured interviews among others included the organizational set-up of the project (e.g. the number of investing firms, the number of suppliers, and the division of investments and project workload), characteristics of the project tasks (e.g. technological uncertainty, interdependence), elements of project management (e.g. communication intensity, decision-making), the proficiency of the development process (e.g. product redesigns), and project performance. For each of these elements specific questions were formulated in advance. Most of the interviews were conducted in the presence of two researchers. Based on our field notes and/or interview tapes we extended our case description immediately after the interviews. Some interviewees were phoned afterwards to obtain additional information. Some interviewees suggested small changes to our reports.

The analysis of the data involved a highly iterative process of within-case analysis and cross-case comparison (Eisenhardt, 1989). The analytic strategy of this chapter is founded on the principle of contingency theory (see Chapter 2). Based on this 'metatheory' (Schoonhoven, 1981), which also guided the structure of the interviews, it is our assumption that the organizational set-up of a project contributes to project performance to the extent that it provides the capability to deal with the specific characteristics of inter-industry architectural innovations, most notably the challenge to exploit the already existing component technologies, the challenge to generate knowledge about how to combine these technologies, and the challenge to manage and coordinate the development effort in the face of large cultural and structural differences. As the results section will show, these challenges were clearly present in our cases and they guided our search for high-performing organizational solutions.

## 6.3 Results

This section presents the insights that emerged from the cross-case analysis. The first three parts address the three organizational challenges for the development of inter-industry architectural innovations and provide qualitative evidence about how they were addressed by the organizational forms of the three projects. The fourth part integrates the first three parts and formulates a proposition about how development projects of inter-industry architectural innovations can be organized to increase the likelihood of high project performance.

### *Exploitation of component technologies*

Inter-industry architectural innovations involve first-time combinations of existing technologies from different industries. As a consequence, individual firms are unlikely to possess all relevant component technologies prior to the development of these innovations. This was also true for the three projects in this study. None of the firms in our cases opted to develop missing technology internally. Instead, all three projects aimed to develop the new product architecture by obtaining the required technologies from specialists in the different industries. The two alliances each included as partners the most important complementors, whereas the start-up purchased several off-the-shelf components from external vendors.

The start-up learned only after the commercialization of the application that it purchased a wrong payment system. As a result, alternative payment software had to be bought and installed. One of the founders of the start-up stated that this was the major reason for the disappointing project costs and project duration. In his view it was a mistake to purchase components without any internal technological knowledge. The start-up was for instance incapable to specify in sufficient detail its own software requirements. To obtain the required capabilities and expertise, the start-up did seek at the start of the project the support of operators and banks, but none of them wanted to participate. According to a director of the start-up, these incumbents all felt that the start-up "*infiltrated their territory*". The absence of incumbents not only complicated the start-up's purchasing process, but it also limited the functionality of its application. Without the support of a bank namely, the start-up lacked the permit to process transactions larger than ten Euros.

Unlike the start-up the two alliances included incumbents from the different industries. This ensured that both applications were developed from building blocks that were already operational and proven within their respective industries. In the case of the mobile banking alliance, both a mobile network operator and a retail bank provided access to their systems (such as the bank's payment system and the operator's mobile network and billing system) and allocated specialists to the project. Furthermore, a sister company of the operator was also involved in the project. This company provided access to its mobile Internet platform. The project also benefited from the active involvement of suppliers. For instance, a handset manufacturer and a SIM card producer respectively customized a mobile handset and a SIM card (the chip inside the mobile phone that identifies the user to the mobile network).

The mobile television alliance also included experts from the relevant industries, i.e. a producer and service provider of telecommunications hardware (the telecom firm), a producer of television shows (the television firm), and a small IT firm specialized in Internet applications and streaming video (the IT firm). Assisted by its expertise of video formats and transcoding technologies, the IT firm developed the core of the application on its own. This technology transforms mobile video calls into the format of television studios and facilitates the editing of video calls and the synchronization of audio and video signals. The IT firm lacked the capabilities however to develop the entire product architecture. It for instance lacked a video gateway, which is required to receive video calls, and the expertise to design the application in line with the needs of its target customers (television studios and broadcasters). The IT firm therefore teamed up with the telecom firm. This firm operates a video gateway of its own and also has vast experience with the development and hosting of complex applications.

However, neither the IT firm nor the telecom firm had a detailed understanding of the television and the multimedia industry. This is why the television firm was included in the project. This firm for instance assisted in the design of the editorial tool that enables television editors to manage the entire solution and to edit video calls. Collectively, these complementary specialists provided the alliance with the necessary inputs to develop a high-quality application that could meet the requirements of both the telecommunications and the media industry.

In sum, the three cases suggest that a high degree of differentiation and specialization (Lawrence and Lorsch, 1967; Dougherty, 2001) contributes to the performance of development projects for inter-industry architectural innovations. The two alliances were both set-up by incumbents from the different industries and as a result the development process was assured of high-quality, co-specialized (complementary) component inputs (e.g. Dyer and Singh, 1998; Gerwin and Ferris, 2004) and of specialist project members. In addition, the mobile banking alliance benefited from the expertise of suppliers by actively involving them in the project. This seems a valid explanation for the absence of problems with individual components in these alliances. The start-up also attempted to include specialists, but incumbents refused to participate. In addition, the start-up lacked the purchasing capability to fully benefit from the specialized knowledge of its suppliers (Araujo et al., 2003; Flowers, 2007). Consequently, the development process as well as the quality of the application suffered.

***Generation of architectural knowledge***

Whereas development projects can benefit from the existing capabilities of incumbents and upstream technology suppliers, the projects themselves have to generate the architectural knowledge about how these (component) technologies can best be interconnected. Given that these building blocks have never been combined before, it is no surprise that it was a difficult task in all three projects to specify and develop component interfaces. Little was known up front about how components would interact and about how they could be adapted to create a coherent system. The cases indicate that frequent and rich communication between component providers contributes to the identification and the resolution of interdependencies.

The mobile television alliance is a case in point. The objective of this project was to develop a centrally hosted application that would be scalable, highly reliable, as well as easy to implement and use. Such a high-quality total solution was seen as an imperative to ‘productize’ the application worldwide. To develop a mutual understanding of each other’s systems and to fine-tune the basic product architecture, project members from the different firms had very frequent and rich contact. This particularly involved the members from the IT firm and the telecom firm. Each firm for instance appointed a solution architect to align the systems from both firms. The solution architects had daily contact by phone and met in person once a week. Furthermore, a test manager from the telecom firm tested changes that were made by the programmers of the IT firm and provided detailed feedback to the solution architects. The development process resulted in a considerable number of architectural changes and component adjustments, such as tools that were developed to monitor the quality of video calls and interconnections that were adjusted to increase reliability. According to our informants the development process resulted in a high-quality solution. A large international broadcaster for instance tested rival solutions, but selected this solution because of its quality.

The other two cases show that the generation of architectural knowledge can be difficult when communication between component providers is limited and problematic. In the mobile banking alliance, the architecture of the application was developed by the bank and the mobile Internet company. The operator was not involved in this design phase, because it was expected that the application could be easily connected to the mobile network. The intention of the design effort therefore was to specify tasks that could be performed independently by the bank and the operator. Reflecting this modular design, the project was organized with a separate structure, i.e. with sub teams from each firm each with its own manager. During product development it soon became clear however that the level of interdependence was considerably underestimated. For instance, it appeared to be very complex to establish a secure connection between the mobile network and the banking system to realize the envisaged direct link to bank accounts (i.e. to facilitate real-time transactions and topping-up of prepaid balance). This required adjustments to numerous components.

In order to identify and address all interdependencies, many meetings were organized. However, information-exchange and collaboration between the bank and the operator was very problematic, for instance because meetings were very detailed and involved a large number of attendants. In addition, there were so many meetings that the team members could not attend all the meetings that they were expected to attend. In principle, collaboration was facilitated because the alliance operated from a joint office in a location separate from the partners' offices. Whereas project members from the bank operated from within this office, members from the operator often only came to this dedicated site to attend meetings. According to the bank's project manager this made it difficult to keep people from the operator up to date.

At the same time, due to its strict security regulations, the bank did not allow direct contact between specialists from both firms outside of the formal meetings. Coupled with its urgency (the bank had a deadline to offer the application (and a mobile phone) as its yearly gift), the limited opportunities for direct and informal communication resulted in conflicts between the bank and the operator. For several tasks it was unclear, for instance, how responsibilities were defined and how processes were aligned. In sum, the development process was highly problematic due to the absence of the operator from the design stage and due to communication difficulties in the development stage. The project for instance failed to meet most of its milestones.

The development of the mobile payment application by the start-up was also characterized by high interface uncertainty. According to the start-up's founder this mainly involved the customized protocols to interconnect both a voice response system and a text messaging platform to the payment system. The start-up hired an external project manager to coordinate the protocol development process together with its subsystem vendors. However, this manager did not possess a detailed technical knowledge of the new product system, and according to the founder this project manager failed to organize sufficient direct contact between the component vendors. This complicated the integration of the payment system. In hindsight the founder of the start-up stated that it would have been better to have an internal project manager with the relevant technological know-how. On the one hand, this would have helped to more actively involve the vendors in the alignment of their respective subsystems. On the other hand, this also would have made it easier to achieve coordination within the start-up. In the chosen set-up, coordination between the external, hired project manager and the start-up team was limited. Next to problems with the suggesting that it was difficult within the start-up to coordinate effectively with the project manager. In addition, the founder admitted that the commitment of external vendors was limited because of the start-up's limited financial resources. This also hampered the effective alignment of the various subsystems. Negative publicity illustrates the architectural difficulties faced by the start-up. After its commercialization system failures were for instance reported in the media about person-to-person transfers and on-line purchases.

In sum, all three projects were characterized by unpredictable interdependencies, i.e. they can be considered ‘systemic innovations’ (Teece, 1996). Consistent with information-processing theory (e.g. Tushman and Nadler, 1978) the cases indicate that mutual adjustment and frequent information exchange between component providers contributes to the identification of interdependencies (Sosa et al., 2004) and helps to achieve unity of effort (Lawrence and Lorsch, 1967; Thompson, 1976). Without such tight ‘coordination integration’ (Robertson and Langlois, 1995) interdependencies might not be discovered until architectural problems arise in later stages of the development process (Sosa et al., 2004). Furthermore, the start-up project illustrates that internal coordination is needed to effectively coordinate supplier relationships (Takeishi, 2001).

***Project control and decision-making***

Without a deep understanding of component interactions and in the absence of a mutual understanding of each other’s technologies, it might be difficult for partnering firms to agree upon component trade-offs and on the design of a joint product architecture. Furthermore, disputes might arise because of different interests or honest differences of opinion as a result of divergent frames of reference (Hitt et al., 1993; Li and Hambrick, 2005; Gulati et al., 2005).

In the mobile banking alliance a strong difference existed between the bank and the operator that reflects a fundamental difference between the financial services industry and the telecommunications industry. Unlike the operator, the bank was very concerned about the security and the reliability of the application. Whereas the bank’s IT policy was based on detailed planning and security checks, the operator used to make ad hoc changes to its IT systems. The operator’s IT specialists - or ‘cowboys’ in the words of the bank’s project manager - for instance wanted to test the application on live servers. Due to this fault line, the bank restricted and monitored information flows between both firms in order to protect its systems. Communication between project members was for instance only possible during formal meetings and team members from the bank were supervised by senior employees from within the bank. Although these mechanisms allowed the bank to monitor the project, as we have seen above they also hampered the generation of architectural knowledge.

Furthermore, decision-making was often time-consuming because both firms shared formal decision-making power. Project management was for instance in the hands of a manager from the bank and a manager from the operator. This meant that neither of them had the authority to make decisions and to resolve conflicts by means of fiat. Problems therefore had to be passed on to the boards of both firms. However, these boards did not communicate with each other directly (there was for instance no joint steering group), which meant that the two project managers had to reach consensus based on the sometimes conflicting directives they received from top management. Because of these difficulties, compounded by the bank’s urgency, the bank hired additional consultants to perform several tasks that were originally assigned to the operator. In this way the need for coordination and decision-making with the operator was reduced. In hindsight, one of the bank’s initiators of the project argued that the bank should have been more involved in the project with a more direct role of its board of directors. In his view this would have increased the speed of decision-making and conflict resolution.

The three partners in the mobile television alliance each financed their own expenses and their top managers together formed the project's steering committee. This committee was closely involved in the development process, but its main responsibility was to negotiate the business model for the commercialization of the application. It was informally agreed that the telecom firm – based on its technological capabilities and its project management expertise – would be responsible for day-to-day project management and would have the final say about the design of the application. Hence, a representative from the telecom firm implemented the telecom firm's project management approach and managed the project on a daily basis. This project manager collaborated intensively with project members from all three firms, but if needed he could make operational decisions on his own. He reported to the steering committee, which made all major decisions. Decision-making in this committee was facilitated because the collaboration in this team resulted in some strong personal relationships.

Because of its limited resources it was easy for the small IT firm to accept the telecom firm as the project leader, even though the IT firm invented the application and developed its technological core. The television producer was also happy to conform to the development approach of the telecom firm, because it was not a technology developing company itself. Although the team members from the IT firm were not used to follow rules and procedures, they quickly learned to see the benefits of clearly specifying roles and responsibilities and of formalizing and standardizing (to a certain extent) inter-firm information exchange. Coupled with the close involvement of top management, this contributed to a smooth development process without major disagreements or time-consuming negotiations.

The two alliances show that decision-making is likely to be faster and more effective if top managers are closely involved. Differentiation as a result of the participation of specialists from the various industries means that fault lines will exist between these interdependent partners and that it will be difficult to achieve unity of effort (Li and Hambrick, 2005; Gulati et al., 2005). The mobile banking alliance clearly illustrates that problems and important architectural decisions might not be readily addressed in the absence of top management involvement. The mobile television alliance shows that effective cooperation can be achieved if top managers from the different specialists are involved in the project and if they communicate directly. In this way conflicts might even be prevented as managers learn about each other's firms and industries and develop personal ties.

In addition, the mobile television alliance shows that many operational issues can be effectively dealt with by a single project manager from one of the firms. In contrast, the mobile banking alliance showed the difficulty to reach consensus among two equally powerful project managers. Hence, we expect that decision-making and problem-solving between interdependent specialists for the creation of a new product architecture are more likely to be timely and effective if one of these specialists is dominant. Such a leading firm will be able to specify procedures, to prevent costly and time-consuming disputes, and to realize cooperation 'by fiat' (Tadelis, 2002). With a dominant actor we do not mean that one of the partners should be highly autocratic. On the contrary, each specialist should be most powerful in its specific area of expertise and should be actively involved in important decision-making processes. Should it be impossible however to make decisions based on consensus, then the dominant actor is able to make qualified decisions that are likely to be accepted by the rest of the team and that help the development effort to move forward (Eisenhardt et al., 1997).

Formally, the case of the start-up clearly involved a dominant actor. The start-up had full 'ownership integration' (Robertson and Langlois, 1995) over the development of the mobile payment application. However, despite its formal control, the start-up was highly dependent on its suppliers because it lacked any assets and expertise of its own. To increase the commitment of suppliers, the start-up selected small-sized suppliers. However, because of its limited financial resources and its inability to specify detailed contracts, the start-up had no choice but to trust its vendors. Especially since the hired project manager did not actively involve the suppliers in the development effort, the start-up in fact only maintained arm's length relationships with its suppliers. Hence, although the start-up had full decision-making power, this authority could not be applied to increase supplier integration and to facilitate project decision-making. Finally, the mobile television alliance shows that project control is not necessarily based on legal ownership. In this case the authority of the telecom firm was based on non-ownership mechanisms (Mohr et al., 1996; Santos and Eisenhardt, 2005), namely its project management capabilities and expertise.

***Cross-case comparison: an ideal-typical organizational configuration***

Above we have identified three organizational elements that help development projects to deal with the characteristics of inter-industry architectural innovations. Table 6.2 provides a brief overview of our findings. When considered jointly, the three projects show that these organizational elements operate collectively rather than independently. First of all, development projects of inter-industry architectural innovations benefit from *differentiation*. Differentiation results if incumbents from the relevant industries provide access to their existing systems and/or allocate specialized employees to the projects (the two alliances). Furthermore, differentiation can result from the active involvement of specialized component suppliers (the mobile banking alliance). Alliances such as these allow the partners to access each other's knowledge (Grant and Baden-Fuller, 2004). Without the input from specialized incumbents or suppliers, development projects face the difficulty to purchase components without any deep technological knowledge of the different industries (the start-up case).

Whereas differentiation helps to develop an architecture that consists of high-quality components, this benefit can only be fully exploited if these components are also successfully integrated. Prior to the development effort no architectural knowledge exists about how this should be done. Frequent and rich information-exchange between component specialists was shown to contribute to the generation of a joint architectural understanding and to successful component alignment (the mobile television alliance). Without such a high degree of *coordination integration* (Robertson and Langlois, 1995) interdependencies are likely to remain undiscovered and the alignment of components is likely to be suboptimal (the start-up and the mobile banking alliance). Hence, the development process is likely to benefit from a *combination* of differentiation and coordination integration between component specialists (Lawrence and Lorsch, 1967; Brusoni et al., 2001; Gulati et al., 2005) as this helps to build a coherent product system from high-quality components.

**Table 6.2 Key organizational elements of the three projects**

| | The mobile television alliance | The mobile payment start-up | The mobile banking alliance |
|---|---|---|---|
| **Organizational Form** | | | |
| *Differentiation* | **High**: the necessary technologies and expertise were brought to the project by the three partner firms: an IT firm, a telecom firm, and a television producer | **Low**: the start-up with no relevant prior knowledge was unable to start a cooperation with incumbents; component vendors were not actively involved in the project and did not contribute their expertise | **High**: the bank and the operator provided access to their systems and closely collaborated with various specialists, such as a mobile Internet company and a handset manufacturer |
| *Coordination integration* | **High**: intense coordination, especially between the IT firm and the telecom firm. Especially the appointment of solution architects and of a test manager helped to generate architectural knowledge | **Low**: limited communication with and interaction of the specialized vendors to develop the required customized interface protocols | **Medium**: limited information exchange between the bank and the operator in the design phase and frequent, but restricted communication in the development phase |
| *Project control* | **Integrated and hands-on**: top managers from the partners were closely involved in the project. The telecom firm acted as the project manager and had the final say in the design of the architecture | **Integrated, yet ineffective**: the start-up was the full owner of the project and the application, but this did not provide the firm with formal control over the external component vendors (on which the start-up was highly dependent) | **Disintegrated and distant**: top managers from the two firms were loosely involved. Project management was based on consensus, which made decision-making and conflict resolution difficult and time-consuming |
| **Project Performance** | **High**: a high-quality application that resulted from a smooth development process | **Low**: quality problems and disappointing project costs and project speed. Difficulty to benefit from the expertise of suppliers | **Low**: much higher costs than expected and slow project progress. Difficult collaboration between the partners |

Especially the start-up shows the difficulty to develop an inter-industry architectural innovation without both differentiation and coordination integration. Of course the start-up lacked the direct capabilities to develop the required component technologies itself, but in the absence of a clear understanding about which components to purchase (Flowers, 2007), and without effective internal coordination (Takeishi, 2001), the start-up also lacked the indirect capabilities to gain access to external capabilities (Loasby, 1998; Araujo et al., 2003). Put differently (see Chapter 3), the start-up lacked the systems integration capabilities to organize and integrate its suppliers in a loosely coupled network that would benefit from both differentiation and coordination (Brusoni and Prencipe, 2001a).

The two alliances indicate that extensive coordination integration is insufficient to achieve effective collaboration between specialist partners. The primary purpose of coordination integration is to generate architectural knowledge, but actual decisions about how to design the architecture of the new product system might still be very difficult and uncertain, especially given the differences that are likely to exist between specialists from different industries. In this respect, the mobile banking alliance shows decision-making and conflict-resolution difficulties in the absence of top management involvement and a clear project leader. In contrast, the mobile television alliance illustrates how top management involvement from all specialists, in combination with a clear project leader, contributes to timely and effective decision-making.

In sum, although differentiation, coordination integration, and project control are each important in the development of inter-industry architectural innovations, our analysis suggests that it is especially their combination that contributes to project performance. Put differently, these three organizational capabilities are far from independent. For instance, without coordination integration between specialists it seems worthless to have access to high-quality component technologies. In addition, projects could still fail in the presence of high-quality components and a detailed architectural understanding, if project participants fail to reach agreements and resolve conflicts about the design of the product architecture. Hence, our understanding of different organizational elements increases substantially when we consider them simultaneously rather than in isolation. In other words, the three organizational capabilities can be considered the building blocks of an ideal-typical organizational configuration (e.g. Doty and Glick, 1994; Miller, 1996; see also Chapter 2). This results in the following tentative proposition:

> Proposition. *The development of inter-industry architectural innovations is more likely to be successful to the extent that its organizational form facilitates (1) high differentiation (by actively involving specialists from the different industries) as well as (2) high coordination integration and (3) timely and effective decision-making.*

**6.4 Discussion and conclusions**

This chapter complements existing literature about architectural innovations (e.g. Henderson and Clark, 1990; Galunic and Eisenhardt, 2001) as it focuses on the development of a specific type of architectural innovation, i.e. inter-industry architectural innovation. These innovations create new product systems by integrating previously unconnected technologies from different industries. They bring together firms from different industries with different capabilities and with no prior ties. Based on a comparative case study we formulated the proposition that development projects of inter-industry architectural innovations are more likely to be successful to the extent that their organizational form facilitates (1) high differentiation (by actively involving specialists from the different industries) as well as (2) high coordination integration and (3) timely and effective decision-making.

Different organizational forms meet the characteristics of this general proposition. Differentiation can for instance result from many different organizational set-ups, such as a joint-venture between firms from different industries, an acquisition of a firm from another industry, a contract with a supplier from another industry, or ‘simply’ a temporary NPD alliance between firms from the different industries. Our results suggest that these organizational forms have to be set up in such a way that coordination between the different specialists is intense. The acquired unit for instance needs to be tightly integrated in the acquiring firm, or the partners in the joint-venture or the alliance need to be heavily involved in the development process and need to collaborate very closely (e.g. mixed teams, co-location, etc.).

Moreover, we indicate that it is important to make sure that the organizational arrangement facilitates timely and effective decision-making and conflict resolution. This is crucial in the development of inter-industry architectural innovations, because this type of innovation is likely to involve difficult and complex architectural decisions and trade-offs. The different background of partners increases the likelihood of lengthy negotiations and conflicts. Obviously, decision-making authority will be relatively clear in buyer-supplier relationships or in unequal joint-ventures, i.e. when one firm is clearly dominant.

In fifty-fifty joint-ventures, or in alliances on an equal basis, decision-making will be more difficult. Which firm will for instance appoint the project manager? Or will decisions be made using team consensus (e.g. Gerwin and Ferris, 2004)? The mobile banking alliance shows that consensus decision-making between lightweight managers without strong top management involvement causes serious problems. We therefore suggest that top managers are heavily involved in the development process, for instance by participating in a steering group. This worked well in the mobile television alliance. In addition, it seems wise to specify clear decision-making and conflict-resolution rules. This might involve third-party arbitration (e.g. Oxley, 1997), but a relatively effective and fast approach is to have one dominant actor among the actively involved partners. In the absence of consensus, this actor is able to make fast and qualified decisions that are often perceived as fair by the other participants (Eisenhardt et al., 1997; Tadelis, 2002)

It has to be stressed that our results indicate that it is especially the interplay of the three organizational characteristics that contributes to project performance rather than each organizational element individually. As such, our findings contribute to the literature about new product development and its (organizational) success factors (e.g. Brown and Eisenhardt, 1995; Henard and Szymanski, 2001). This literature typically investigates the individual effects of success factors rather than their holistic effect.

This study also complements the literature that focuses on the combination of integration and differentiation (e.g. Lawrence and Lorsch, 1967; Orton and Weick, 1990; Sheremata, 2000; Gulati et al., 2005), which also includes the literature about systems integration. The systems integration literature takes the perspective of firms producing complex product systems, i.e. multi-component, multi-technology products (e.g. Hobday, 1998; Brusoni et al., 2001; see also Chapter 3). Because of the complexity of their products, these firms can not develop and produce all components themselves, i.e. they have to make use of external specialists (differentiation). At the same time, these firms are faced with the need to coordinate their network of component and subsystem suppliers to ensure the integrity of their products (coordination integration). For this purpose these 'systems integrators' need detailed architectural knowledge (Brusoni et al., 2001; Hobday et al., 2005). The coordination of component providers and the creation of a coherent product system are also key challenges for inter-industry architectural innovations, but as our cases illustrate this takes place without the leadership of an incumbent systems integrator that already possesses detailed architectural understanding.

Whereas Brusoni et al. (2001) consider systems integration as an organizational form that combines the benefits of differentiation and (coordination) integration, our analysis also includes issues of control. In the absence of prior architectural knowledge and without knowledge overlap between collaborating specialists, project-decision making should preferably facilitate negotiations and conflict-resolution. In this regard, having a dominant firm with authority over the development process complements coordination and decision-making that is based on less formal mechanisms, such as mutual adjustment and teamwork (Mintzberg, 1979; Radner, 1992). Hence, systems integration is seen here not only as a combination of differentiation and coordination, but as a configuration of differentiation, coordination, and control.

Our findings also have relevance for the literature about transaction cost economics and strategic alliances. In development projects of inter-industry architectural innovations asset-specificity tends to be high, because project investments are likely to be valuable only in this specific product architecture. Especially in the absence of prior ties between partners, this results in the expectation to find organizational solutions that provide strong transactional safeguards, such as full integration or equity joint-ventures (e.g. Williamson, 1985; Gulati and Singh, 1998; Geyskens et al., 2007). Furthermore, appropriation concerns can result from learning asymmetries between partners (Gerwin and Ferris, 2004). In the development of inter-industry architectural innovations learning opportunities involve both the architectural knowledge that is generated in the project as well as co-specialized skills from partners (e.g. Dyer and Singh, 1998).

In our cases transaction costs appeared to play a limited role however, as it appeared that strategic considerations and task characteristics (i.e. architectural uncertainty and task interdependence) governed the design of the organizational form rather than concerns over opportunistic behavior and appropriation (e.g. Casciaro, 2003; Gulati et al., 2005). The start-up involves a highly integrated organizational solution of course, but this was not the result of transaction costs. The start-up preferred to collaborate with incumbents, but these actors did not want to collaborate because of strategic rather than transaction-cost concerns. In the mobile banking alliance the bank did aim to protect its part of the project, but this was mainly as it feared security problems rather than opportunism.

Furthermore, the mobile television alliance started as an informal alliance with no contractual basis. The three partners committed themselves to the project and trust seemed to exist right from the start of the alliance. In addition, the telecom firm and the television firm were large firms for which it was important to maintain their reputation of being a trustworthy partner. The entrepreneurial nature and the dependence of the small IT firm meant that it entered the alliance without any hesitation. Furthermore, even in the presence of behavioral uncertainty, investments by partners from the different industries are likely to create a situation of a mutual hostage which prevents hold-ups (Williamson, 1985). More in general, appropriation concerns regarding each other’s co-specialized skills will be difficult to realize in development projects of inter-industry architectural innovations. Given that the partners come from different industries, their absorptive capacity is likely to be limited (Cohen and Levinthal, 1990). The telecom firm and the television firm for instance possessed completely different capabilities, as did the bank and the mobile operator.

***Limitations and future research***

Several characteristics of this chapter have to be kept in mind when interpreting its results. First, it has to be noted that we mainly focused on explaining the short-term performance of the three development projects. We did not explicitly consider any long-term effects. The mobile television alliance shows however that asymmetric learning of the new architectural knowledge does affect the evolution of the project in the long-term. This mobile television application was designed as a total solution that could be sold to many companies and that would have to be continuously upgraded in the future. The telecom firm had a big say in the design of the application and also absorbed the new architectural knowledge because of its heavy involvement and monitoring. Hence, the telecom firm positioned itself as the systems integrator for this application and its future evolution. This became all the more apparent, as the telecom firm - after the successful completion of the development project - obtained the property rights of the application. In other words, the organization of the development project and the way in which architectural knowledge is created and absorbed by the project participants can have a strong impact on the division of future profits from the application. An opportunity for future research is therefore to explicitly consider strategies to obtain a leading position as a systems integrator (e.g. Adner, 2006).

Secondly, to facilitate cross-case comparison, the three cases all come from one particular empirical setting as they all included mobile telecommunications technology as part of the product architecture. As a result, limited evidence exists about the domain of our tentative proposition. External validity was not the main purpose of this study however, as our main objective was to generate a better understanding about how inter-industry architectural innovations can best be developed. For this purpose, we selected differently organized development projects from the same empirical context. Informed by our findings and our tentative proposition, future studies are therefore needed to refine and test this proposition in different empirical settings. One opportunity for future research would be to investigate organizational forms that comply with our proposition, including joint ventures or acquisitions. In addition, replications are needed of projects that deviate (preferably to a great extent) from the proposition. An interesting setting would be to investigate extreme cases such as incumbents that go it alone or acquisitions. In such cases it would be interesting to study how the highly complementary but very distinct capabilities are organized within a single administrative framework. Richardson (1972) for instance argued that coordination will be very difficult under these circumstances. Strategic alliances might therefore be more efficient for the purpose of bringing together and integrating inter-industry architectural innovations (Grant and Baden-Fuller, 2004). Finally, large-sample studies are of course needed to draw conclusions about the extent that (fit with) the proposed configuration explains project performance.[7]

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[7] Another limitation of our study is - of course - that other factors might drive a project's organizational form than the three characteristics of inter-industry architectural innovations that we focused on in this chapter. In this regard, Chapter 4 pointed to the novelty of the mobile network (in terms of interfaces) and the novelty of the mobile application (in terms of functionality) as determinants of operator involvement. In this chapter, based on principles of information-processing, coordination and integration by a mobile operator was expected to be beneficial for project (and also market) performance when network interfaces are new. In this chapter, the mobile payment alliance involved relatively new, yet standardized WAP interfaces. A mobile operator was involved in this project, but coordination intensity was limited. In line with what we might expect based on Chapter 4, we find that this negatively influenced project performance as a result of difficulties to resolve interdependencies. Furthermore, Chapter 4 discussed application novelty in relation to the commercial performance of the application. It was hypothesized that external application developers - to the extent that the application provides new functionality - need to take on a larger part of the investments in a development project. This would bring additional incentives to the project. Although commercial performance is not the prime interest in this chapter, all three applications provided considerably new functionality at the time of their development. Consistent with the view of Chapter 4, we observe in all three cases that non-mobile operators take on all of the project investments (the mobile payment start-up and the mobile television alliance) or half of the project investments (the mobile banking alliance).

***Managerial implications***

Despite these limitations, this chapter sheds light on the specifics of inter-industry architectural innovations, which are becoming more prominent in the recent times of industry convergence. For managers this study first of all illustrates the challenges to develop inter-industry architectural innovations. The relevant technological building blocks will be dispersed across firms from different industries and the processes to design and develop a new architecture and to resolve interdependencies are likely to be problematic due to the lack of existing architectural knowledge and the lack of prior ties among participants. This chapter proposes a practically relevant organizational form for this type of development effort, i.e. an organizational form that (1) provides access to high-quality capabilities related to the technologies from which to create the new product; (2) that facilitates rich and frequent information exchange between the different specialized technology providers; and (3) that makes it possible to make timely and effective decisions. Key to our argument is that all three elements need to be present in order to be effective, i.e. the likelihood of a successful project decreases in the absence of one of the elements. For example, the presence of a dominant actor does not reduce the need for information-exchange to develop architectural knowledge. Neither will the presence of such a leading firm be effective for projects that have no access to strong component capabilities.

As indicated above, our proposition leaves room for many different practical interpretations to organize this type of development project. The proposition offers managers a basic tool that they can use to organize development projects in line with their own preferences. For instance, if the firm has a strong desire to control the project, or if trustworthy partners do not exist, it could be decided to acquire a company or to hire experts. Because inter-industry architectural innovations tend to involve the first-time collaboration of firms, managers could be inclined to equally share investments and decision-making power (e.g. the mobile banking alliance). Difficult architectural decisions are likely to be required however and consensus decision-making is likely to be difficult given the lack of a prior history and the different backgrounds of these firms. We therefore argue that this type of innovation calls for arrangements that help to prevent and resolve conflicts, e.g. by involving top management, by specifying clear decision-making procedures, and/or by having one actor that takes the formal lead in the project.

In addition, managers must be aware that it is very important for partnering firms to closely collaborate given the need for the joint creation of architectural knowledge. This should be considered in the selection of a partner and in the set-up of the partnership itself. Another important criterion in the selection of a partner from another industry involves its technological capabilities related to that specific industry (for the purpose of differentiation). Conversely, our proposition suggests that some organizational solutions will be inappropriate for this type of innovation. It will for instance be very difficult for a single firm to go it alone, especially if it involves a relatively small firm, such as a start-up. Finally, it is important to note that the proposition does not suggest that the ideal-typical organizational form makes it easy to develop this type of innovation. It does provide an organizational setting however that is tailored to the characteristics and the challenges of this particular type of development effort, and that therefore increases the likelihood to achieve high project performance.

# PART 3.

# SYSTEMS INTEGRATION AND PROBLEM SOLVING

# 7. The Effect of NPD Project Organization on Problem-Solving Proficiency: The Moderating Role of Systemic Problems

**Abstract**
Given the importance of new product development (NPD) in the quest for competitive advantage, it is of great importance to understand what organizational characteristics of NPD projects contribute to project performance. However, little quantitative evidence exists about the causal mechanisms that bring about project outcomes. This chapter contributes to our understanding of this 'black box' by investigating the extent that several integration and differentiation mechanisms determine the capability to solve technical problems fast, cost-efficiently, and effectively. More specifically, we hypothesize that different types of problems require a different organizational approach. On the one hand, autonomous problems, i.e. problems with individual components, generally require differentiation to acquire deep component knowledge. On the other hand, systemic problems, i.e. problems affecting multiple components, generally require extensive integration to realize coordination and generate detailed architectural knowledge. The results from a survey of web application development projects indicate that the effects of decentralization and reach (differentiation mechanisms) and of project-manager influence and connectedness (integration mechanisms) on problem-solving proficiency are moderated by the extent that a project's problems are systemic rather than autonomous.

*We thank Sebastian Fixson for his useful comments and suggestions.*

## 7.1 Introduction

Reflecting the inherent uncertainty of new product development (NPD), NPD projects are often characterized by unexpected technical and operational problems (e.g. Wheelwright and Clark, 1992; Clark and Fujimoto, 1990; Brown and Eisenhardt, 1995; Sheremata, 2000; Gouel and Fixson, 2006). These problems can have enormous consequences for project outcomes. The development of the Airbus A380 was for example delayed by more than a year because the cabin wiring (100,000 wires and more than 40,000 connectors) of the first batch of airplanes had to be substantially adjusted. For managers a key issue involves how they can organize NPD teams to increase their capability to solve problems fast, cost-efficiently and with high-quality solutions, for instance in terms of team composition, the type of project leader, and the degree and type of project control (e.g. Henard and Szymanski, 2001; Cooper and Kleinschmidt, 1995; Brown and Eisenhardt, 1995).

According to Sheremata (2000) proficient problem solving requires ambidextrous organizational forms that make project teams act creatively as well as collectively. More specifically, she proposed that project teams require differentiation as well as integration (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Daft and Lengel, 1986; Tushman and Nadler, 1978). Differentiation mechanisms mainly "*increase the quality and quantity of ideas, knowledge, and information an organization can access*" (Sheremata, 2000; p.395), whereas integration mechanisms predominantly *"integrate dispersed information, knowledge, and ideas into collective action"* (Sheremata, 2000, p.398). User involvement and decentralization can for instance be considered differentiation mechanisms, because their main effect seems to be to increase a project team's knowledge reservoir (Sheremata, 2000). In contrast, heavyweight managers can be considered integration mechanisms, since they are able increase the team's unity of effort (Sheremata, 2000).

Atuahene-Gima (2003) put Sheremata's model to a first empirical test and he found that several differentiation and integration mechanisms predicted one or more dimensions of a team's problem-solving proficiency (e.g. problem-solving speed, solution quality). In addition, he found that problem-solving proficiency partly mediates the effects of some organizational characteristics on overall project performance (e.g. development speed and product quality). Despite these initial theoretical and empirical insights, additional research is required to replicate and refine these findings. For instance, little evidence exists about whether the effects of differentiation and integration on a team's problem-solving proficiency hold for all types of problems.

In the development of complex products, i.e. products consisting of multiple interdependent and technologically distinct components, a distinction can be made between two types of problems: autonomous problems and systemic problems. *Autonomous problems* are problems related to the 'hidden design rules' (Baldwin and Clark, 1997) of individual components with no implications for other components, i.e. they are stand-alone problems. In the design and development of a mobile phone for instance, the phone manufacturer might find that the phone prototype malfunctions because the application processor has insufficient capacity to fully support the functionality incorporated in the mobile phone (e.g. mobile Internet, a video/photo camera, etc.). This would be an autonomous problem if the processor could be easily replaced however by a higher-capacity processor without requiring any rework on other components, such as the phone's operating system.

In contrast, s*ystemic problems* are related to multiple components and possibly affect the entire product architecture (e.g. Chesbrough and Teece, 1996). Consider again the case of a mobile phone development project. The phone manufacturer might want to incorporate a digital camera unit into an existing mobile phone design. This may have huge implications however for the existing product architecture. It might not only mean the relatively simple adjustment of the phone's exterior design to integrate the lens and to include a button to shoot pictures, as it could also mean a total reshuffling, resizing, and reprogramming of existing components as well as including one or more new components, such as a better processor, new software, etc. In addition, it is likely that trade-offs are required in this process, i.e. do we include a better processor or do we settle for the old processor by including a less advanced operating system? Hence, the systemic problem in this case requires consideration of and changes to multiple parts of the product.

In this chapter we argue that each type of problem has its own organizational requirements to facilitate proficient problem solving. First of all, autonomous problems can be expected to benefit especially from the presence and the generation of detailed component knowledge, since these problems are related to individual components and since they do not affect other component in the product system. From the product modularity literature we learn that specialization and differentiation are particularly beneficial in the case of stand-alone problems (e.g. Sanchez and Mahoney, 1996; Schilling, 2000; Brusoni et al., 2001). We can for instance expect that specialist team members are able to solve autonomous problems on their own, without much involvement of project management or coordination with other team members.

Secondly, in order to solve systemic problems proficiently, development teams can be expected to require not only deep component knowledge, but especially knowledge about how components interrelate, i.e. architectural knowledge (Henderson and Clark, 1990). Systemic problems are likely to require decisions from project management and system engineers to resolve design trade-offs as well as extensive coordination with and between team members to resolve interdependencies (e.g. Teece, 1996). Hence, if project problems are predominantly systemic in nature, our general expectation is that project teams will be better able to solve problems when they are tightly coupled, i.e. when their organizational forms facilitate coordination and integration among the project members responsible for different parts of the new product (e.g. Weick, 1976; Sanchez and Mahoney, 1996; Brusoni et al., 2001).

In sum, based on the fundamental differences between both autonomous and systemic problems, we expect that NPD project teams need to be organized differently in terms of differentiation and integration dependent on the extent that the project's problems are systemic rather than autonomous. In this chapter we develop a set of hypotheses about specific differentiation mechanisms (e.g. decentralization and external search for information) and integration mechanisms (e.g. team connectedness and project manager influence) and how their effects on problem-solving proficiency (i.e. in terms of cost efficiency, speed, and solution quality) are moderated by the extent that projects are confronted with one type of problem or the other. We test our hypotheses using stepwise regression analysis based on survey data about web application development projects.

Two theoretical contributions of this chapter are the following. First of all, we contribute to the literature about the development of complex product systems (e.g. Hobday et al., 2005; Prencipe et al., 2003) by shifting the unit of analysis from the level of the firm to the level of the NPD project team. Typically, this literature considers the boundary of an orchestrating firm (i.e. a systems integrator) with respect to the design and development of a product architecture and its individual components and subsystems. Brusoni et al. (2001) for instance propose that the decision to integrate detailed component design and development depends on the need for differentiation and integration as determined by the technical characteristics and dynamics of component technologies and interfaces. Here, we apply these ideas at a lower level of analysis by studying the organization of project teams for the development and the integration of a product system.

Secondly, we add to the literature about NPD success factors by providing further insights about the 'black box' of the NPD process (Brown and Eisenhardt, 1995). More specifically, we add to the literature that treats NPD as a problem-solving process (e.g. Sheremata, 2000; Atuahene-Gima, 2003) by investigating how the organization of the NPD project as a problem-solving capability is contingent upon different types of problems. Below we first of all provide a theoretical background on the organization of NPD projects and formulate hypotheses. Subsequently, we outline our methodology to test these hypotheses. Next, we present our results. This chapter ends with a discussion and conclusions.

## 7.2 Theory

Literature reviews have shown that organizational characteristics (e.g. decentralization, communication, and project leadership) constitute an important group of NPD success factors (e.g. Henard and Szymanski, 2001; Cooper and Kleinschmidt, 1995), but far less evidence exists about the processes that mediate the causal effects of these success factors (Brown and Eisenhardt, 1995). Sheremata (2000) directly addressed this 'black box' (Brown and Eisenhardt, 1995) as she proposed that the effects of a project's organizational characteristics on project performance are mediated by the extent that these organizational factors help the team to solve technical problems proficiently, i.e. fast, cost-efficiently, and effectively.

The capabilities of project teams to solve problems fast, cost-efficiently, and with high-quality can be seen as *"intangible, higher-order capabilities that enable a firm to perform critical product development activities better than its competition"* (Atuahene-Gima, 2003, p.363). Proficient problem solving for instance means that project teams absorb and generate new knowledge, e.g. about specific technologies, user needs, or task interdependencies, and apply this knowledge to meet project goals in terms of budget, time-to-market, and quality (Sheremata, 2000; Atuahene-Gima, 2003). Prior studies have rarely considered however whether and how this effect is contingent upon different types of technical and operational problems. This chapter aims to address this gap.

***Autonomous problems and systemic problems***

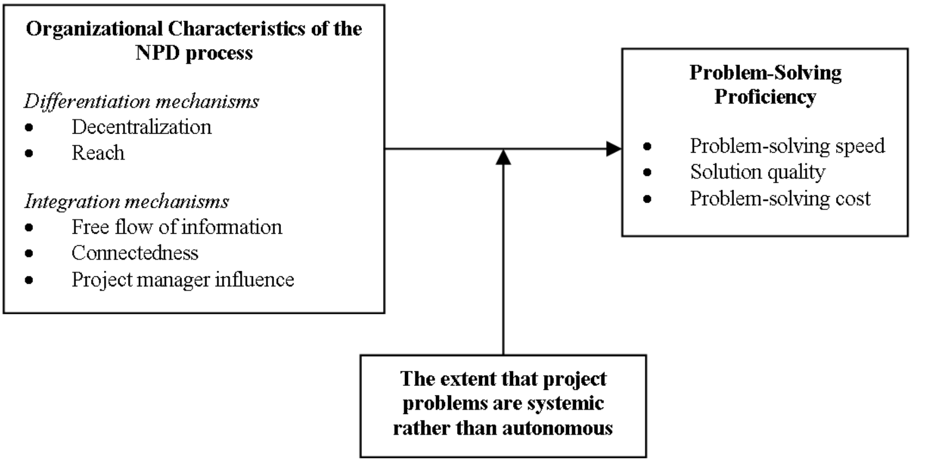
Given that many products consist of multiple components or subsystems (Hobday, 1998; Dvir et al., 1998; Sosa et al., 2004), we make a distinction between autonomous problems and systemic problems. *Autonomous problems* are technical and operational problems that are related to individual components and that have no implications for other components. *Systemic problems*, on the other hand, are problems that have implications for multiple, interdependent components (e.g. Chesbrough and Teece, 1996). Autonomous problems and systemic problems have different demands in terms of proficient problem solving. Autonomous problems mainly require technical knowledge about individual components (e.g. Baldwin and Clark, 1997), whereas systemic problems also require deep expertise about component interrelationships. Such architectural knowledge (Henderson and Clark, 1990) is required to optimize the joint quality of the components that are affected by systemic problems.

In general, we expect that differentiation mechanisms are especially important in the case of autonomous problems, because they tend to increase the team's specialized expertise about individual components. On the other hand, integration mechanisms will be especially important for the fast and efficient generation of high-quality solutions for systemic problems, as they help to achieve unity of effort (Tushman and Nadler, 1978; Thompson, 1967; Lawrence and Lorsch, 1967). More specifically, integration mechanisms facilitate the generation of architectural knowledge and the coordination of project members working on and responsible for different components, i.e. integration mechanisms provide the team with a systems integration capability (cf. Brusoni et al., 2001). Autonomous problems are unlikely to benefit from integration mechanisms, because they can be solved by specialists on their own and because coordination with other project members might bring irrelevant information to the problem-solving process. This might even result in ineffective compromises.

***Hypotheses***

In this chapter we focus on five organizational characteristics of NPD projects. Decentralization and reach can be classified as differentiation mechanisms, whereas connectedness, project manager influence and free flow of information can be regarded integration mechanisms (Sheremata, 2000). In this section we formulate hypotheses about how the effects of these mechanisms on problem-solving proficiency are moderated by the extent that project problems are systemic rather than autonomous (Figure 7.1). As dependent variables we consider solution quality, problem-solving speed, and problem-solving efficiency. Solution quality refers to the extent that solutions contribute to the quality of the new product. Problem-solving speed and efficiency refer to the time and cost required to find and implement solutions. These dimensions will often be related (e.g. Sheremata, 2002). Fast problem-solving might for instance mean that fewer resources are used (e.g. man hours) and high-quality solutions might increase problem-solving speed and efficiency as it prevents rework (Gouel and Fixson, 2006).

**Figure 7.1 Conceptual framework**




***Decentralization*** exploits the component knowledge that is present within teams by giving project members the freedom to solve problems that are related to the components they are working on (Sheremata, 2000). Component specialists will be comparatively less effective to make decisions that are in the interest of the product as a whole, such as decisions about trade-offs between components. This is more likely to be done effectively by central leaders who are responsible for the product as a whole (e.g. Adner, 2006; Brusoni et al., 2001). Decentralization will therefore have a weaker effect on solution quality for systemic problems than for autonomous problems. Furthermore, decentralization generally makes it more difficult to reach consensus among project members (Sheremata, 2000; Atuahene-Gima, 2003). This especially increases the time and resources required for solving systemic problems, but this effect might be absent for autonomous problems, since these problems do not require joint decision-making. Hence, in the case of systemic problems decentralization will also have a comparatively weak effect on problem-solving efficiency and speed. This results in the following hypotheses.

> Hypothesis 1a. *Decentralization contributes less to solution quality for projects with mostly systemic problems than for projects with mostly autonomous problems.*
>
> Hypothesis 1b. *Decentralization contributes less to problem-solving speed for projects with mostly systemic problems than for projects with mostly autonomous problems.*
>
> Hypothesis 1c. *Decentralization contributes less to problem-solving efficiency for projects with mostly systemic problems than for projects with mostly autonomous problems.*

***Reach*** refers to the extent that a project team searches for ideas and information at external specialists, such as suppliers, i.e. it refers to the breadth of search (Brusoni et al., 2007). In more general terms, the use of external sources in the innovation process is also referred to as open innovation (Chesbrough, 2003). According to Chesbrough (2003) the main rationale for open innovation is the presence of 'abundant knowledge' in the environment of firms. This especially holds for specialist knowledge about individual technologies though, since architectural knowledge is in general highly tacit and product-specific (e.g. Henderson and Clark, 1990). Deep architectural knowledge is therefore more likely to be generated within projects. In sum, reach provides a means to acquire high-quality component knowledge faster than would be possible based on internal knowledge only (Clark and Fujimoto, 1990; Cooper and Kleinschmidt, 1987; Atuahene-Gima, 2003). In the case of systemic problems, smaller reach means that teams can focus their time and resources on the internal creation of architectural knowledge. Hence, the following hypotheses can be formulated.

> Hypothesis 2a. *Reach contributes less to solution quality for projects with mostly systemic problems than for projects with mostly autonomous problems.*
>
> Hypothesis 2b. *Reach contributes less to problem-solving speed for projects with mostly systemic problems than for projects with mostly autonomous problems.*
>
> Hypothesis 2c. *Reach contributes less to problem-solving efficiency for projects with mostly systemic problems than for projects with mostly autonomous problems.*

***Connectedness*** refers to the extent of direct contact among team members in for instance meetings and team work (Sheremata, 2000; Atuahene-Gima, 2003). Connectedness therefore brings people together and allows for the integration of diverse fields of expertise and provides opportunities for feedback and mutual adjustment (Ancona and Caldwell, 1992; Clark and Fujimoto, 1990; Daft and Lengel, 1986; Tushman and Nadler, 1978; Van de Ven et al., 1976). Hence, connectedness is likely to contribute to the team's understanding of component interrelationships and to its capability to solve and implement systemic problems fast, cost-efficiently and effectively. In contrast, connectedness will be less important for solving autonomous problem-solving, because these problems require less coordination with project members working on other components. Here, contact with project members not directly relevant to the problem-solving process might delay this process and result in ineffective compromises. Hence, the following hypotheses can be formulated.

> Hypothesis 3a. *Connectedness contributes more to solution quality for projects with mostly systemic problems than for projects with mostly autonomous problems.*
>
> Hypothesis 3b. *Connectedness contributes more to problem-solving speed for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Hypothesis 3c. *Connectedness contributes more to problem-solving efficiency for projects with mostly systemic problems than for projects with mostly autonomous problems.*

***Project management influence*** refers to the authority and expertise of the project management (Atuahene-Gima, 2003). Influential and skilled leaders generally enjoy great freedom and they are likely to motivate a team for collective action (Clark and Fujimoto, 1990). They also tend to possess A-shaped skills, which allow them to integrate different disciplines (Madhavan and Grover, 1999). Hence, strong leaders seem especially relevant in the case of systemic problems. Furthermore, strong project managers are thought to increase the speed of problem-solving, because they can use their influence to prevent lengthy negotiations and their expertise to speed-up the design and implementation of solutions (Atuahene-Gima, 2003; Clark and Fujimoto, 1990). This effect will be especially strong for systemic problems, which involve multiple actors and might therefore suffer from goal differences and honest differences of opinion (Gulati et al., 2005).

Hypothesis 4a. *Project management influence contributes more to solution quality*
*for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Hypothesis 4b. *Project management influence contributes more to problem-solving speed for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Hypothesis 4c. *Project management influence contributes more to problem-solving efficiency for projects with mostly systemic problems than for projects with mostly autonomous problems.*

***Free flow of information*** was classified by Sheremata (2000) as a differentiation mechanism, but she indicates that organizational factors can have multiple effects. This seems true for free flow of information, because this mechanism can be expected to have an important integrative effect. By facilitating unrestricted information exchange between project members, free flow of information is likely to improve the T-shaped skills of team members, which allows them to understand the systemic impact of their tasks (Iansiti, 1993; Madhavan and Grover, 1999). It also reduces the likelihood of misunderstandings between different team members as a result of fast feedback (Atuahene-Gima, 2003; Brown and Eisenhardt, 1995). Free flow of information will therefore help to generate high-quality architectural knowledge fast and efficiently. In contrast, autonomous problems will benefit comparatively less from a free flow of information among team members, because the resolution of this type of problem typically requires information from component specialists. In this case, team-wide information flows can be excessive, which reduces problem-solving speed and efficiency.

Hypothesis 5a. *Free flow of information contributes more to solution quality for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Hypothesis 5b. *Free flow of information contributes more to problem-solving speed for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Hypothesis 5c. *Free flow of information contributes more to problem-solving efficiency for projects with mostly systemic problems than for projects with mostly autonomous problems.*

Table 7.1 provides an overview of the predicted moderating effects of the extent that project problems are systemic rather than autonomous. Decentralization and reach (differentiation mechanisms) are comparatively beneficial in terms solving autonomous problems, because of their capability to provide fast and cost-efficient access to high-quality component knowledge. Free flow of information, connectedness, and project management influence (integration mechanisms) are especially important for solving systemic problems. This is because of their benefits in terms of architectural knowledge creation and achieving unity of effort among project members.

**Table 7.1 Overview of hypothesized moderating effects***

| | Solution Quality | Problem-solving Efficiency | Problem-solving Speed |
|---|---|---|---|
| **DIFFERENTIATION** | | | |
| **Decentralization**<br>The extent that project problems are systemic rather than autonomous | - | - | - |
| **Reach**<br>The extent that project problems are systemic rather than autonomous | - | - | - |
| **INTEGRATION** | | | |
| **Free flow of information**<br>The extent that project problems are systemic rather than autonomous | + | + | + |
| **Connectedness**<br>The extent that project problems are systemic rather than autonomous | + | + | + |
| **Project manager influence**<br>The extent that project problems are systemic rather than autonomous | + | + | + |

* A positive (negative) sign means that the independent variable contributes more (less) to the dependent variable for projects with mostly systemic problems than for projects with mostly autonomous problems.

## 7.3 Method

We tested our hypotheses using survey data on development projects of web applications that were performed in the Netherlands. Development projects of web applications constitute a suitable empirical context. Firstly, problem solving is likely to be a crucial element in these projects, because software development in general is problem-prone

(Faraj and Sproull, 2000; Sheremata, 2000). Secondly, with the increased availability of broadband Internet connections, web applications - in areas as diverse as health care, education, entertainment, and e-business - have become more advanced and increasingly complex in recent years. Despite the use of standardized communication protocols and object-oriented programming, the development of many ‘Rich Internet’ or ‘Web 2.0’ applications involve customized software programming, extensive fine-tuning, and possibly even hardware adjustments, thus increasing the likelihood of systemic problems.

Furthermore, the Dutch market is a suitable empirical setting for our study, because the wide availability and rapid growth of broadband Internet in the Netherlands promotes the development of web applications. The adoption of broadband connections in the Dutch market is among the highest in the world (more than 25 subscribers per 100 inhabitants [OECD, 2005]) and in the Netherlands unique competition exists at the infrastructural level between the traditional telecommunications infrastructure (using DSL technologies) and the cable, which covers over ninety percent of Dutch households.

In the absence of an encompassing population of Dutch web application development projects, we established our target population as follows. First, we approached 74 projects that were performed as part of a government program called ‘Kenniswijk’ to promote the development of broadband services. We obtained data on 39 of these projects (53%). Secondly, we compiled a list of 43 Internet bureaus made up of members of an association of Dutch Internet bureaus and of Internet bureaus mentioned in a list of top ICT companies in 2005 (published by a leading Dutch ICT magazine). We asked a director of these firms to complete our survey for a recently finished project that was relatively complex for their firm. This increased the likely variation in our dataset in terms of the extent that problems are systemic rather than autonomous. In some cases the directors themselves were the project manager of these projects. In other cases the directors provided us with the name of the project manager. From this list 27 firms completed the survey (63%). Finally, we compiled a list of new applications mentioned on an ICT news site (Planet Multimedia) in 2006 and 2007. Of these 36 projects we got response on 26 projects (72%).

A comparison of the three subpopulations in terms of our variables of interest (see Figure 7.1) as well as several control variables (see below) revealed that these three groups are very similar[8]. In sum, our overall population consists of 153 projects and our dataset consists of 92 projects, which is a response rate of sixty percent. With respect to all of the variables that we included in our analysis, we compared the group of responses that we obtained after the first contact (63 respondents) and the group of responses that we obtained after sending out a reminder e-mail (29 respondents). We found no significant differences between these two groups (Oneway ANOVA), which is typically seen as evidence for the absence of nonresponse bias (Wright and Overton, 2008).

[8] Of the variables included in our analysis One-way ANOVA revealed different means for team size, connectedness, and reach. Subsequent Tukey tests revealed only two significant mean differences ($p<0.05$), i.e. Kenniswijk projects are smaller-sized than Planet Multimedia projects and Kenniswijk projects on average reach out more to their environment than the projects performed by Internet bureaus.

The average project duration from start to completion was nine months. In general, the web applications were considerably new (3.8 on a five-point scale ranging from not new at all to very new) and they were developed under considerable time pressure (with an average value of 3.7 on a five-point scale ranging from minimal to huge time pressure). In general, the teams in our dataset were small. For instance, 54% of the project teams consisted of 2-5 full-time project members. Another thirty percent of the teams consisted of 6-25 full-time team members. In terms of firm size the number of employees in about one third of the firms was in the range of 1 to 5. Another one third of the firms had more than one hundred employees. Finally, about one third of the firms existed for more than twenty years, while another one third of the firms existed five years or less.

***Data collection and measurement***
To collect data we used an on-line questionnaire. We pretested our questionnaire with colleagues and the self-completion of the on-line questionnaire was pretested in on-site think-aloud interviews with two managers of web application development projects (Hak et al., 2004). With our questionnaire we targeted project managers as single informants, because they are generally the most knowledgeable actors. For most cases we found the names of project managers or company directors and their telephone numbers on the Internet. We first approached respondents by phone and invited them to participate. If they agreed we sent them an e-mail with a link to the questionnaire.

Our approach of single respondents might have introduced a common variance problem (Podsakoff et al., 2003). We think that this threat is limited in our case, since it is unlikely that the ratings of respondents were structured by implicit theories they might have had that resembled our moderation hypotheses (e.g. Doty et al., 1993; Podsakoff et al., 2003). Further evidence for the absence of common method bias is provided by the Harman's single-factor test (Podsakoff et al., 2003). Principal component analyses on the variables for each of the six regression models reported in Table 7.3 revealed multiple factors. We would expect one factor to emerge should strong common method bias exist. In the case of multiple factors we would expect the largest factor to account for a large degree of the covariation among the variables. The explained variation of the largest variable is limited however (less than 24 percent), which reduces concerns of common method bias.

We measured most of our concepts using (5-point Likert) scales that were validated in prior research. Some items were adapted to reflect the characteristics of our particular empirical context. Appendix A provides a detailed overview of the measures used and their sources. In the Appendix we also provide the results from the exploratory factor analysis (Varimax rotated principal axis factoring) we used to validate the scales. All scales point to a one-factor model. They all have an eigenvalue greater than 1 and all but one explain more than 70% of the variance in the data. Appendix A also presents the Cronbach's alpha values. One of these coefficient reliabilities (connectedness) is slightly below the common threshold value of 0.70. All other scales are (well) above this value. Table 7.2 presents descriptive statistics (mean, standard deviation, and correlations).

**Table 7.2 Correlations and descriptive statistics**

| | mean | s.d. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | 17. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Project speed | 2,90 | 1,14 | | | | | | | | | | | | | | | | | |
| 2. Product quality | 3,61 | 0,95 | 0.35*** | | | | | | | | | | | | | | | | |
| 3. Project cost efficiency | 3,22 | 1,08 | 0.54*** | 0.28** | | | | | | | | | | | | | | | |
| 4. Problem-solving speed | 3,67 | 0,93 | 0.32** | 0.24* | 0.30** | | | | | | | | | | | | | | |
| 5. Solution quality | 3,65 | 0,90 | 0,13 | 0,19 | 0,09 | 0,16 | | | | | | | | | | | | | |
| 6. Problem-solving efficiency | 3,49 | 1,04 | 0.42*** | 0.34*** | 0.55*** | 0.56*** | 0,17 | | | | | | | | | | | | |
| 7. Decentralization | 3,31 | 0,95 | 0.25* | 0,03 | 0.44*** | 0,14 | 0.30** | 0.25* | | | | | | | | | | | |
| 8. Free flow of information | 3,57 | 0,90 | 0.25* | 0,20 | 0.36*** | 0.39*** | 0.42*** | 0.26* | 0.35*** | | | | | | | | | | |
| 9. Reach | 3,64 | 0,93 | 0,05 | 0,14 | 0,07 | -0,06 | 0,11 | -0,09 | -0,04 | 0,06 | | | | | | | | | |
| 10. Connectedness | 3,39 | 0,77 | -0,09 | -0,03 | -0,04 | -0,01 | 0,02 | -0,12 | 0,09 | 0.41*** | -0,02 | | | | | | | | |
| 11. Project management influence | 3,53 | 0,84 | 0,08 | 0,11 | 0,15 | 0,08 | 0,21 | -0,04 | 0,13 | 0.26* | 0,15 | 0,04 | | | | | | | |
| 12. Application novelty | 3,98 | 1,11 | -0,09 | -0,02 | 0,14 | -0,07 | -0,05 | -0,20 | 0,16 | -0,01 | 0,12 | -0,10 | 0,10 | | | | | | |
| 13. Team size | 3,47 | 1,24 | -0.25* | -0,08 | -0.39*** | -0,21 | 0,05 | -0,17 | -0.22* | -0,07 | -0,06 | 0.27* | -0,17 | -0,05 | | | | | |
| 14. Ownership integration dummy | 0,53 | 0,50 | -0,09 | 0,02 | -0,07 | 0,01 | -0,04 | -0,11 | -0,01 | 0,05 | -0,20 | 0,04 | 0,17 | 0,14 | -0,12 | | | | |
| 15. Number of invest. firms (R) | 2,39 | 2,11 | 0,00 | 0,11 | -0,01 | 0.21* | -0,14 | 0,00 | 0,06 | 0,04 | -0,13 | -0,01 | 0,14 | -0,06 | -0.28** | 0.62** | | | |
| 16. If > 1, no. of invest. firms (R)[a] | 3,61 | 2,27 | 0,11 | 0,19 | 0,07 | 0.34** | -0,20 | 0,13 | 0,12 | 0,01 | 0,00 | -0,06 | 0,06 | -0,06 | -0.36** | NA | -1.00*** | | |
| 17. Problem frequency | 2,76 | 1,29 | -0.39*** | -0,17 | -0.38*** | -0.63*** | -0,14 | -0.53*** | -0,19 | -0.24* | 0,17 | 0,12 | -0,03 | 0.24* | 0.30** | -0,04 | 0,12 | 0,24 | |
| 18. Extent problems are systemic | 2,88 | 1,13 | -0,16 | -0,05 | -0,20 | -0,18 | -0.25* | -0,20 | 0,02 | -0,17 | 0,06 | 0,08 | -0,13 | 0,18 | 0,14 | -0,14 | 0,06 | -0,05 | 0.31** |

* $p<0.05$; ** $p<0.01$; *** $p<0.001$; N=92; [a]N=49; (R) Reversed-scored.

## 7.4 Results from hierarchical regression analyses

For each of the three dependent variables (problem-solving efficiency, solution quality, and problem-solving speed) we performed a hierarchical regression analysis. In Model 1 we entered several control variables as well as the five independent variables. In Model 2 we added the five interaction terms to test our hypotheses. We also controlled for time pressure and firm size, but we excluded them because they failed to reach significance. Table 7.3 presents the results. Multicollinearity is of no concern in the analyses, since the values of the Variance Inflation Factor are all below 2.0. Overall, we find significant regression models that explain more than twenty percent of the variation in the dependent variable (up to 31 percent adjusted $R^2$). In addition, in all three analyses the addition of the interaction terms involves a significant step that improves the explained variance with about ten percent. In addition to several significant main effects, we find five significant interaction effects. Three effects support their corresponding hypothesis (Hypotheses 2a, 3a, and 4b), whereas two of them show a positive sign instead of an expected negative sign (Hypotheses 1c and 2c).

**Table 7.3 Results of the hierarchical regression analyses**

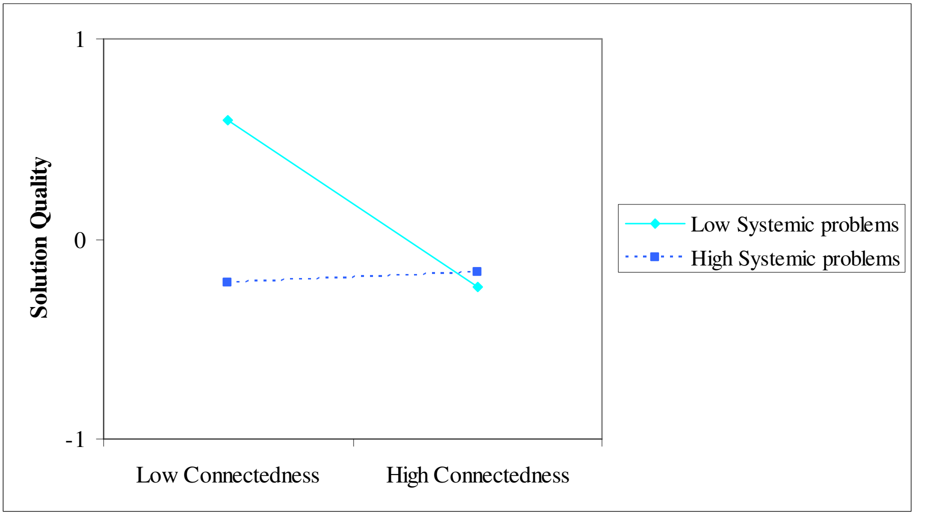
| | Solution Quality | | Problem-solving Efficiency | | Problem-solving Speed | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Team size | 0.23* | 0.17* | -0,06 | -0,17 | -0,14 | -0.18* |
| Application novelty | -0,09 | -0,11 | -0.22* | -0.21* | -0,06 | -0,07 |
| Extent that problems are systemic | -0.19* | -0.17* | -0,09 | -0,07 | -0,06 | 0,00 |
| Decentralization | 0.24** | 0.22* | 0.21* | 0.23* | -0,02 | -0,10 |
| Reach | 0,11 | 0,11 | -0,06 | -0,04 | -0,08 | -0,04 |
| Free flow of information | 0.37*** | 0.31** | 0.30** | 0.30** | 0.45*** | 0.45** |
| Connectedness | -0.21* | -0.21* | -0.26* | -0.28** | -0,16 | -0.25* |
| Project management influence | 0,09 | 0,03 | -0,12 | -0,13 | -0,04 | -0,07 |
| Decentralization * Systemic | | -0,10 | | 0.33* | | -0,19 |
| Reach * Systemic | | -0.23** | | 0.18* | | -0,11 |
| Free flow of information * Systemic | | -0,01 | | -0,20 | | 0,17 |
| Connectedness * Systemic | | 0.22* | | 0,06 | | 0,04 |
| Project management influence * Systemic | | 0,07 | | 0,05 | | 0.33*** |
| Incremental R^2 | | 0,10 | | 0,09 | | 0,13 |
| Partial F | | 2.55* | | 2.08* | | 3.19** |
| R^2 | 0,31 | 0,41 | 0,24 | 0,33 | 0,22 | 0,35 |
| Adjusted R^2 | 0,25 | 0,31 | 0,17 | 0,22 | 0,14 | 0,24 |
| F | 4.75*** | 4.17*** | 3.22** | 2.98*** | 2.87** | 3.23*** |
| n | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

Below we investigate the statistically significant interaction effects in greater detail using simple slope analyses. Based on the coefficients reported in Table 7.3, these analyses compare the mean values of the dependent variables for values of one standard deviation above and one standard deviation below the mean values of the independent variable and the interaction variable. After the presentation of the results from these simple slope analyses we report the findings of additional (polynomial) regression analyses to further investigate the robustness of the interaction effects.

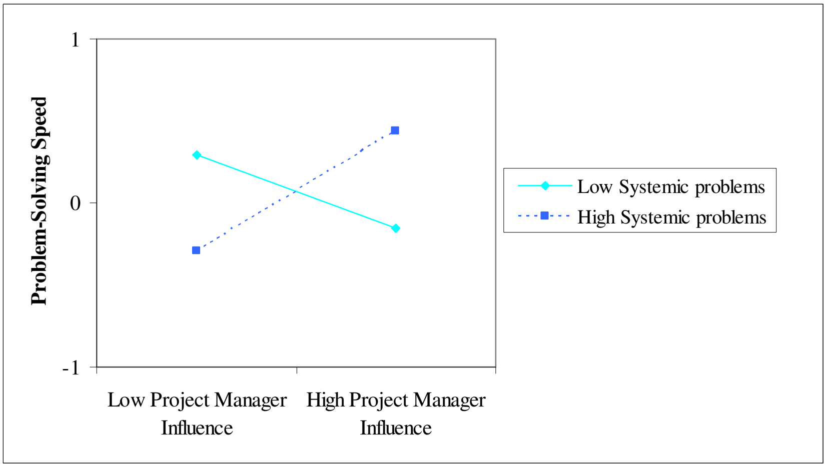
***Moderation of integration mechanisms: connectedness and project manager influence***
Our general expectation was that integration mechanisms are moderated positively by the extent that project problems are systemic rather than autonomous (see Table 7.1). We find two significant interaction effects involving integration mechanisms and both support this view. First, this involves the relationship between connectedness and solution quality (Hypothesis 3a). Slope analysis reveals that the relationship between connectedness and solution quality is marginally positive under conditions of systemic problems, but that a statistically significant ($p<0.001$) negative association exists under conditions of autonomous problems (see Figure 7.2). Figure 7.2 reveals that a high degree of connectedness will on average result in solutions of about the same quality regardless of the type of problems. For low values of connectedness however, solution quality is on average much higher for autonomous problems than for systemic problems.

**Figure 7.2 Moderation of the effect of connectedness on solution quality**




In line with hypothesis 4b we find that project management influence contributes stronger to problem-solving speed under conditions of mostly systemic problems than under conditions of mostly autonomous problems (see Figure 7.3). If projects are confronted with mostly systemic problems, the effect of project management influence is significantly positive ($p<0.05$), but for predominantly autonomous problems the presence of an influential project manager or project management team is associated with lower problem-solving speed ($p<0.10$).

**Figure 7.3 Moderation of the effect of PM influence on problem-solving speed**




***Moderation of differentiation mechanisms: reach and decentralization***

Our general expectation for differentiation mechanisms holds that they are comparatively more beneficial for problem-solving proficiency when projects are confronted with mostly autonomous problems. The regression analysis supports this view regarding the effect of reach on solution quality (Hypothesis 2a). Figure 7.4 takes a more detailed look at this finding and shows that a significantly positive association exists for projects with mostly autonomous problems ($p<0.05$) and that a negative association exists (insignificant) between reach and solution quality for projects that are confronted with mostly systemic problems. On average, low reach results in roughly the same quality of the solution regardless of the type of problem. For high values of reach, solution quality is on average much higher for systemic problems than for autonomous problems.

Contrary to our expectations (Hypotheses 1c and 2c), we find that the effects of reach and decentralization on problem-solving efficiency are positively moderated by the extent that problems are systemic rather than autonomous. In the case of reach (Figure 7.5), a positive effect exists for projects with mostly systemic problems. In addition, a negative effect exists for projects with mostly autonomous problems. Hence, when we compare Figure 7.4 and Figure 7.5, a trade-off exists in terms of reach: it appears very difficult to solve problems (of either type) efficiently and with a high quality. We discuss this effect in greater detail in the discussion section.

**Figure 7.4 Moderation of the effect of reach on solution quality**

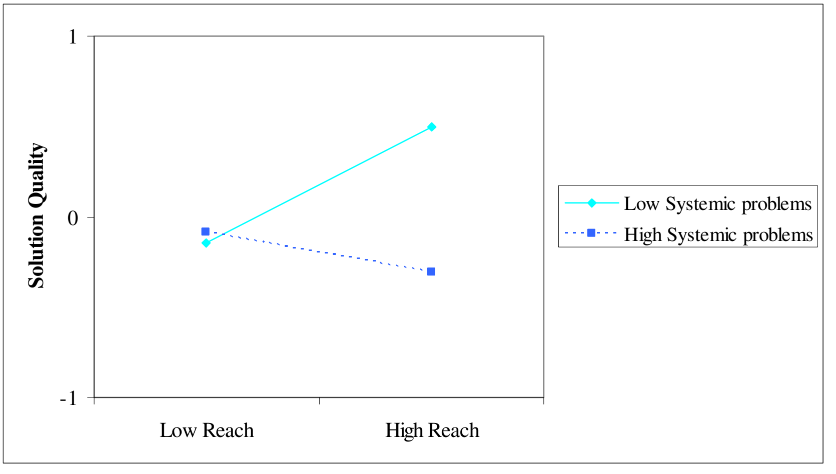
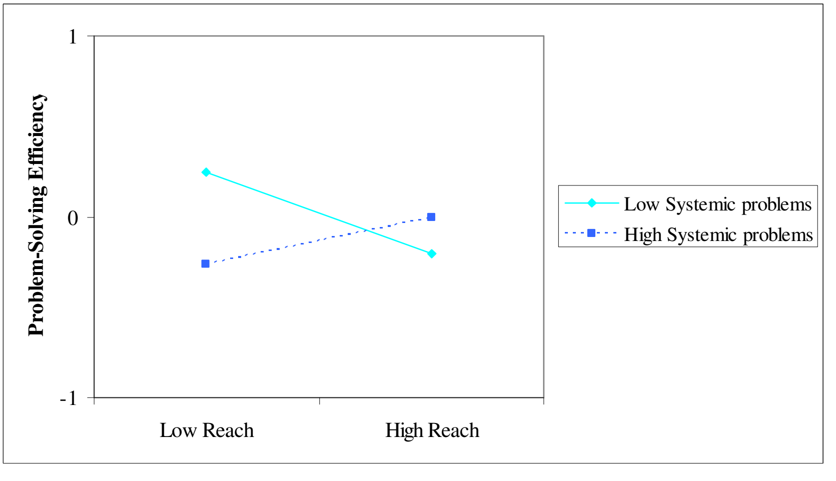
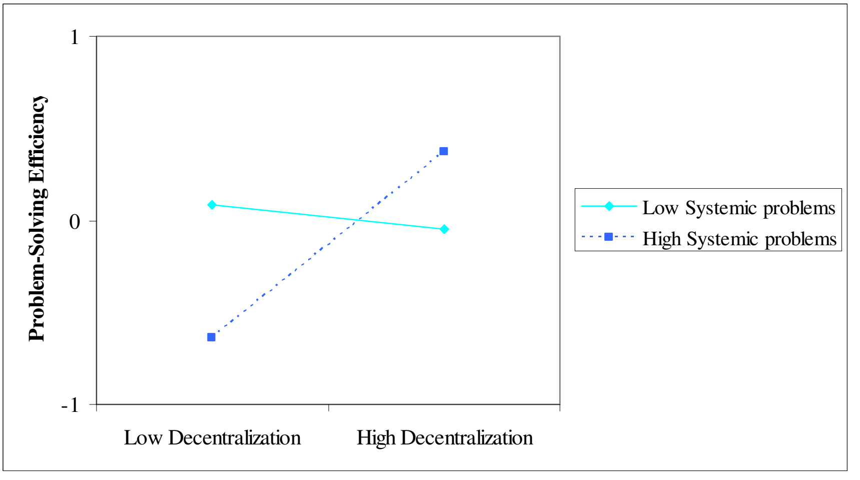



**Figure 7.5 Moderation of the effect of reach on problem-solving efficiency**




Finally, simple slope analysis (Figure 7.6) reveals that decentralization has a slightly negative effect on problem-solving efficiency if problems are autonomous. If projects are confronted with predominantly systemic problems a positive, statistically significant relationship exists ($p<0.01$). We discuss also this effect in greater detail in the next section.

**Figure 7.6 Moderation of the effect of decentralization on problem-solving efficiency**




**7.5 Additional polynomial regression analyses**

In this section we present the results from additional analyses that complement the step-wise regression analyses reported above. These prior analyses only report main effects and interaction effects. As discussed earlier (Chapter 2) this provides only a partial and constrained picture of the fit between the independent variables and the interaction variable (e.g. Edwards, 1993). Polynomial regression relaxes these constraints and is therefore able to investigate the robustness of the significant interaction effects that we found earlier. These effects might namely be confounded with nonlinear effects in terms of the independent variable and or the interaction variable.

In adopting this approach we first of all scale-centered the independent variables and the interaction variable by subtracting the mean from each rating. These scales therefore run from -2 to 2 with a value of 0 as their midpoint. This helps to mitigate problems due to multicollinearity and - when presented graphically in 3-D plots - makes interpretation of the results easier (Edwards and Parry, 1993). In the first step of each regression analysis (see Table 7.4) we entered the control variables, the independent variables, and the interaction variable. In the second step we entered the squared terms of the independent variables and the interaction variable. This step increases the explained variance with 8 to 10 percent. This step is significant only for problem-solving speed.

In the final step we entered the significant interaction effects that we found in the prior analyses. Because of concerns about the power of the test we did not include the other interaction terms. This last step helps to explain an additional 5 to 6 percent of variance in the dependent variable. All interaction variables turn out to be significant in these new analyses. Hence, our original findings do not appear to be confounded by the effects of squared terms. Furthermore, this final step is significant in all three analyses.

**Table 7.4 Results from polynomial regression analysis**

| | Solution Quality | | | Problem-solving Efficiency | | | Problem-solving Speed | | |
|---|---|---|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M3** | **M1** | **M2** | **M3** | **M1** | **M2** | **M3** |
| Constant | 3.63*** | 3.76*** | 3.69*** | 3.57*** | 3.45*** | 3.49*** | 3.48*** | 3.66*** | 3.57*** |
| Team size | 0.16* | 0.16* | 0.10 | -0.02 | -0.01 | 0.04 | -0.10 | -0.09 | -0.09 |
| Application novelty | -0.02 | 0.04 | 0.06 | -0.17 | -0.12 | -0.12 | -0.05 | 0.00 | 0.03 |
| Extent that problems are systemic | -0.08 | -0.08 | -0.07 | -0.14 | -0.16 | -0.38** | -0.11 | -0.12 | -0.22* |
| Decentralization | 0.20* | 0.21* | 0.16 | 0.21* | 0.26* | 0.32** | -0.02 | 0.10 | 0.09 |
| Free flow of information | 0.39*** | 0.33* | 0.25* | 0.37** | 0.42** | 0.42** | 0.47*** | 0.62*** | 0.61*** |
| Reach | 0.05 | 0.21* | 0.19* | -0.05 | -0.04 | -0.01 | -0.12 | -0.06 | -0.04 |
| Connectedness | -0.26* | -0.16 | -0.15 | -0.35** | -0.26 | -0.33 | -0.19 | -0.38* | -0.47*** |
| Project manager influence | 0.13 | 0.08 | -0.06 | -0.18 | -0.14 | -0.12 | -0.10 | 0.01 | -0.05 |
| | | | | | | | | | |
| Extent that problems are systemic^2 | | 0.00 | -0.03 | | 0.21* | 0.18* | | 0.13 | 0.18* |
| Decentralization^2 | | -0.04 | -0.01 | | 0.05 | -0.03 | | -0.19* | -0.20* |
| Free flow of information^2 | | 0.08 | 0.08 | | -0.19 | -0.14 | | -0.13 | -0.15 |
| Reach^2 | | -0.23** | -0.22** | | 0.02 | 0.05 | | -0.04 | -0.02 |
| Connectedness^2 | | -0.15 | -0.11 | | -0.10 | -0.11 | | 0.05 | 0.09 |
| Project manager influence^2 | | 0.05 | 0.10 | | 0.04 | 0.05 | | -0.15 | -0.02 |
| | | | | | | | | | |
| Decentralization * Systemic | | | | | | 0.21* | | | |
| Reach * Systemic | | | -0.18* | | | 0.30* | | | |
| Connectedness * Systemic | | | 0.25* | | | | | | |
| Project manager influence * Systemic | | | | | | | | | 0.30** |
| | | | | | | | | | |
| Incremental R^2 | | 0.09 | 0.06 | | 0.08 | 0.06 | | 0.10 | 0.05 |
| Partial F | | 1.74 | 3.91** | | 1.54 | 3.65* | | 2.02* | 5.73** |
| R^2 | 0.28 | 0.36 | 0.42 | 0.22 | 0.31 | 0.37 | 0.24 | 0.34 | 0.39 |
| Adjusted R^2 | 0.21 | 0.25 | 0.30 | 0.15 | 0.18 | 0.23 | 0.16 | 0.22 | 0.27 |
| F | 3.95*** | 3.13*** | 3.43*** | 2.67** | 2.41** | 2.71*** | 3.22** | 2.84*** | 3.20*** |
| n | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; Unstandardized regression coefficients are reported for a 1-sided test.

For each dependent variable the full model is significant at $p<0.001$ with the percentage of variance explained ranging from 23 percent up to 30 percent (Adjusted $R^2$). Multicollinearity is of limited concern in these additional analyses. Except for connectedness and free flow of information, all VIF values are below 2.5. Connectedness and free flow of information are only slightly above this strict rule of thumb (VIF = 2.7).

To increase our understanding of the findings in Table 7.4, we used the unstandardized regression coefficients to plot the effects for each significant interaction as a three-dimensional surface. These plots also take into account the direct effects and the squared terms of the two variables that make up the significant interaction effect. In these analyses we assume that the other variables take on the mean value of 0. Below we discuss the results from these additional analyses for each of the three dependent variables, starting with solution quality.

***Solution Quality***

Whereas our original results reported an insignificant effect from *reach* (see Table 7.3), our additional polynomial analysis (see Table 7.4) indicates that reach has a positive main effect and that its squared term has a significant negative value (which indicates an inversed U-shape effect). The interaction term between reach and systemic problems has a significant negative value, which is in line with our original findings. These effects are visualized in three-dimensional space in Figure 7.7.

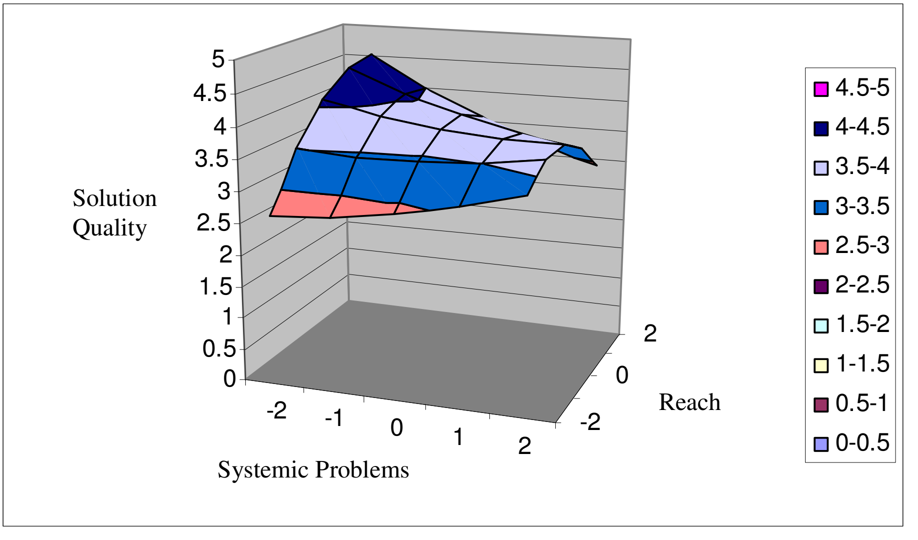
This figure presents a concave surface.[9] From this figure we learn that the positive main effect holds under conditions of autonomous problems. In other words, reach is especially likely to result in high-quality solutions for autonomous problems (in fact, solution quality reaches its peak in the corner where reach is high and systemic problems are low). Conversely, autonomous problems will be of a significantly lower quality if the project team aims to solve autonomous problems on its own without the help of external specialists (see also Figure 7.4).

In Figure 7.7 it is also apparent that the inversed U-shape relationship especially holds for situations of systemic problems. In other words, if teams are confronted with mostly systemic problems, then it appears that a moderately open approach is most likely to result in high-quality solutions. In this way the team might obtain relevant information from external sources, but at the same time balance this with internal effort to integrate this information in high-quality architectural knowledge. This effect went unnoticed in the original analysis. This effect also indicates that teams might 'over-search' (Katila and Ahuja, 2002) for relevant ideas and solutions. Prior studies also found and explained these limits of Open Innovation (e.g. Laursen and Salter, 2006). Traditional explanations are related to the limits of a firm's resources and attention to successfully search for external ideas, i.e. firms face the difficulty to absorb and choose between the many ideas and solutions; ideas may come at the wrong time; and ideas may be too many to implement each of them (Koput, 1997). Since we find that the inversed U-shaped effect especially

[9] Concave surfaces are those surfaces for which any line connecting two points on the surface lies on or below that surface. In contrast, a surface is convex if any line connecting two surface points lies on or above the surface (Edwards and Parry [1993] referring to Chiang [1974, p.255]).

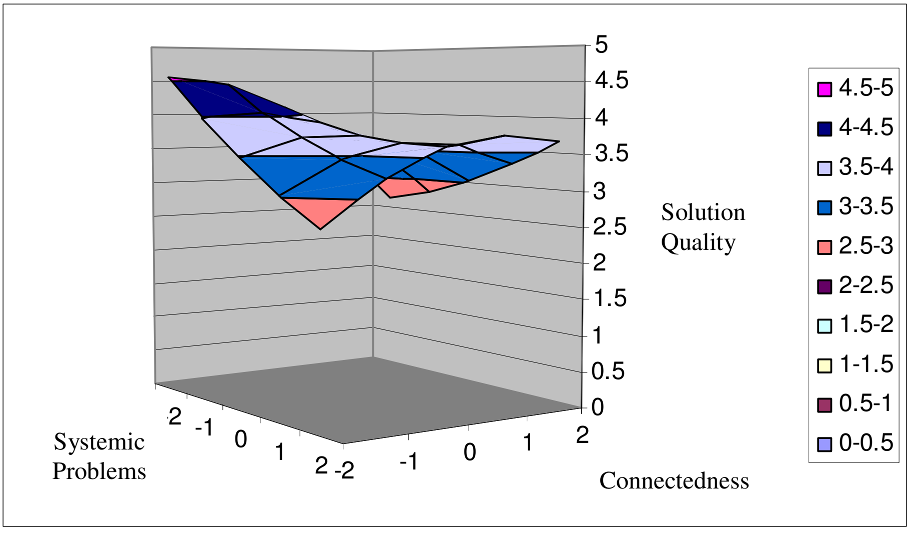
holds under conditions of systemic problems, we add to this literature by suggesting that over-search is more likely if a firm's open search activities are aimed at finding high-quality architectural knowledge. This knowledge tends to be scarce as well as highly specific and tacit and therefore difficult to absorb (e.g. Reagans and McEvily, 2003). At least some internal knowledge generation is therefore required to reach high-quality solutions for systemic problems.

**Figure 7.7 Effects of reach and systemic problems on solution quality**




The second significant interaction term in the explanation of solution quality involves *connectedness* (see Table 7.3). Table 7.4 reveals that the main and squared terms for connectedness are insignificant. Supporting our initial findings, the interaction term is also significant in Table 7.4. Figure 7.8 plots the effects of connectedness and systemic problems. In this saddle-shaped figure connectedness is associated slightly positively with solution quality if problems are highly systemic. In contrast, higher values of connectedness tend to be associated with solutions of lower quality in situations of mainly autonomous problems. This latter effect is statistically significant as judged by the simple slope analysis presented above. Given the absence of significant main and squared terms, this figure adds little to the effects already visualized in Figure 7.2.

**Figure 7.8 Effects of connectedness and systemic problems on solution quality**




***Problem-solving efficiency***

In the case of problem-solving efficiency the additional analyses (Table 7.4) first of all reveal a significantly negative association with the extent that problems are systemic (indicating that systemic problems are in general more difficult to solve efficiently). The results also indicate a significantly positive effect for the squared term of the extent that problems are systemic (indicating a U-shaped relationship). This analysis therefore refines our prior analysis. Finally, the interaction terms involving decentralization and reach are also significant in our additional analysis, which supports our original findings. Figure 7.9 and Figure 7.10 illustrate the effects for decentralization and reach.

Both figures present more or less the same surface. First of all, both illustrate the negative main effect of systemic problems and its positive squared term. These effects appear to be contingent upon the degree of decentralization and reach: for low values of reach and (especially) decentralization problem-solving efficiency tends to decrease if problems become more systemic (reflecting the main effect). For high values of decentralization and reach the U-shaped association becomes visible. This U-shaped relationship indicates that reach and decentralization are especially likely to result in efficient problem solving if the projects are confronted with only systemic problems or only autonomous problems. To the extent that a project is confronted with problems of both types, problem solving tends to become less efficient. The explanation for this finding might be specialization: if teams are only confronted with systemic problems or only with autonomous problems, this means that the team's external search effort can focus on finding architectural knowledge or component knowledge. Similarly, in the case of autonomous problems, empowered team members can fully specialize with respect to their own component. In the case of systemic problems, individual team members learn how to accomplish their tasks while being sensitive to the tasks of other team members.

**Figure 7.9 Effects of decentralization and systemic problems on problem-solving efficiency**

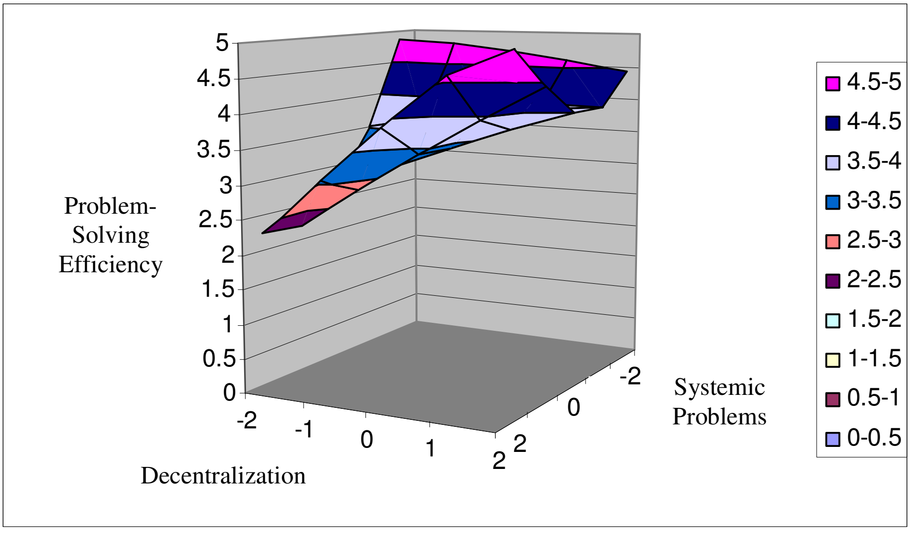



**Figure 7.10 Effects of reach and systemic problems on problem-solving efficiency**

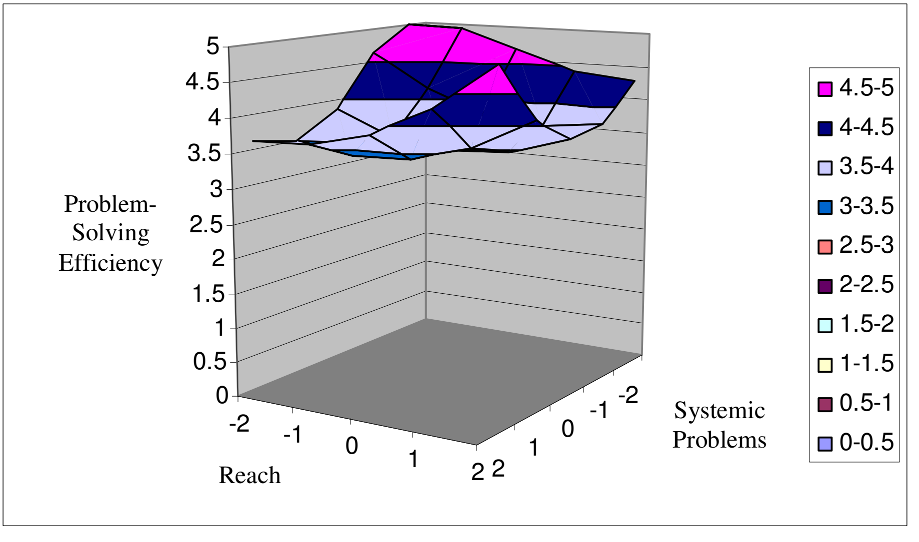
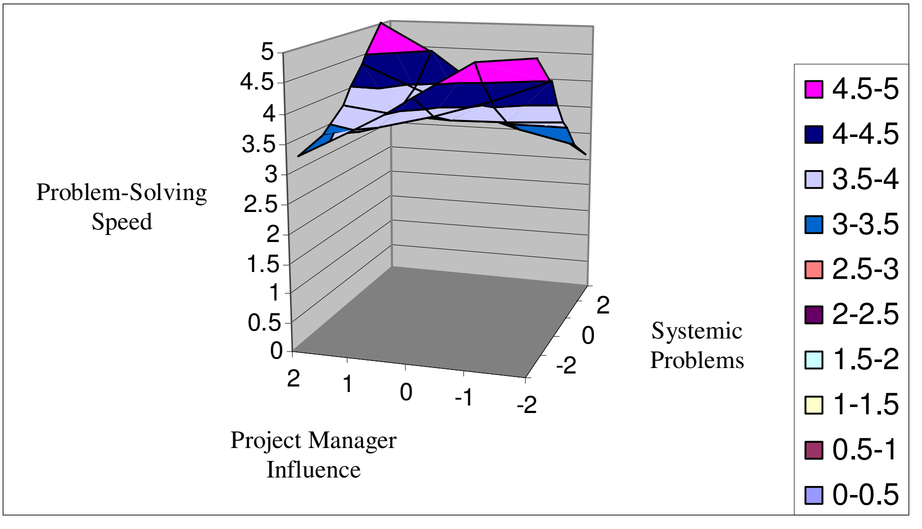



Figure 7.9 and 7.10 also visualize the interaction effects: decentralization and reach are associated somewhat negatively with problem-solving efficiency under conditions of autonomous problems. In contrast, both organizational characteristics (especially

decentralization) appear to be positively associated with problem-solving efficiency in case of systemic problems. This is in line with Figure 7.5 and Figure 7.6 above.

***Problem-solving speed***
Regarding problem-solving speed we find that the extent that problems are systemic has a negative main effect and a positive effect of its squared term (just as for problem-solving efficiency). We also find that the interaction term between project management influence and the extent that problems are systemic is significant. This supports our initial finding. The saddle-shaped surface in Figure 7.11 clearly visualizes this interaction effect.

**Figure 7.11 Effects of PMI and systemic problems on problem-solving speed**




## 7.6 Discussion and conclusions

This study meets the call to generate a better understanding of the new product development process (Brown and Eisenhardt, 1995). In particular, this chapter improves our understanding of NPD as a problem-solving process (e.g. Sheremata, 2000; Atuahene-Gima, 2003). As far as we know, this study is the first that looks into the moderating effect of different types of problems. We argue that NPD projects - for the purpose of proficient problem solving - need to be organized differently dependent on the extent that problems during the NPD process are systemic rather than autonomous. Our results indicate that problem solving is far from a universal NPD capability.

First of all, we found that connectedness and project management influence (i.e. two integration mechanisms) contribute significantly more to respectively solution quality and problem-solving speed when project problems are systemic rather than autonomous. This is in line with our expectation that integration mechanisms are especially helpful for solving systemic problems, as they help to generate architectural knowledge and to achieve unity of effort. We also found that reach (i.e. a differentiation mechanism) contributes more to solution quality for projects that are confronted with mostly autonomous problems than for projects that are confronted with mostly systemic problems. This is in line with our expectation that differentiation mechanisms are especially useful for autonomous problems, as they promote the development and exploitation of detailed expertise about individual components.

In contrast to our expectations, we find that reach and decentralization (i.e. differentiation mechanisms) are particularly helpful for problem-solving efficiency when projects are confronted with predominantly systemic problems. Given the strong positive correlation between problem-solving efficiency and problem-solving speed ($\rho=0.56$; $p<0.001$; Table 7.2), we also might expect to find similar interaction effects for the relationships between these differentiation mechanisms and problem-solving speed. We find no (directional) support for such relationships however (see Table 7.3), which might reflect the conceptual difference between problem-solving speed and problem-solving efficiency (in spite of the strong correlation still considerable unexplained variance exists between the two).

How can we explain these unexpected interaction effects? Regarding decentralization this effect might be explained by its benefits in terms of the implementation of solutions. In the case of systemic problems, decentralization was expected to be comparatively costly because of the difficulty to reach consensus among the affected team members. However, decentralization might be a particularly efficient way to implement solutions for systemic problems once they have been decided upon. Imagine the time and resources it would require for a central actor to specify in detail how project members have to make local changes to all the components that are affected by a systemic problem. Instead, it seems more efficient to provide general specifications and design information within which empowered specialists are able to optimize their components. Future research should attempt to distinguish between the generation and the implementation of solutions.

When we investigate Figure 7.4 and Figure 7.5 it becomes apparent that a strong trade-off exists in terms of reach. In the case of autonomous problems, problem-solving based on extensive reach appears to be a less efficient problem-solving tactic than limited reach. Whereas relevant specialized component knowledge is likely to exist in a firm's environment (which is indicated by the positive association with the quality of solutions for autonomous problems), this might be comparatively costly as a result of for instance licensing fees, supplier contracting, or knowledge absorption.

In the case of projects with mostly systemic problems, reach is an efficient problem-solving approach, but at the same time it is likely to result in solutions of significantly lower quality. Above we have already seen that extensive external search is unlikely to provide the team with the architectural knowledge that is required for high-quality solutions. Such external search obviously requires resources, but we expect that this is considerably less expensive than the internal investments that are required to generate detailed architectural knowledge. This is likely to be a lengthy process that demands large investments in for instance people, training, and integration mechanisms. In other words, the development of a systems integration capability is costly, but crucial for the development of high-quality product architectures (Adner, 2006; Brusoni et al., 2001).

Although not the main focus of our chapter, we also find several direct effects. First, free flow of information (for which we found no moderating effect) has an overall positive effect on problem-solving proficiency. Hence, project teams whose members communicate without any restrictions are likely to be more proficient in problem solving than teams whose members communicate less easily, e.g. as a result of geographical dispersion or political issues. In terms of solution quality and problem-solving speed these findings are in line with prior research (Sheremata, 2000; Atuahene-Gima, 2003). Sheremata (2000) proposed a negative effect however of free flow of information on problem-solving efficiency, because extensive use of information exchange requires additional resources (e.g. communication channels and increased labor costs). We find a positive effect on problem-solving efficiency however. Possibly, free flow of information results in more efficient problem solving because of its positive effects on problem-solving speed and solution quality. A faster process might mean that fewer resources are used (e.g. man hours) and better solutions might mean that less rework is required.

Secondly, connectedness has a consistently negative effect on problem-solving proficiency. Contrary to the proposition formulated by Sheremata (2000) we therefore found that frequent contact between team members delays the problem-solving process. Although Atuahene-Gima (2003) expected a positive effect of connectedness on solution quality, we find that solution quality suffers from frequent meetings. An explanation might be that 'forced' meetings might result in solutions as compromises that include input from project members that are not directly relevant to the specific problem at hand.

Considered jointly, the opposing effects of free flow of information and connectedness are intriguing. In Table 7.2 we find a significant positive association between both factors ($\rho = 0.41$; $p<0.001$), but factor analysis clearly separates the items of both factors. It might well be that team meetings are an important way to freely exchange information or to promote information-exchange when communication barriers are present. Information can be exchanged in many other ways though, such as through file sharing, phone calls, e-mails, and informal face-to-face deliberations. Especially in small teams we might expect these mechanisms to be more important than meetings. This view is supported in Table 7.2 by a significant correlation between team size and connectedness ($\rho = 0.27$; $p<0.05$). Since most of the surveyed project teams are small, direct contact through meetings might delay the problem-solving process, because other communication mechanisms are less time-consuming in such settings.

Another explanation is that connectedness forms a suppressor effect (Maassen and Bakker, 2001). Free flow of information is significantly correlated with the three dependent variables. It is therefore no surprise to find significant regression coefficients for this variable. Connectedness however is hardly correlated with the three dependent variables, but it is significantly correlated with free flow of information, e.g. the more people meet, the more they will exchange information. Regression models without connectedness still show strong and significant regression coefficients for free flow of information, but they are significantly increased if connectedness is entered into these models. For solution quality and problem-solving efficiency this step is statistically significant. This indicates a suppressor effect, i.e. even though connectedness is not related to the dependent variable, its correlation with free flow of information suppresses irrelevant variation from free flow of information, thus increasing the explanatory power of this variable.

Two other direct effects were the relationships between decentralization and respectively problem-solving efficiency and solution quality. The positive effect on problem-solving efficiency is not in line with the expectation formulated by Sheremata (2000), who proposed that autonomous specialists might push problem-solving too far (thus reducing efficiency). A possible explanation is that the allocation of discretion to specialists increases their commitment and results in a better use of their expertise. Hence, decentralization might help to solve problems once and for all with high-quality solutions. This is likely to prevent costly rework and additional problem-solving expenditures. The positive effect that we found between decentralization and solution quality supports this view. This latter finding supports the proposition as formulated by Sheremata (2000) and is also in line with the empirical findings from Atuahene-Gima (2003).

The additional polynomial analyses explored whether new insights would emerge based on the findings of less-constrained and more comprehensive regression models. For this purpose we took the significant interaction effects from the original analyses and we included in their regression models the squared terms of the moderating variable and of the five independent variables. Several interesting insights emerged from these additional analyses. Most importantly, all five interaction effects remained significant in these new analyses. This indicates that the original findings were not confounded by curvilinear effects. Furthermore, their inclusion in the regression models involved significant steps.

In addition, the polynomial analyses did result in several new insights. First, we found that reach – in combination with the extent that problems are systemic – has a more complex effect on solution quality than previously recognized. Whereas our original analysis did not reveal a significant main effect of reach on solution quality, by including its squared term we find a significant main effect as well as a significant squared term. The resulting three-dimensional surface (Figure 7.7) supports our earlier finding that the quality of solutions to autonomous problems benefits from increasing levels of reach (although this effect diminishes as the value of reach increases). In addition, a new insight indicates that as problems become more systemic it becomes important to gradually decrease the team's reach until a medium degree of reach, which seems optimal for projects with mostly systemic problems. Consistent with our theory this indicates that it is important to gather component knowledge from external sources under these circumstances, but that significant attention and resources are also required to integrate and combine (internally) the different component-level insights into deep architectural knowledge. This finding shows the limits of Open Innovation, which is based on the premise that firms operate in 'a landscape of abundant knowledge' (Chesbrough, 2003). Our results indicate that – as far a architectural knowledge is required – this is more likely to be generated internally than that it can be found externally. A moderate extent of external search for component knowledge might be appropriate, but subsequently this needs to be applied internally to develop an understanding of their interrelationships. Typically, architectural knowledge is very product-specific and highly tacit, which makes it much more suitable to develop internally. As we have seen, this internal development is likely to be a very expensive effort though.

Secondly, for the models explaining problem-solving efficiency, we found that the extent that problems are systemic has a significantly negative main effect and a significantly positive squared term (indicating a U-shaped relationship). In our original models we did not find a significant direct effect. In combination with the three significant interaction effects (between systemic problems and respectively decentralization and reach) we found two surfaces of roughly the same shape (Figures 7.9 and 7.10). Whether the extent that problems are systemic has a negative main effect or the U-shape effect appeared to be contingent upon the value of decentralization or reach. For low values of these organizational characteristics autonomous problems can be solved more efficiently (this reflects the negative main effect of systemic problems), whereas for high values of the organizational characteristics especially systemic problems can be solved efficiently. This latter effect diminishes as problems become less systemic and thereafter increases again as problems become mainly autonomous.

This U-shaped effect not only indicates that decentralization and reach are especially relevant for systemic problem-solving, but it also shows that these organizational characteristics can be beneficial to solve autonomous problems, albeit less significantly than in the case of systemic problems. This U-shaped relationship indicates that – for high values of decentralization and reach – it is difficult to deal with projects that are confronted with both systemic and autonomous problems. If one of the two types of problems dominates then the organizational factors become more effective, possibly because the team can switch to a specific problem-solving mode, whereas the best of both worlds have to be combined for projects with mixed problems, thus causing efficiency problems.

***Limitations and future research***

Our study has several limitations. First, the size of our dataset is limited. Although a larger dataset increases the power of the test, the current study provides sufficient possibility to detect the strongest – and therefore the most relevant – effects. Secondly, common method bias might have influenced our results. We do not expect though that respondents have completed the questionnaire based on an implicit theory that resembles our conceptual model (e.g. Podsakoff et al., 2003). Third, we used project managers as single respondents because they are generally the most knowledgeable respondents in our context. Although the use of multiple respondents often results in higher validity, single-respondent designs are justified in certain situations (Pagell and Krause, 2008). We targeted project managers since we expected that our respondents had a good understanding of the characteristics and the efforts of the generally small-sized teams. For instance, project managers can be considered the most appropriate respondents to judge on the creativity and the quality of solutions (e.g. Shalley and Gilson, 2004). Interviews and survey pretests confirmed this expectation. Furthermore, we only asked for issues related to the team itself, i.e. issues the respondent was directly responsible for. We did not focus on constructs outside of the project team. By contacting respondents by phone, we ensured as much as possible that the right person completed the questionnaire. Finally, it was difficult to collect data from multiple respondents in our empirical context. For instance, it was impossible to gather data from CEOs and project managers, because this was in many cases one and the same person.

Fourth, we used subjective ratings because objective data is difficult to collect for NPD projects. Hence, the extent that a project's problems are systemic rather than autonomous is not determined by the technical characteristics of problems. Instead the type of problem heavily depends on the perceptions and choices of project managers and their team members. Managers and teams can namely influence whether a problem is systemic or autonomous, because the solutions that they pursue may or may not have systemic consequences. Consider the development of a mobile phone and assume that its processor turns out to provide insufficient capacity for the phone to perform as intended. One solution may be to simply replace the processor by a better one. If the implementation of this new processor requires no adjustments to other components or interfaces, then the problem can be considered autonomous. Another solution to this same problem might however be to maintain the original processor and to opt for the redesign of the mobile phone itself, e.g. less or 'downsized' software applications and more basic hardware elements, such as the screen and the camera. This solution therefore requires decisions, trade-offs, and redesigns for multiple components, which makes this same problem a systemic problem. Following the basic assumptions of this study, teams need organizational forms that match the systemic consequences that are implied by the solutions they implement.

In this respect is that the chosen solution might be determined by the organizational form of the project team, which points to the possibility of reversed causality. Very differentiated project teams can be expected to perceive problems as being autonomous and might tend to prefer autonomous solutions. At the same time, this might mean that such teams fail to recognize the systemic nature of problems. Such a mismatch provides a potential rival explanation of the effects that we found in this chapter. Consider for instance the negative effect of project management influence on problem-solving speed under conditions of autonomous problems (see Figure 7.3). It might well be that a respondent defines problems as autonomous and manages the problem-solving process accordingly, whereas problems are in fact highly systemic. In this case the speed of a project might especially suffer from the presence of a strong leader, because these leaders might be less inclined to adapt the problem-solving process when interdependencies become apparent. In contrast, project members might enjoy more freedom to meet the needs of these systemic problems when a relatively weak leader heads the project. This potential explanation points to the importance for future research to develop a better understanding of the process of problem finding and of problem definition in project teams. There is only very limited research about this topic (Sheremata, 2002).

In terms of the extent that our findings are generalizable to the population as a whole we concluded in the methods section that there were no statistically significant differences between the first wave of respondents and the second wave of respondents. This is what many studies report as evidence for the absence of nonresponse bias. However, given the relatively small size of the two groups we are likely to lack the power to detect group differences (Wright and Overton, 2008). Finally, the external validity of our results has clear limits. It is for instance important to note that our study focused on software-based products. Furthermore, the size of most project teams was small (i.e. 54% of the projects consisted of 2-5 full-time team members). Hence, additional studies in different empirical settings are required to replicate our findings and to increase our confidence in them. The investigated effects might for instance be different for larger project teams, e.g. larger projects might benefit more strongly from integration mechanisms in case of systemic problems (since it is typically more difficult to achieve unity of effort among a larger number of individuals) and from differentiation mechanisms in case of autonomous problems (since more specialist expertise is likely to be present in larger projects).

Besides replications in theoretically selected populations to increase our confidence in the validity of the current conceptual framework (Figure 7.1), another opportunity would be to study which configurations of specific organizational characteristics contribute to problem-solving proficiency. For instance, which specific combinations of differentiation and integration mechanisms are especially beneficial under which contingencies? Sheremata (2000) also indicated that the organization of the NPD process can be considered as a balanced mix of organizational and managerial elements. Limited research exists however that explicitly adopts configurationalism (Doty et al., 1994).

***Managerial implications***

Given the strategic importance of NPD it is important that managers aim to increase its chances of success. NPD is inherently risky and uncertain, and therefore very much a problem-solving process (Brown and Eisenhardt, 1995). Our results provide further support for the view that the organizational design of the NPD process contributes to the teams' problem-solving proficiency. This chapter shows that problem solving is a complex capability that needs to be sensitive to the type of problems encountered during the development process. Systemic problems and autonomous problems are two different types of problems and have very different requirements. This needs to be accounted for in the organization of the NPD process to increase the chance of successful problem-solving. This finding seems all the more relevant given that products in many industries are becoming more complex (which increases the likelihood of systemic problems).

A strong and important finding is the trade-off that exists in terms of reach, i.e. the extent that teams adopt an external perspective. Active search for information from for instance users and technology suppliers is likely to help improve the efficiency of problem-solving in case of systemic problems, but it might work completely the opposite way in case of autonomous problems. Reach has exactly the opposite effect on solution quality: in the case of systemic problems reach decreases the likelihood to generate high-quality solutions, whereas high-quality solutions are likely in case of autonomous problems. Managers therefore need to trade-off both effects. Managers must realize that frequent contact and consultation with external sources must not prevent the project team from integrating these acquired insights to be able to deal with systemic problems. Conversely, managers must be aware that autonomous problems are likely to be efficiently solved using internal knowledge, but that the quality of solutions (at the expense of decreasing efficiency) can be improved by engaging with external actors.

The direct effects indicate that free flow of information contributes to faster, better, and less costly problem-solving. This implies that it is important to facilitate communication between project members as much as possible and to remove any barriers. Furthermore, if high-quality and cost-efficient solutions are required it seems important that team members have the authority to make their own decisions in the problem-solving process.

To act upon our findings, managers must of course know the extent that their products will be confronted with autonomous or systemic problems. In general, projects are more likely to be confronted with technical problems if the innovation is technologically new to the project team. Novelty means that project tasks will be more uncertain and more unpredictable for the project team and that more problems have to be solved to generate the knowledge that is needed to complete the project. More specifically, problems are more likely to be systemic in nature to the extent that the innovation involves new architectural knowledge, i.e. if new combinations of components are involved and/or adjusted or new interface protocols. On the other hand, problems are more likely to affect individual components if existing interfaces are reinforced. Hence, systemic problems can be expected to occur especially in new, integral product designs, whereas autonomous problems are more likely to occur in stable, modular product architectures.

Finally, it should also be noted - as mentioned in the limitations - that managers themselves can often decide whether a problem is systemic or autonomous, because the solutions that they pursue may or may not have systemic consequences. Dependent on the solutions selected by managers, this chapter provides clues about how they can subsequently organize their teams for the proficient realization and implementation of ‘autonomous solutions’ or ‘systemic solutions’.

# APPENDIX A. Measures and Factor Analysis Results

Almost every development project faces technical or operational problems that threaten the goals of the project, for instance in terms of project costs, quality, or speed. To what extent do you agree or disagree with the following statements about the way problems were solved during this project? (1 = strongly disagree; 5 = strongly agree)
*In italics: results from varimax rotated principal axis factoring and the Cronbach's Alpha reliability statistic.*

**Problem-solving speed**; scale based on Atuahene-Gima (2003)
- Problem-solving took a lot of time during this project. (reverse-coded)
- Solutions found for problems we faced were not timely. (reverse-coded)
- The project team was very slow in finding and implementing solutions to the problems we encountered. (reverse-coded)
- Ideas for solving the problems encountered were discovered rather late to be implemented successfully. (reverse-coded)
  *Factor loadings are respectively 0.79; 0.92; 0.78; 0.68. Eigenvalue: 2.89. Variance explained: 72% . Cronbach's Alpha: 0.87.*

**Solution quality**; new scale developed for this research
- The solutions found solved the problems effectively.
- The solutions found were of high quality.
- The solutions found were based on detailed knowledge of the nature of the problems.
- The solutions found did not result in new problems.
  *Factor loadings are respectively 0.83; 0.81; 0.77; 0.69. Eigenvalue: 2.81. Variance explained: 70% . Cronbach's Alpha: 0.85.*

**Problem-solving efficiency**; new scale developed for this research
- Problem-solving in this project was very expensive. (reverse-coded)
- During this project a lot of financial resources were expended on problem-solving. (reverse-coded)
- The implementation of solutions found was very expensive. (reverse-coded)
- The costs of problem-solving formed a substantial part of the total development costs. (reverse-coded)
  *Factor loadings are respectively 0.88; 0.83; 0.88; 0.72. Eigenvalue: 3.05. Variance explained: 73% . Cronbach's Alpha: 0.89.*

Indicate your agreement with these statements regarding the project team's product development activities:

**Decentralization**; Adapted from Atuahene-Gima (2003); Ayers, Dahlstrom, Skinner (1997)
- Project members had great freedom to make decisions of their own.
- Project members hardly had to ask permission of a higher manager to take action.
- Project members to a large extent determined how they realized their tasks.
  *Factor loadings are respectively 0.84; 0.86; 0.80. Eigenvalue: 2.38. Variance explained: 79% . Cronbach's Alpha: 0.87.*

**Free flow of information**; Based on Atuahene-Gima (2003) and Hyatt and Rudy (1997).
- Access to information from team members was quick and easy.
- Project team members engaged in open and honest communication.
- Team members willingly kept each other informed at all times.
  *Factor loadings are respectively 0.76; 0.90; 0.82. Eigenvalue: 2.38. Variance explained: 79%. Cronbach's Alpha: 0.87.*

**Reach**; Based on Atuahene-Gima (2003)
- The project team collected a lot of information about new market developments.
- Technological developments were monitored very closely by the project team.
  *The factor loadings for this two-item scale have a value of 0.82. Eigenvalue: 1.66. Variance explained: 83%; Cronbach's Alpha: 0.80.*

**Connectedness**; Based on Sheremata (2002) and Van de Ven, Delbecq, Koenig (1976)
- Project members had frequent, informal interactions with other team members
- Project members frequently met in planned meetings
- Project members often met in informal meetings.
- Project members often collaborated in teams.
  *Factor loadings are respectively 0.47; 0.44; 0.71; 0.67. Eigenvalue: 2.22. Variance explained: 50%. Cronbach's Alpha: 0.66.*

**Project management influence**; Adapted from Tatikonda and Montoya-Weiss (2001)
- Project management was free to determine interim schedule targets.
- Project management was free to adapt the technical design of the web application.
- Project management was free to adapt the functionality of the web application.
- Project management was free to choose the format of progress reviews.
  *Factor loadings are respectively 0.58; 0.78; 0.64; 0.55. Eigenvalue: 2.22. Variance explained: 55%. Cronbach's Alpha: 0.73.*

**The extent that problems are systemic rather than autonomous**; New scale.
- Technical problems were often the result of problems with interfaces between components.
- Solving technical problems often involved the adjustment of multiple components.
  *The factor loadings for this two-item scale have a value of 0.81. Eigenvalue: 1.66. Variance explained: 83%; Cronbach's Alpha: 0.79.*

**Application novelty (1 = not new at all; 5 = very new)**
- How new was the software code of this web application?

# 8. More on Problem Solving: Does Problem-solving Proficiency Mediate and Does Problem Frequency Moderate?

**Abstract**
The previous chapter has investigated how the organization of NPD projects influences the project team's problem-solving proficiency. This chapter uses the dataset of the previous chapter to investigate to what extent problem-solving proficiency itself predicts project performance and whether problem-solving proficiency in this way mediates the effects from project organization on project performance. We also ask the question how the relationship between problem-solving proficiency and project performance is contingent upon the frequency of problems during the NPD project. We find that especially problem-solving efficiency contributes to project performance. We also find that project efficiency suffers strongly if a large number of problems are solved fast. Furthermore, a limited number of mediated effects is present. Particularly the effects from free flow of information on project performance are mediated by problem-solving efficiency.

## 8.1 Introduction

In Chapter 7 we have investigated how the organization of NPD projects influences the capability of NPD teams to solve problems proficiently. We found that this relationship is contingent upon the type of problems a project team is confronted with. In this way we complemented Sheremata (2000), who focused on the direct effects of a project's organizational form on problem-solving proficiency. In addition to this direct effect, Sheremata (2000) also proposed that problem-solving proficiency can be seen as a capability that mediates the effect of the project's organizational form on project performance (i.e. project speed, new product quality, and project cost efficiency). In this chapter we focus on this mediating effect.

In a first empirical test of Sheremata's mediating effect, Atuahene-Gima (2003) found that problem-solving proficiency *partially* mediates the effect of several NPD process characteristics on project outcomes. This means that a project's differentiation and integration mechanisms influence project performance directly as well as indirectly through its effect on problem-solving proficiency. In this study we first of all replicate the test as performed by Atuahene-Gima (2003) in an attempt to further increase our confidence in the validity of the mediating effect. In part, we also provide a first empirical test of Sheremata's original model, because we also include in our analysis problem-solving cost efficiency and project cost efficiency, which Atuahene-Gima (2003) did not include in his analysis.

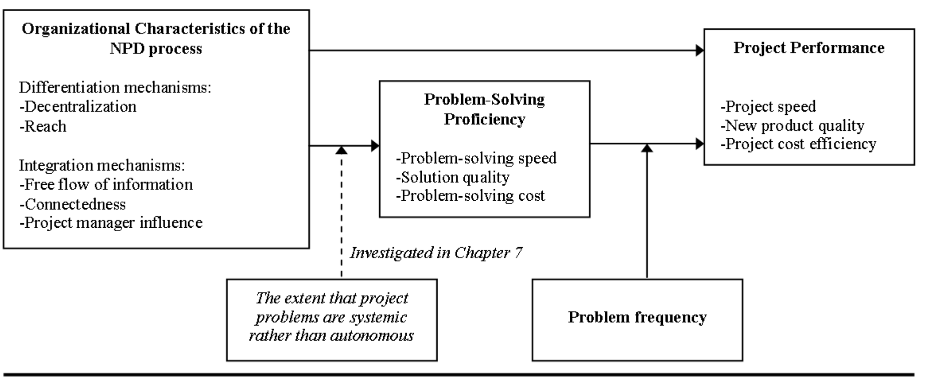
Key to the existence of a mediating effect is that a relationship exists between problem-solving proficiency and project performance. We aim to increase our understanding of this relationship by investigating how its effect on project performance is moderated by the frequency with which a project team is confronted with problems. In general, Sheremata and Atuahene-Gima suggest positive effects in this regard, because problem-solving involves a critical capability that allows teams to achieve their objectives. On the other hand, the more that a project team is asked to apply its problem-solving capabilities the more that this might for instance delay the project irrespective of the speed of the problem-solving process. Problems are an inherent part of new product development projects, but more problematic projects with a larger number of problems might on average perform worse than less problematic projects irrespective of a team's problem-solving capability. In the next section we elaborate on the theory underlying this study and we formulate hypotheses. Subsequently we briefly discuss the method used to test these hypotheses. After that we present the results from our analysis and we end with a discussion and with several concluding remarks.

## 8.2 Theory and hypotheses

Sheremata (2000) proposed that problem-solving proficiency can be seen as an intermediate goal of NPD projects that mediates the effect of the project's differentiation and integration mechanisms on the project's overall performance. Atuahene-Gima (2003) discussed this proposition from the perspective of the input-process-output model of group effectiveness (McGrath, 1984). Seen from this theoretical perspective, the organization of the NPD project (i.e. the differentiation and integration mechanisms) constitutes the input to the NPD project team's problem-solving process, which in turn determines the team's output in terms of project performance.

Drawing on the resource-based view of the firm (e.g. Barney, 1991), Atuahene-Gima argues that the structure and the managerial processes within NPD teams reflect organizational capabilities that can provide the basis for competitive advantage. These company-specific capabilities collectively play a critical role in helping the firm to create attractive new products that contribute to the firm's competitiveness. These organizational process characteristics of NPD projects are widely regarded as an important group of determinants of NPD performance (e.g. Cooper and Kleinschmidt, 1995; Henard and Szymanski, 2001), thus suggesting that these process characteristics influence project performance directly. This apparent explanatory strength of the project's organizational characteristics prompted Atuahene-Gima to investigate whether the effects of the differentiation and integration mechanisms are indeed fully mediated (as implied by Sheremata's model) or whether they are actually partially mediated, which assumes the existence of a direct effect on project performance as well (see Figure 8.1).

**Figure 8.1 Problem-solving as a mediator and problem frequency as a moderator**




***The direct effect of problem-solving proficiency on project outcomes***

A prerequisite for any mediating effect through problem-solving proficiency is that problem-solving proficiency is strongly related to project performance. Atuahene-Gima (2003) again cites the resource-based view of the firm as the theoretical basis for the effect that problem-solving proficiency has on project outcomes. Problem-solving processes are "*intangible, higher-order capabilities that enable a firm to perform critical product development activities better than its competition*" (Atuahene-Gima, 2003, p.363). Atuahene-Gima found that problem-solving speed is related positively with the speed of the development project and with the quality of the new product and that solution quality is associated positively with the quality of the new product. This is in line with his expectations. Fast problem-solving means that teams are able to learn and to generate new knowledge and solutions fast. This indicates is likely to contribute to the speed of the development project and to the quality of the product. Similarly, high-quality solutions mean that project teams are able to solve problems in line with the requirements of customers in terms of for instance durability and reliability (Atuahene-Gima, 2003).

Atuahene-Gima found no strong effect however of solution quality on project speed. Whereas he expected a positive effect, he actually found a (modest) negative effect (Beta = -0.12; n.s.). This suggests that high-quality solutions in general increase the duration of the project. This makes intuitive sense, because it can be expected to take time to understand problems in detail and to develop, test, and revise solutions in order to solve problems optimally.

Atuahene-Gima did not include as a dependent variable project cost efficiency. This raises the question how this dimension of project performance is affected by problem-solving speed and solution quality. In general we expect negative relationships in this regard, because it is likely to take considerable resources to generate and implement solutions of high quality and in a short amount of time. This for instance involves getting the opinion and input from experienced and highly-trained employees or external specialists, simultaneous investments in the generation of alternative solutions, and increasing project staffing to implement and test solutions.

Neither did Atuahene-Gima include in his analysis the cost-efficiency of the problem-solving process itself. How does this relate to the three dimensions of project performance, i.e. product quality, project speed, and project cost efficiency? First of all, cost-efficient problem-solving might positively influence the budget performance of projects, because it results in comparatively little expenditures on problem-solving. Furthermore, cost-efficient problem-solving might mean that relatively few resources are needed, such as man hours, and that the required resources and equipment are readily accessible to the firm and that they do not have to be obtained from external sources. In addition, it might indicate that the implementation of the solution requires fairly limited adjustments to the product. This could all mean that cost-efficient problem solving is associated positively with the project meeting its time schedule.

In a similar vein, cost-efficient problem solving might indicate that limited resources are needed to solve problems in line with product requirements. If not, we can expect project teams to invest substantially more to meet the demands of customers. Hence, problem-solving cost-efficiency can be expected to contribute positively to product quality. Based on the above, we can formulate the following hypotheses regarding the direct effects of problem-solving proficiency on project performance.

> Hypothesis 1. *Problem-solving speed is related positively to (a) project speed and to (b) product quality, but related negatively to (c) project cost efficiency.*
>
> Hypothesis 2. *Solution quality is related negatively to (a) project speed; positively to (b) product quality; and negatively to (c) project cost efficiency.*

> Hypothesis 3. *Problem-solving cost efficiency is related positively to (a) project speed, (b) to product quality, and (c) project cost efficiency.*

***The moderating effect of problem frequency***

Problems are an inherent element of new product development projects. Some projects are confronted with problems more often than other projects however, for instance because of the difficulty of project tasks or because of a lack of expertise of project team members. Above we have formulated claims about how problem-solving proficiency influences project performance on average, without taking into account how frequently a project team is confronted with problems.

Let us first of all consider problem-solving speed. Although fast problem solving can on average be expected to contribute to project speed and product quality, this effect might be substantially less if projects are confronted with a large number of problems. A very problematic project that is confronted with a large number of problems might easily fail to meet the project schedule and the project budget even though the team is very proficient in solving problems fast. Hence, it is more likely that problem-solving speed positively influences project speed and product quality if a limited number of problems occurs. In general, project frequency therefore negatively moderates the effect of problem-solving speed on project performance.

> Hypothesis 4. *Problem frequency negatively moderates the relationships between problem-solving speed and (a) project speed, (b) project cost efficiency, and (c) product quality.*

How can problem frequency be expected to moderate the relationship between solution quality and project performance? First of all, solution quality was expected to contribute to product quality (Atuahene-Gima, 2003). It is difficult to see whether this becomes stronger or weaker if the number of problems varies. If the quality of the solution stays the same for each problem, we would not expect any particular moderating effect. In addition, solution quality was expected to contribute negatively to project speed and project cost efficiency because the generation of high-quality solutions takes time and resources. If problems occur frequently we would expect this effect to be particularly strong. For a limited number of problems project speed and project cost efficiency might be influenced substantially less. This results in the following hypotheses.

> Hypothesis 5. *Problem frequency (a) does not moderate the relationships between solution quality and product quality, and it negatively moderates the relationship between solution quality and (b) project speed and (c) between solution quality and project cost efficiency.*

Finally, we expect that problem frequency negatively moderates the effects of problem-solving cost efficiency on project performance. Even though problems are solved-cost efficiently, the fact that a large number of problems has to be solved means that it is more likely that budget and schedule objectives are met. Furthermore, especially in the case of a large number of problems, problem-solving cost efficiency might indicate that the average number of resources available for each problem is limited, which might compromise the quality of the product.

> Hypothesis 6. *Problem frequency negatively moderates the relationships between problem-solving cost efficiency and (a) product quality, (b) project speed, and (c) project cost efficiency.*

***The mediating effect of problem-solving proficiency***

In the previous chapter we have seen that several differentiation and integration mechanisms strongly explain problem-solving proficiency. Subsequently, we have predicted above that problem-solving proficiency is directly related to project outcomes. This suggests that the effects of the organizational mechanisms effect project outcomes completely through problem-solving processes, i.e. full mediation (Atuahene-Gima, 2003). For several effects Atuahene-Gima found partial mediation however, with several organizational factors also influencing project performance directly. To be more precise, he for instance found that problem-solving speed partially mediates the effect of reach on development speed and the effect of free flow of information on product quality. Atuahene-Gima did not include in his analysis problem-solving cost efficiency and project cost efficiency. We therefore replicate and extend his study by testing the following hypothesis:

> Hypothesis 7. *The effects of differentiation and integration mechanisms on project performance (cost efficiency, speed, product quality) are partially mediated by problem-solving proficiency (speed, cost efficiency, solution quality).*

## 8.3 Method

We tested the above hypotheses based on the same dataset as the one described in Chapter 7. Two new variables in this particular study involve project performance and problem frequency. We conceptualized project performance in terms of three different dimensions: *project cost efficiency, project speed, and product quality*. Following Tatikonda and Montoya-Weiss (2001) we measured each dimension with a single item asking for the extent that the project manager at the end of the development project was satisfied with ([1] very dissatisfied – [5] very satisfied): the costs to develop the web application; the time that was required to develop the web application; and the quality of the web application. In terms of *project frequency* we asked respondents the following question: how frequently was this project confronted with technical problems? On a five-point scale the answer categories for this question ranged from (1) ‘rarely’ to (5) ‘very frequently’. Another response category was ‘never’, but none of the respondents selected this option. Table 7.2 in the previous chapter presents descriptive statistics and correlations.

To test our hypotheses we use regression analysis. To test the mediating effect using regression analysis we apply the procedure as proposed by Baron and Kenny (1986). This approach was also applied by Atuahene-Gima (2003) in his first empirical test of Sheremata’s conceptual framework. This procedure works as follows. Suppose we are interested in the following mediated relationship: $X \rightarrow M \rightarrow Y$. Here, X denotes the independent variable, M the mediating variable, and Y the ultimate dependent variable. To test whether a mediating effect exists, it is first of all necessary to assess whether there is any direct effect of X on Y if we take M out of the equation (Step 1). If no direct effect is found, than we can safely assume that there is no mediation. If we do find a direct effect of X on Y, then the next step is to investigate whether there is a direct effect of X on M (Step 2). If this is not the case, then we can assume that M does not act as a mediator.

However, if we do find that X is strongly related to M, then the possibility exists that the direct effect of X on Y is mediated by M (Step 3). This final step is executed by means of a step-wise regression analysis, i.e. include X (and possibly several control variables) in the first step of the regression analysis and subsequently add M to the model in the second step. We already know that the first step of this regression analysis will reveal a direct effect of X on Y. If we find that M is significant if we add this to the first model and if this results in a significant effect *and* in substantially reduced effect size for X, than we can assume that the effect of X on Y is at least partially mediated by M. The effect of X on Y appears to be fully mediated if its direct effect becomes insignificant after including M.

### 8.4 Results

First of all we present the results to test the mediating effect of problem-solving proficiency (Hypothesis 3). Part of this analysis is to test the direct effect of problem-solving proficiency on project outcomes. Hence, we automatically test Hypothesis 1 as well. Secondly, we present the results from regression analysis to test Hypothesis 2 about the moderating effect of problem frequency.

**Table 8.1 Results of regression analysis: project outcomes as dependent variables**

| | Product Quality | | Project Cost Efficiency | | Project Speed | |
|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| Team size | -0,03 | -0,03 | -0.26** | -0.21** | -0,15 | -0,11 |
| Application novelty | -0,05 | 0,04 | 0,09 | 0.18* | -0,13 | -0,07 |
| Extent tof systemic problems | 0,02 | 0,07 | -0,15 | -0.14* | -0,08 | -0,06 |
| Decentralization | -0,04 | -0,15 | 0.31** | 0.24** | 0,18 | 0,13 |
| Reach | 0,12 | 0,12 | 0,06 | 0,10 | 0,06 | 0,08 |
| Free flow of information | 0.25* | 0,09 | 0.24* | 0.21* | 0.23* | 0,14 |
| Connectedness | -0,13 | -0,01 | -0,08 | 0,00 | -0,17 | -0,10 |
| Project manager influence | 0,04 | 0,07 | -0,03 | 0,05 | -0,03 | 0,01 |
| Solution Quality | | 0,13 | | -0.17* | | -0,05 |
| Problem-solving efficiency | | 0.35** | | 0.53*** | | 0.27* |
| Problem-solving speed | | 0,02 | | -0,13 | | 0,06 |
| Incremental R^2 | | 0,11 | | 0,19 | | 0,07 |
| Partial F | | 3.52** | | 11,19*** | | 2.62* |
| R^2 | 0,08 | 0,18 | 0,37 | 0,57 | 0,18 | 0,25 |
| Adjusted R^2 | -0,01 | 0,07 | 0,31 | 0,51 | 0,10 | 0,15 |
| F | 0,84 | 1,63 | 6,10*** | 9,43*** | 2,25* | 2.45* |
| n | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

***The mediating effect of problem-solving proficiency***

Table 8.1 presents the results from regression analyses with project outcomes as the dependent variables. Model 1 contains as most important explanatory variables the project's differentiation and integration mechanisms. Only those direct effects on project outcomes can possibly be mediated by problem-solving proficiency. Regarding these direct effects we find only few strong direct effects. Just as for problem-solving proficiency in the previous chapter, we find that free flow of information has a strong overall effect on project performance. Hence, easy and rich communication between team members has a positive effect on product quality, project cost efficiency, and project speed. The only additional substantial effect involves the positive relationship between decentralization and project cost efficiency. In sum, we find only few potentially mediated effects.

Table 8.2 (which is similar to Models 1 in Table 7.3 of Chapter 7) presents the results from regression analyses with problem-solving proficiency as the dependent variables. Next to several control variables these models contain as explanatory variables the project's differentiation and integration mechanisms. Mediation can only exist for those mechanisms that significantly predict one or more dimensions of project outcomes as well as one or more dimensions of problem-solving proficiency. As we found earlier, free flow of information has strong overall effect on problem-solving proficiency. Hence, the direct effects of free flow of information on project performance can possibly be mediated by the three dimensions of problem-solving proficiency.

**Table 8.2 Results of regression analysis: problem-solving as dependent variables**

| | **Solution Quality** | **Problem-solving Efficiency** | **Problem-solving Speed** |
|---|---|---|---|
| Team size | 0.23* | -0,06 | -0,14 |
| Application novelty | -0,09 | -0,22 | -0,06 |
| Extent of systemic problems | -0.19* | -0,09 | -0,06 |
| Decentralization | 0.24** | 0.21* | -0,02 |
| Reach | 0,11 | -0,06 | -0,08 |
| Free flow of information | 0.37*** | 0.30** | 0.45*** |
| Connectedness | -0.21* | -0.26* | -0,16 |
| Project management influence | 0,09 | -0,12 | -0,04 |
| R^2 | 0,31 | 0,24 | 0,22 |
| Adjusted R^2 | 0,25 | 0,17 | 0,14 |
| F | 4.75*** | 3.32** | 2.87** |
| n | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

We also find that decentralization is positive related to solution quality and problem-solving efficiency. Hence, the effect of decentralization on project cost efficiency is possibly mediated by solution quality and/or problem-solving efficiency. The other direct effects resulting from Table 8.2, i.e. the strong negative effects of connectedness do not involve effects that are potentially mediated, because connectedness is not directly related to project outcomes (see Table 8.1).

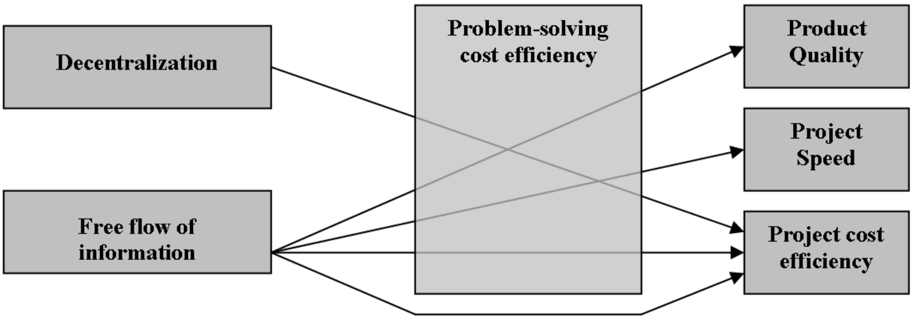
Now let us return to Table 8.1. To investigate whether any mediating effect exists, we should investigate the transition from Model 1 to Model 2 for each dimension of project performance. This transition involves the inclusion of the problem-solving proficiency indicators. In order for any mediating effect to exist we first of all need to assess whether problem-solving proficiency has a direct effect on project performance. We find that Problem-solving efficiency is strongly related (positively) to each of the three project outcomes. This means that the effects of free flow of information on all three project outcomes are possibly mediated by problem-solving efficiency, because free flow of information is directly related to both the project outcomes and problem-solving efficiency. In addition, the direct effect of decentralization on project cost efficiency is also potentially mediated by problem-solving efficiency. We also find that solution quality directly related (negatively) to project cost efficiency. Solution quality therefore also possibly mediates the effect of decentralization and free flow of information on project cost efficiency.

Finally, to find whether any mediating effect exists, we need to investigate how the direct effect of the potentially mediated mechanisms changes with the change from Model 1 to Model 2. The effects of free flow of information on product quality and on project speed become insignificant as a result from this change. This indicates that these effects are fully mediated by problem-solving efficiency. The effects of free flow of information and decentralization on project cost efficiency are somewhat reduced in absolute terms, but both remain statistically significant. This indicates that both effects are partially mediated. In this case it is unclear however which variable acts as the mediator, since it can be either problem-solving efficiency or solution quality or both. To investigate this mediating effect in greater detail we performed two additional regression analyses: one without problem-solving efficiency and the other without solution quality.

In the analysis without problem-solving efficiency we find that solution quality remains significant and that decentralization and free flow of information remain significant with roughly the same effect size as reported in Table 8.1. This suggests that solution quality does not act as a mediator. In the analysis without solution quality we find that problem-solving efficiency remains significant. We also find that the effect sizes for decentralization and free flow of information are substantially reduced. For decentralization Beta changed from 0.31 ($p<0.01$) in Model 1 to 0.20 ($p<0.05$) in Model 2. For free flow of information Beta changed from 0.24 ($p<005$) in Model 1 to 0.14 (n.s.) in Model 2.

This suggests that problem-solving efficiency acts a mediator variable for these two variables. Translated back to our original findings in Table 8.1, this indicates that problem-solving efficiency can be regarded as the factor that partially mediates the effect of decentralization and free flow of information on project cost efficiency. Graphically our results can be depicted as in Figure 8.2. The partially mediated effect of free flow of information on project cost efficiency provides support for Hypothesis 3, but the other four mediating effects suggest that problem-solving cost efficiency is a strong full mediator.

**Figure 8.2 Problem-solving cost efficiency as a mediator**




All effects are positive.

***The moderating effect of problem frequency***

Above we have already seen that problem-solving efficiency is a strong and significant predictor of project performance. This supports Hypothesis 1. However, we also found that solution quality has a negative effect on project cost efficiency (see Table 8.1). This disconfirms Hypothesis 1. In this section we consider the relationship between problem-solving proficiency and project performance in some greater detail. Table 8.3 present the results from regression analysis with the three project performance dimensions as dependent variables. Besides several control variables the first regression model (Model 1) also includes problem frequency and the three dimensions of problem-solving proficiency.

**Table 8.3 Results of regression analysis: problem frequency as a moderator**

| | Product Quality | | Project Cost Efficiency | | Project Speed | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Team size | -0,03 | -0,04 | -26** | -0.25** | -0,15 | -0,15 |
| Application novelty | 0,04 | 0,01 | 0.26** | 0.25** | 0,01 | -0,01 |
| Solution Quality | 0,14 | 0,15 | 0,02 | 0,03 | 0,06 | 0,04 |
| Problem-solving efficiency | 0.31** | 0.30* | 0.55*** | 0.48*** | 0.28* | 0.28* |
| Problem-solving speed | 0,09 | 0,08 | -0,15 | -0,09 | -0,01 | 0,01 |
| Problem frequency | 0,07 | 0,18 | -0,17 | -0,09 | -0,20 | -0,01 |
| Solution quality * Problem freq | | 0,02 | | -0,01 | | -0,17 |
| Problem-solving efficiency * Problem freq | | -0,18 | | 0,10 | | -0,14 |
| Problem-solving speed * Problem freq | | -0,06 | | -0.24* | | -0,04 |
| Incremental R^2 | | 0,04 | | 0,03 | | 0,05 |
| Partial F | | 1,22 | | 1,64 | | 1,78 |
| R^2 | 0,14 | 0,18 | 0,46 | 4,94 | 0,24 | 0,28 |
| Adjusted R^2 | 0,08 | 0,09 | 0,43 | 0,44 | 0,18 | 0,21 |
| F | 2.30* | 1.95* | 12.25*** | 8.90*** | 4.41*** | 3.62*** |
| n | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

In all three models we find that problem-solving cost efficiency has a strong positive association with project cost efficiency, project speed, and product quality. This is also what we found in Table 8.1. All other factors are fairly limited compared to this direct effect. This also means that the negative effect of solution quality on project cost efficiency (Table 8.1) disappeared in this model, suggesting that this effect is unstable. A possible explanation is multicollinearity, but according to the VIF values this was of no concern. However, relationships between the independent variables might still have affected the outcomes. From the correlation matrix (Table 7.2 in the previous chapter) we learn that several of the independent variables are strongly correlated with each other and also with the dependent variables. It is therefore surprising that we find only one strong predictor of project performance, i.e. problem-solving cost efficiency. It may well be that this factor suppresses (Maassen and Bakker, 2001) the effects of the other independent variables.

To investigate this possibility, an analysis without problem-solving efficiency indicates that problem frequency reduces strongly (and statistically significantly) both project cost efficiency ($\beta$=-0.31; $p<0.01$) and project speed ($\beta$=-0.20; $p<0.05$). In the original analysis (Table 2) these effects were already substantial, but they failed to reach statistical significance. In addition, if we also eliminate problem frequency from the analysis, then it appears that problem-solving speed substantially increases the project managers' satisfaction with project cost efficiency ($\beta$=0.23; $p<0.05$) and project speed ($\beta$=0.25; $p<0.01$). As a result, we can conclude that other factors besides problem-solving cost efficiency strongly influence project performance as well (e.g. problem frequency, problem-solving speed), but that our multivariate analysis makes it difficult to disentangle these effects.

In the regression analyses (Table 8.3) we were not only interested in the main effects of problem-solving proficiency and problem frequency. In Model 2 we investigate whether moderating effects exist if we combine problem frequency with the three elements of problem-solving proficiency. The variables in this model were mean-centered. Again the VIF values indicated the absence of multicollinearity. From Table 8.3 we can see that none of the three steps substantially improves the explanation of the dependent variables. We do find one statistically significant moderating effect for the relationship between satisfaction with the cost efficiency of the project and the interaction between problem-solving speed and problem frequency. This negative interaction effect suggests that it is especially detrimental to a project manager's satisfaction with project cost efficiency if the project team attempts to solve a large number of problems in a very short amount of time. This makes sense, since this is likely to require many resources, such as an increase in the number (senior) employees that has to be allocated to the project. Overall this single interaction effect provides very limited support for Hypothesis 2.

Finally, two noteworthy direct effects are the negative effect of team size on satisfaction with project cost efficiency and the positive effect of application novelty on this same outcome variable. Apparently, larger teams are perceived to be less efficient by project managers. This seems to make sense, because larger teams require more expenses as a result of larger personnel costs, more meetings, more extensive control mechanisms and larger overhead costs. The second effect is somewhat surprising: newer applications - in terms of the novelty of the software code underlying these applications - are associated positively with the project managers' satisfaction with project cost efficiency.

One might expect that newer applications are more problem-prone, which is supported by a substantial correlation between application novelty and problem frequency ($\rho=0.24$; $p<0.05$). Consequently, the development of novel applications can be considered to result less easily in high satisfaction with project cost efficiency. An explanation for our finding of a positive effect might be that older applications have to deal with legacy systems, which are typically costly to adjust and change. Another explanation involves the way that project managers develop their expectations: maybe managers expect very novel projects to be disappointing, which increases the likelihood relative to incrementally new products that one's expectations for novel products are met or exceeded. Another explanation could be that newer applications make use of newer and easier programming protocols, which increases the development efficiency.

### 8.5 Discussion and conclusions

This study contributes to the literature about problem-solving in new product development. Our findings are important complements to existing literature. Atuahene-Gima (2003) provided the first empirical test of problem-solving proficiency as a mediator of the effect between the project's organizational structure and project performance. However, he did not include in his analysis problem-solving efficiency. We find that it is especially this variable that acts as a mediator. Furthermore, we find both partially mediated effects and fully mediated effects. We therefore find evidence in support of Sheremata's original fully mediated model as well evidence that supports Atuahene-Gima's partially mediated model. We also provided the first empirical test with project cost efficiency as the dependent variable. Just as for project speed and product quality, we found that problem-solving efficiency is a very strong predictor of project cost efficiency. We also found that this performance indicator is positively influenced by decentralization and free flow of information and that both effects are mediated by problem-solving efficiency. For decentralization this involves a fully mediated effect and for free flow of information this involves a partially mediated effect. Free flow of information therefore increases project cost efficiency directly as well as indirectly through its effect on problem-solving efficiency. The positive effects of free flow of information on product quality and project speed are also mediated by problem-solving efficiency. These two effects are fully mediated.

Finally, we contribute to the literature by considering the frequency with which projects are confronted with problems. Problem frequency hardly appears to moderate the relationship between problem-solving proficiency and project performance. We did find however that problem frequency substantially reduces the effect of problem-solving speed on project cost efficiency. This suggests that project cost efficiency tends to be especially disappointing if project teams solve a large number of problems in a short amount of time. This might be because of the resources that are required to solve problems, such as man hours and additional equipment.

***Limitations and future research***

An important finding of this study is that problem-solving cost efficiency acts as a strong mediator. This is partly due to the strong effect of problem-solving cost efficiency on all three dimensions of project performance (product quality, project speed, and project cost efficiency). We have to nuance this finding however, because other factors also explain project performance, including problem frequency (negatively) and problem-solving speed (positively). Suppressor effects preclude the accurate detection of these effects however (Maassen and Bakker, 2001). This effect might have also influenced our findings regarding the mediating effects of problem-solving proficiency and of the moderating role of problem frequency. This has to be investigated in future research. An important opportunity for future research is to integrate the mediating effect (this chapter) and moderating effects (this chapter and the previous chapter) in a single integrative framework. Recent analytical advances offer opportunities to do so using moderated path analysis (Edwards and Lambert, 2007).

Consistent with the apparent interrelatedness of problem-solving proficiency dimensions, Sheremata (2000) argues that the interaction of these dimensions influences the project's goal attainment. In other words, it is especially if problems are solved fast, cost-efficiently, and with high-quality solutions that projects succeed. Without either slow problem-solving, expensive problem-solving, or ineffective solutions project might fail altogether (Sheremata, 2000). As a result, future research could adopt a configurational approach to the study of problem-solving in new product development (see Chapter 2).

Suppressor effects might also explain the different findings between our study and the empirical study of Atuahene-Gima (2003). The relationships between the independent variables might have blown up the effect sizes of problem-solving cost efficiency, thus artificially reducing the effect size of other explanatory variables. Atuahene-Gima did not include this variable in his analysis however, and therefore comes to different conclusions. For instance, he found only partially mediated effects, whereas we find mostly full mediation through problem-solving cost efficiency. Other explanations for the divergent findings are the differences between project teams in the Netherlands (our study) and teams in Hong Kong (Atuahene-Gima). The latter are for instance well-known for their use of consensus decision making, which might be less prevalent in the Netherlands. On the other hand, both studies are roughly similar in terms of their industrial settings, i.e. both investigated project teams in ICT-related industries. Our projects involve only software development projects however, whereas Atuahene-Gima studied both software projects (46 percent) and hardware projects (54 percent).

Furthermore, we used measures that are in large part based on the study performed by Atuahene-Gima. Unlike Atuahene-Gima we did not use multiple respondents, which possibly caused common method bias in our study. We did not find higher correlations between our variables however, which suggests that this is of limited concern. Furthermore, we might speculate that our respondents are unlikely to know the mediation and moderation models of our interest. Hence, it is unlikely that they have consistently influenced their ratings in such a way as to substantially influence our results (Podsakoff et al., 2003). In addition, any differences between the two studies are unlikely to be attributes to differences in statistical power. The datasets in both studies are almost of the same size.

One possible explanation of different effects involves omitted variable bias (Shaver, 2005). In the previous study we have for instance seen that the extent of systemic versus autonomous problems influences relationships in our model. This might have differed across the two studies.

As another limitation, our measures are self-scored perceptual measures. For project performance it should for instance be kept in mind that its indicators reflect the project manager's self-scored *satisfaction* with the various project performance dimensions. In addition, we measured each dimension with a single item. From the perspective of classical test theory this might be dangerous as the use of multiple items might cancel out error (Nunnally, 1978). However, a manager's satisfaction with for instance project cost and project speed can be considered to be fairly concrete, which makes it appropriate to assess these concepts with single items (Rossiter, 2002). In this way we follow Tatikonda and Montoya-Weiss (2001).

***Managerial implications***

We conclude with the most important managerial implication from our study. Keeping in mind the limitations of this study, we find that teams report an overall better performance if they are able to solve problems cost-efficiently. For managers it is important to note that our study indicates that the structure and processes within the team strongly influence problem-solving cost efficiency. For instance, project team members with greater freedom over their activities and decisions are more likely to solve problems cost-efficiently and they are therefore more likely to contribute in high project performance. Similarly, unrestricted and rich communication and information exchange between team members improves the cost-efficiency with which problems are solved and therefore contribute to project performance.

# 9. Multiple Levels in the Organization of Innovation: Ownership Integration and Project Organization

**Abstract**

Studies about how the organization of NPD projects influences project performance typically investigate this in single-firm projects, i.e. projects with high ownership integration. However, NPD projects are often performed by two or more partnering firms (low ownership integration). In this chapter we investigate whether the project-level differentiation and integration mechanisms as discussed in the previous two chapters have different performance effects in single-firm projects than in multi-firm projects. We expect that integration mechanisms are especially helpful in multi-firm projects to integrate and align members and factions from the different firms. Conversely, we expect that differentiation mechanisms are especially useful to single-firm projects, which lack the differentiation potential of multi-firm projects. Using the same data as the previous two chapters, the interaction of ownership integration and project-level organizational mechanisms especially appears to explain a project's problem-solving proficiency. In line with our expectations, project-level integration mechanisms contribute more strongly to the speed of problem solving in alliance projects than in single-firm projects.

## 9.1 Introduction

The management and organization of innovation is a complex and a multi-level phenomenon (Gerwin and Ferris, 2004; Gupta et al., 2007; Tiwana, 2008). Chapter 5 for instance investigated the extent that a systems integrator integrates component development projects as judged by four dimensions of integration. There we already pointed out that such project-level studies are few in number relative to the number of studies that investigate issues of integration at the level of the firm, such as the breadth and the depth of a firm's knowledge base (knowledge integration) and the extent that a firm buys, makes, or allies for its new components and technologies (ownership integration). In this chapter we aim to increase our understanding of the performance of NPD projects by explicitly studying the complementarities between a project's firm-level organizational form and its project-level organizational form.

In Chapter 7 and Chapter 8 we have seen how project performance and the project team's problem-solving proficiency are influenced by the way the NPD process is organized, structured, and executed. To be more precise, these organizational elements of NPD projects involved differentiation and integration mechanisms such as free flow of information, project manager influence, and decentralization. Earlier in this thesis (Chapter 4, Chapter 5, Chapter 6) we considered other organizational characteristics of the way NPD projects are organized, such as ownership integration and task integration. These organizational elements operate at a different level of analysis than the differentiation and integration mechanisms. Ownership integration and task integration determine the organizational set-up of a project at the firm-level. These factors for instance determine how many firms are involved in the project, how investments are divided, and how tasks are allocated to the partnering firms and suppliers. Within a particular firm-level setup (e.g. a single innovator with multiple suppliers or a fifty-fifty alliance project with no supplier involvement) the NPD process is subsequently executed in a way that is managed and structured based on the project-level differentiation and integration mechanisms.

In this chapter we investigate the interplay of a project's firm-level organizational characteristics and its project-level organizational form. In other words, this chapter centers on the research question whether, and if so how and to what extent, a project's firm-level organizational form interacts with project-level organizational characteristics in its effect on the team's problem-solving proficiency as well as on project performance. Such multi-level innovation research is scarce and important opportunities therefore exist to generate a more comprehensive understanding of the management of innovation (Gerwin and Ferris, 2004; Gupta et al., 2007; Tiwana, 2008).

In terms of the firm-level organizational variable this chapter focuses on the degree of ownership integration. Ownership integration was also discussed as one of the four dimensions of integration in Chapter 5. Chapter 5 and this chapter use different definitions however. Ownership integration as used in Chapter 5 takes the perspective of a systems integrator as it refers to the extent that this firm invests in a new product (component) development project. In this chapter we consider a project's degree of ownership integration without adopting the perspective of any particular firm. Here we define ownership integration as the number of firms that invests in a project. In general, ownership integration increases if fewer firms invest in a new product development project, i.e. ownership integration is high for single-firm projects, and it is considered to be low for multi-firm/alliance projects. Below we first of all formulate hypotheses. After that we present the methodology that will be used to test these hypotheses, which is followed by our results. We end this chapter with a discussion and conclusions.

**9.2 Theory**

As already outlined in Chapter 1, innovation is a phenomenon that is influenced by factors that operate at many levels of analysis, such as the level of individuals, the level of groups or teams, the level of organizations, and the level of industries (Gopalakrishnan and Damanpour, 1997; Gupta et al., 2007). Most innovation studies focus on only one level of analysis, whereas multi-level theory has the potential to explain a phenomenon more precisely by generating a better understanding of the ways in which different levels of analysis are related (Klein et al., 1994; Gupta et al., 2007). Recently some innovation studies have explicitly taken into account multiple levels of analysis, but mostly these studies aim to explain firm-level performance, i.e. in terms of patenting, rather than project performance (Rothaermel and Hess, 2007; Somaya et al., 2007).

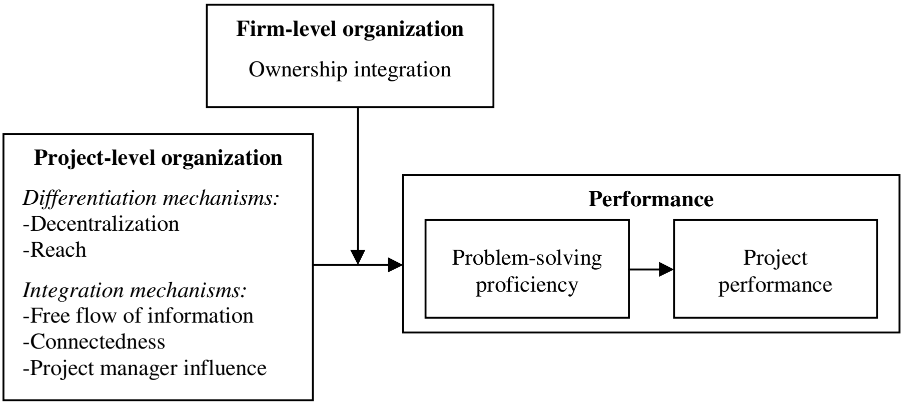
The literature about new product development success factors (Brown and Eisenhardt, 1995) has mostly proceeded without taking into account multiple levels of analysis. For instance, this literature typically considers projects that are financed and executed by individual firms on their own. As a result, most of the literature about success factors related to issues of project management falls into this category. Shenhar and Dvir (1996) recognized that research is needed that explicitly consider the role of organizational boundaries.

Gerwin and Ferris (2004) met this call as they investigated theoretically the costs and benefits of alternative ways to organize NPD projects in strategic alliances (as opposed to projects in single firms). For instance, one or both of the partners in an alliance project might actually perform project tasks, i.e. 'single participation projects' or 'dual participation projects'. If both firms choose to perform part of the workload, then several project-level organizational decisions have to be made about whether and how to perform tasks separately or in an integrated approach with collaborating team members from both firms, i.e. 'dual separate' or 'dual integrated'. In addition, for dual integrated alliance projects, project management can be organized in different ways, such as by means of a single project manager or by means of a team that takes decisions based on consensus.

In a recent empirical study, Tiwana (2008) aimed to explain the performance of alliance projects by means of 'bridging ties' and 'strong ties'. Alliances involve a bridging mechanism to bring together the expertise and capabilities of different firms (i.e. structural holes). In order to fully realize the potential that is created by this differentiation at the level of the firm, projects need to be structured in such a way that they are able to effectively integrate and combine the capabilities from the different firms, i.e. strong ties.

In other words, Tiwana (2008) argues and also finds empirical support that differentiation brought about by alliances of diverse partners (bridging ties) complements integration mechanisms at the project level (strong ties) in the explanation of alliance project performance. This shows that multiple levels of analysis interact in their effect on the outcome, i.e. cross-level moderators (Klein et al., 1994; Gupta et al., 2007).

**Figure 9.1 Conceptual framework**




Like Tiwana we are also interested in the cross-level moderating effects of the project-level and the firm-level on project performance. Whereas Tiwana - at the firm-level - considers variation in terms of the type of alliances (i.e. the extent that partners have different capabilities, or bridging ties), we consider a different type of firm-level variation. We namely take into account that projects can be performed in alliances or not, i.e. alliance projects or single-firm projects. At the project-level our study also differs from and complements Tiwana's study. Whereas Tiwana focuses on the extent that the project's organizational structure provides integration mechanisms (the strength of ties), we not only focus on integration mechanisms, but also on project-level differentiation mechanisms (i.e. reach and decentralization, see Chapter 7 and Chapter 8). Figure 9.1 represents the theoretical relationships we are interested in. Next we formulate hypotheses.

***Hypotheses***

The extent of ownership integration, i.e. the decision to finance a project alone or to ally with one or more external parties, is an important decision for innovating firms. Partnering of course reduces the required financial resources and allows risks to be shared. At the same time, partnering could mean that different capabilities are allocated to the project, which is likely to increase the chance of success (Tiwana, 2008). As potential drawbacks, partnering is likely to result in reduced project control and decision-making power and in the risk that a partner acts opportunistically (Gulati et al., 2005). Next to these behavioral and appropriation uncertainties, information-exchange and coordination between partners might be problematic as a result of structural and cultural barriers (Li and Hambrick, 2005). Furthermore, partners might develop honest differences of opinion and conflicts (Gulati et al., 2005).

Hence, at the level of the firm, the fact that multiple firms are brought together in an alliance means that opportunities are generated for novel ideas and creativity. In terms of the project problem-solving, multi-firm projects might for instance be comparatively faster, more efficient, and more effective if the partners possess complementary information and capabilities. At the same time, the fact that multiple routines, interests, and frames of reference are involved complicates the realization and exploitation of this potential (Tiwana, 2008). Hence, at the project-level, integration mechanisms are needed to facilitate communication, collaboration, and decision-making across the fault line that might exist between team members from different firms (Li and Hambrick, 2005).

In the previous section and also in the previous two chapters we have distinguished between project-level differentiation and integration mechanisms. In Chapter 7 we considered decentralization and reach as differentiation mechanisms to provide the project team with a greater quantity and quality of specialized expertise (Sheremata, 2000). In contrast, free flow of information, connectedness, and project management influence help the project team to integrate knowledge and to align activities (Sheremata, 2000). Hence, these mechanisms provide the team with an integrative capability.

Also firm-level organizational decisions influence a project's integration and differentiation capabilities. Brusoni et al. (2001) for instance define different firm-level organizational forms (i.e. make, buy, and systems integration) as different combinations of differentiation and integration (see also Chapter 1 and Chapter 3). In principle, single-firm projects ('make') can be characterized as scoring high on integration and low on differentiation (e.g. Brusoni et al., 2001). The single investing firm has formal authority over the project and is able to exert extensive control if needed. At the same time, the differentiation benefits of this organizational form are limited, because there are no partnering firms that bring incentives and unique capabilities to the project. In contrast, multi-firm projects typically indicate that decision-making and project control is executed by multiple firms. In principle, such projects are therefore less integrated than single-firm projects. At the same time, multi-firm projects have a larger potential to benefit from differentiation because of the involvement of multiple distinct and committed parties.

Based on the same logic as in Tiwana (2008) we argue that project-level integration mechanisms are especially beneficial in multi-firm projects to help realize their differentiation potential. These mechanisms can for instance help to achieve unity of effort among the multiple investing firms. In a similar vein, differentiation mechanisms might be less effective in multi-firm projects than in single-firm projects. For single-firm projects it will be comparatively easy to align incentives and to coordinate effectively, because people will know each other and because they are likely to have the same routines and goals. At the same time, differentiation mechanisms, when compared to their potential in multi-firm projects, can be expected to be particularly useful in single-firm projects. Since these projects lack the diversity that often characterizes alliances, differentiation mechanisms might compensate for this by exploiting as much as possible the incentives, specialization, and diversity from within the firm. We expect that these moderating effects hold for project performance as well as for problem-solving proficiency. Hence, we can formulate the following general hypotheses:

Hypothesis 1a. *Project-level differentiation mechanisms* (decentralization and reach) *contribute more to project performance* (project speed, project cost-efficiency, and product quality) *in single-firm projects (high ownership integration) than in multi-firm projects (low ownership integration).*

Hypothesis 1b. *Project-level integration mechanisms* (free flow of information, connectedness, and project management influence) *contribute less to project performance* (project speed, project cost-efficiency, and product quality) *in single-firm projects (high ownership integration) than in multi-firm projects (low ownership integration).*

Hypothesis 2a. *Project-level differentiation mechanisms* (decentralization and reach) *contribute more to problem-solving proficiency* (problem-solving speed, problem-solving cost-efficiency, and solution quality) *in single-firm projects (high ownership integration) than in multi-firm projects (low ownership integration).*

Hypothesis 2b. *Project-level integration mechanisms* (free flow of information, connectedness, and project management influence) *contribute less to problem-solving proficiency* (problem-solving speed, problem-solving cost-efficiency, and solution quality) *in single-firm projects (high ownership integration) than in multi-firm projects (low ownership integration).*

## 9.3 Method

We tested the above hypotheses based on the same dataset as the one described in Chapter 7. In sum, this dataset contains data on 92 Dutch web application development projects. This dataset was obtained by means of an on-line questionnaire with the project manager as the single respondent. If multiple firms were involved in the project, our respondent was typically the project manager from the leading firm in the project. For more details about this dataset and about how we collected the data we refer the interested reader to Chapter 7. Here we delimit ourselves to the notable differences with Chapter 7. This chapter for instance includes the ownership integration variable.

*Ownership integration* is operationalized in two different ways. First of all, we use a dummy variable. A value of 1 indicates development projects that were financed by a single firm. This reflects a high (maximum) value of ownership integration. A value of 0 indicates a low degree of ownership integration. This reflects that two or more firms financed the total expenses to complete the development project, i.e. multi-firm or alliance projects. Secondly, we consider ownership integration in terms of the absolute number of investing firms. Table 9.1 provides an overview of the frequency of the number of investing firms. It appears that 43 projects were financed by a single firm and 49 projects were financed by two or more firms. Most of the alliances involved two or three investing partners (seventeen projects and sixteen projects respectively). Eight projects were financed by four firms and the remaining eight projects had five or more investing firms. Ownership integration is high if a single firm invests in the project, and ownership integration by any single firm generally decreases as the number of investing firms increases. Note that this treatment of ownership integration in terms of the number of investing firms includes no data about the actual division of investments between the investing firms.

**Table 9.1 Frequency of the number of investing firms**

| | Frequency (no. of projects) |
|---|---|
| 1 investing firm | 43 |
| 2 investing firms | 17 |
| 3 investing firms | 16 |
| 4 investing firms | 8 |
| 5 investing firms or more | 8 |
| *Total* | *92* |

For all other measures, such as those for the differentiation and the integration mechanisms, we refer to Chapter 7. In this regard it is important to stress that we asked respondents to complete these questions for all the project members working on the project from all the firms involved. Although the project manager might for instance not know the details of the way that a partner organizes its separate workload, we expect that this actor is the most knowledge single respondent regarding these matters. Table 7.2 in Chapter 7 presents a correlation matrix together with descriptive statistics. This table not only includes the ownership integration dummy, but also (and both of them reverse-scored) the absolute number of investing firms and the absolute number of investing firms for all multi-firm projects.

To test our hypotheses we use hierarchical regression analysis. Multicollinearity was of no concern in these analyses. We used mean-centered variables (except for the ownership integration dummy) and the VIF values were below 2.5 for most factors. The maximum VIF value was still very limited with a value of 3.6. This also suggests that there is no particular direct effect of ownership integration on the way projects are organized. This is also the picture that emerges if we investigate the correlation coefficients in Table 7.2 between the five organizational project characteristics and the absolute number of investing firms (both in the dataset as a whole and in the multi-firm subset, i.e. variables 15 and 16 in Table 7.2).

Neither do we find much differences if we compare the average values of the differentiation and integration mechanisms across the two sub groups of the ownership integration dummy (i.e. single-firm projects and alliance/multi-firm projects). The results from a one-sided t-test indicate that in our dataset only one factor substantially differs across the two groups. Reach is on average higher for alliance projects than for single-firm projects. This mean difference is 0.38 on a five-point scale ($p<0.05$). The other four project-level organizational factors do not differ significantly for the two types of ownership integration (see Table 9.2).

**Table 9.2 Means in the two sub groups of high and low ownership integration**

| | Ownership integration | Mean (on a 1-5 scale) |
|---|---|---|
| **Decentralization** | High (one investing firm) | 3,29 |
| | Low (two or more investing firms) | 3,32 |
| **Reach*** | High (one investing firm) | 3,44 |
| | Low (two or more investing firms) | 3,82 |
| **Free flow of information** | High (one investing firm) | 3,62 |
| | Low (two or more investing firms) | 3,52 |
| **Connectedness** | High (one investing firm) | 3,42 |
| | Low (two or more investing firms) | 3,36 |
| **Project management influence** | High (one investing firm) | 3,68 |
| | Low (two or more investing firms) | 3,40 |

* Statistically significant one-sided t-test ($p<0.05$).

## 9.4 Results

***Do the moderating effects contribute to the explanation of project performance?***
Table 9.3 presents the results from regression analyses for project speed, product quality, and project cost efficiency. In each of these three analyses, Model 1 includes two control variables, the five project-level characteristics and the ownership integration dummy. In absolute sense the largest standardized regression coefficient for the ownership integration dummy in these six models is -0.12. This suggests that projects with high ownership integration (one investing firm) are in general somewhat less successful than projects with low ownership integration (two or more investing firms). This is however a small effect size (and statistically not significant). Furthermore, the effect of the ownership integration dummy as reported in Table 9.3 (Model 1) remains limited if we run these same regression models without the five project-level organizational factors. The largest regression coefficient in these models is still -0.12 (this result also holds for the regression analyses reported in Table 9.4, which we discuss below). The absence of a strong direct effect in these limited regression models allows us to rule out the possibility that ownership integration does have an effect on one or more of the performance indicators, but that this effect is (at least partially) mediated by one or more of the project-level organizational factors (Baron and Kenny, 1986; see also Chapter 8).

In Table 9.3 the shift from Model 1 to Model 2 involves the inclusion of the five moderating effects. We find that this step adds very little to the explanation of the three dimensions of project performance. We find just one significant moderating effect: reach appears to contribute comparatively less to project speed in single-firm projects than in alliance projects ($\beta$=-0.31). This is the opposite of what we would expect based on Hypothesis 1a. Also noteworthy is the joint effect of connectedness and ownership integration on product quality ($\beta$=-0.32; n.s.). This substantial effect suggests that connectedness (a project-level integration mechanism) complements multi-firm projects by contributing to (greater satisfaction with) product quality. This is in line with our hypothesis.

**Table 9.3 Results of regression analyses – project performance**

| | Product Quality | | Project Cost Efficiency | | Project Speed | |
|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1** | **Model 2** | **Model 1** | **Model 2** |
| Team size | -0,02 | -0,03 | -0.30** | -0.27** | -0,17 | -0,10 |
| Application novelty | -0,05 | -0,04 | 0,08 | 0,06 | -0,13 | -0.19* |
| Decentralization | -0,04 | -0,04 | 0.28** | 0.32* | 0,16 | 0.33* |
| Reach | 0,13 | 0,16 | 0,01 | -0,05 | 0,02 | -0,15 |
| Free flow of information | 0.25* | 0.33* | 0.28** | 0.32* | 0.25* | 0.27* |
| Connectedness | -0,12 | -0.29* | -0,08 | -0,12 | -0,17 | -0,17 |
| Project manager influence | 0,03 | -0,11 | 0,04 | -0,07 | -0,04 | 0,01 |
| Ownership integration (OI) | 0,03 | 0,13 | -0,12 | -0,01 | -0,09 | 0,03 |
| Decentralization * OI | | 0,03 | | 0,02 | | 0,20 |
| Reach * OI | | 0,01 | | -0,14 | | -0.31* |
| Free flow of information * OI | | 0,21 | | 0,08 | | 0,03 |
| Connectedness * OI | | -0,32 | | -0,06 | | -0,04 |
| Project manager influence * OI | | -0,18 | | -0,12 | | -0,02 |
| Incremental R^2 | | 0,04 | | 0,02 | | 0,05 |
| Partial F | | 0,72 | | 0,36 | | 1,03 |
| R^2 | 0,08 | 0,12 | 0,36 | 0,37 | 0,17 | 0,23 |
| Adjusted R^2 | -0,02 | -0,04 | 0,29 | 0,26 | 0,09 | 0,09 |
| F | 0,82 | 0,77 | 5.58*** | 3.43*** | 2.08* | 1.68* |
| n | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

In additional analyses we used the absolute number of investing firms (reverse-scored and as a standardized variable) as the moderator instead of the dummy variable. Also in these analyses we found no significant steps from Model 1 to Model 2. Similar to the results with the ownership integration dummy (Table 9.3) we found a strong moderating effect involving reach in its effect on project speed ($\beta$=-0.27; p<0.05; one-sided test). Additionally, we found in this model that ownership integration positively moderates the relationship between decentralization and project speed if ownership integration increases ($\beta$=0.25; p<0.05; one-sided test). This positive moderating effect is in line with what we would expect based on Hypothesis 1a. Just as for Model 1 in Table 9.3 we found no particular direct effect of ownership integration on project performance.

Finally, we also performed the regression analyses in the subset of multi-firm projects with the absolute number of investing firms (i.e. two or more) as a proxy for ownership integration. This was to investigate whether it matters whether one allies with one or more partners. In this small dataset (N=49; see Table 9.1) we found no strong predictors of any of the three project performance indicators. Overall, we find little support for the claim that ownership integration and project-level differentiation and integration mechanisms interact in their effect on project performance. The steps have little explanatory power and the moderating effect involving reach disconfirms our hypothesis. The findings involving connectedness and decentralization do provide some support for our hypothesis however.

***Do the moderating effects contribute to problem-solving proficiency?***
Unlike the results for project performance, the inclusion of the moderating effects results in a substantially improved explanation of problem-solving proficiency (see Table 9.4). For all three dimensions of problem-solving proficiency the step from Model 1 to Model 2 explains about ten percent additional variation (and is statistically significant; p<0.05). We find strong (negative) regression coefficients for the interaction effects involving the three integration mechanisms (free flow of information, connectedness, and project management influence). This is in line with what we would expect based on Hypothesis 2b. Particularly connectedness and project management influence appear to be negatively moderated by the ownership integration dummy in their effect on problem-solving speed (p<0.05).

**Table 9.4 Results of regression analyses – problem-solving proficiency**

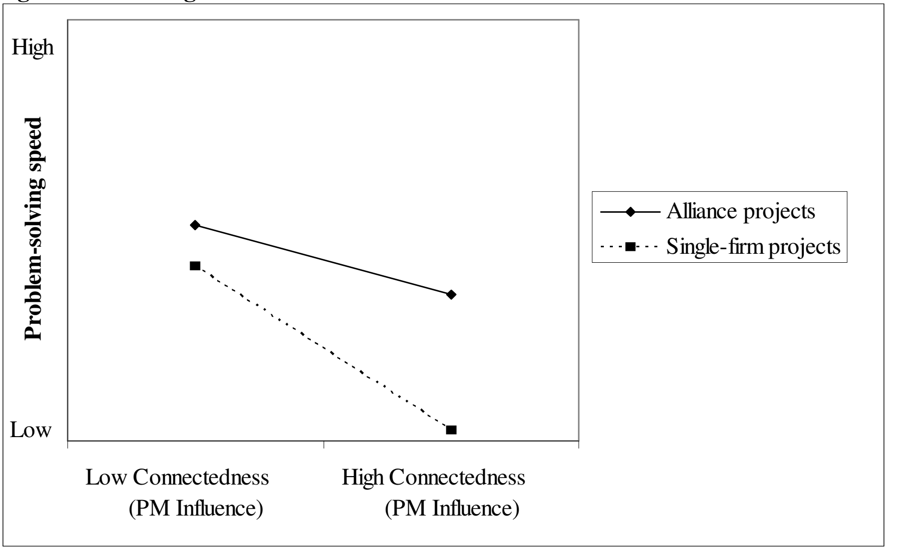
| | Solution Quality | | Problem-solving Efficiency | | Problem-solving Speed | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Team size | 0.21* | 0,17 | -0,09 | -0,06 | -0,17 | -0.20* |
| Application novelty | -0,13 | -0,07 | -0.23* | -0.25** | -0,07 | -0,03 |
| Decentralization | 0.21* | 0,10 | 0,18 | 0,21 | -0,05 | -0,07 |
| Reach | 0,10 | 0.24* | -0,09 | -0,15 | -0,09 | 0,04 |
| Free flow of information | 0.42*** | 0.28* | 0.33** | 0.25* | 0.46*** | 0.39** |
| Connectedness | -0.23* | -0.43** | -0.25* | -0.42** | -0,13 | -0.36** |
| Project management influence | 0,11 | -0,10 | -0,11 | -0.30* | -0,04 | -0.32* |
| Ownership integration (OI) | -0,02 | 0,18 | -0,08 | 0.26* | -0,02 | 0,20 |
| Decentralization * OI | | -0,07 | | 0,02 | | 0,04 |
| Reach * OI | | 0,18 | | -0,21 | | 0,14 |
| Free flow of information * OI | | -0,21 | | -0,10 | | -0,06 |
| Connectedness * OI | | -0,24 | | -0,22 | | -0.36* |
| Project management influence * OI | | -0,21 | | -0,27 | | -0.31* |
| Incremental R^2 | | 0,09 | | 0,09 | | 0,10 |
| Partial F | | 1.97* | | 2.00* | | 2.09* |
| R^2 | 0,28 | 0,37 | 0,24 | 0,33 | 0,22 | 0,31 |
| Adjusted R^2 | 0,21 | 0,26 | 0,16 | 0,21 | 0,13 | 0,19 |
| F | 3.76*** | 3.22*** | 3.09** | 2.79** | 2.66** | 2.56** |
| n | 92 | 92 | 92 | 92 | 92 | 92 |

* p<0.05; ** p<0.01; *** p<0.001; standardized coefficients are reported for a 1-sided test.

We should note however that the results in Table 9.4 also indicate that the inclusion of the moderating effects substantially reduces the main effects of the integration mechanisms. For illustrative purposes we plotted the overall effects of connectedness and project management influence on problem-solving speed in Figure 9.2. For both factors the effects are almost identical. That is why we report only one figure. In general low values of these integration mechanisms seem to work best for both single-firm projects and alliance projects. If these mechanisms are extensively applied however, then it appears that they work much better (in terms of problem-solving speed) in alliance projects than in single-firm projects.

Another result from the inclusion of the moderating effects in Model 2 is the increase in the regression coefficient for the ownership integration dummy for each dependent variable. This indicates that problems on average are solved more proficiently in single-firm projects than in multi-firm projects. This especially holds for problem-solving efficiency ($\beta=0.26$; $p<0.05$). However, if judged by Figure 9.2 (which also incorporates the main effect of the ownership integration dummy), then alliance projects on average tend to perform better than single-firm projects. This supports the view that it is better to interpret the results from Model 1 regarding the direct effects of the interacting variables (Carte and Russell, 2003). Hence, ownership integration does not have a direct effect on problem-solving proficiency.

**Figure 9.2 Contingent effects of connectedness and PM influence**




Also for problem-solving proficiency we performed additional analyses with ownership integration as measured by the absolute number of investing firms. In neither of these analyses the step from Model 1 to Model 2 was significant. This indicates that especially the distinction between single-firm projects or multi-firm projects (as captured by our dummy variable) matters. We also performed the additional analyses with the absolute number of investing firms in the small subset of alliance projects. In these analyses again none of the steps from Model 1 to Model 2 was significant, although we did find one significant moderating effect in this subset: connectedness has a relatively weak effect on problem-solving speed if the number of investing firms increases ($\beta=-0.30$; $p<0.01$; one-sided). In these additional analyses we found no strong direct effects from the absolute number of investing firms on problem-solving proficiency (both in the entire dataset and in the multi-firm subset). This also means that we found no particular effects on problem-solving speed, despite their substantial bivariate correlations (respectively $\rho=0.21$; $p<0.05$ and $\rho=0.34$; $p<0.01$; see Table 7.2). In sum, we can conclude that we find strong support for Hypothesis 2b that ownership integration (single-firm projects vs. multi-firm projects) interacts with project-level integration mechanisms in the explanation of problem-solving proficiency.

## 9.5 Discussion and conclusions

In this chapter we investigated how the multiple levels of a NPD project's organizational form influence problem-solving proficiency and ultimately project performance. More specifically we studied five project-level organizational factors and ownership integration as the firm-level organizational factor, i.e. single-firm projects versus multi-firm projects. Our findings first of all indicate that ownership integration hardly moderates the relationships between project-level mechanisms and project performance.

We found one significant moderating effect though, which involves reach. We found that the search for external information tends to contribute substantially more to project speed in multi-firm projects than in single-firm projects. In terms of Open Innovation, this suggests that firm-level Open Innovation contributes relatively strongly to project speed if it is complemented with project-level Open Innovation. This negative moderating effect is not in line with our expectation that project-level differentiation mechanisms complement an integrated firm-level organizational form, i.e. single firm projects. This indicates that firms are not always in need of a balance between differentiation and integration mechanisms, which is the fundamental assumption underlying our expectations. This is not uncommon though, since several authors for instance argue that very uncertain and complex innovations might best be performed within a highly integrated organizational setting (Pisano, 2006; Hoetker, 2005).

With respect to reach, we must also note that the single-firm projects in our dataset tend to make less use of external sources of information than multi-firm projects. In other words, projects that are closed at the firm-level (single-firm) also tend to be closed at the project-level (limited external search). Conversely, when Open Innovation is applied at the firm-level (partnerships), it also tends to be applied at the project-level (i.e. extensive search for external information). We can not exclude the possibility however, for alliance projects, that respondents assigned a higher score to reach because of the fact that an external firm acted as a partner in the project. This would suggest that reach and the ownership integration dummy partially capture the same phenomenon.

Besides investigating as dependent variables project outcomes (project speed, project cost efficiency, and product quality), we also investigated how our models explained problem-solving proficiency (problem-solving speed, problem-solving cost efficiency, and solution quality). For these models we found that ownership integration strongly interacts with the project-level mechanisms. Hence, although the moderating effect does not influence project performance directly, it does tend to affect a team's problem-solving proficiency. An explanation might be that a project's organizational set-up is much more closely related to the processes within projects, such as the problem-solving process, than to the eventual performance of the project. Project performance is likely to depend on a larger number of factors than the proficiency of project processes, which decreases the relative effect of a project's organizational form.

More specifically, and in line with our expectations, we find that project-level integration mechanisms complement differentiated firm-level organizational forms, i.e. alliance projects. This holds for problem-solving cost efficiency and for solution quality, but it especially holds for the speed of problem-solving. Two strong interaction effects in this regard involve the integration mechanisms connectedness and project management influence. These moderating effects suggest that the speed of problem-solving in alliance projects benefits strongly from the integration of team members from the different firms. This is in line with our expectations and this is similar to our conclusion in Chapter 6, where we concluded that strong leadership is needed to prevent and resolve conflicts in alliances of firms from different industries. This finding is also in line with the view that project-level integration is needed to realize the creative potential of alliances (Tiwana, 2008).

However, as indicated in Figure 9.2, irrespective of the extent of connectedness and the influence of the project's management, the speed of problem solving in general tends to be higher in alliance projects than in single-firm projects. Reflecting the moderating effect, this difference in terms of problem-solving speed is especially strong if team members are highly connectedness and if the project's management is highly influential. In single-firm projects, the extensive presence of these integration mechanisms appears to reduce comparatively strongly the speed of problem solving. An explanation is that the goals of project members tend to be more aligned in single-firm projects than in multi-firm projects and that project members in single firm project tend to have a better mutual understanding than the members of multi-firm projects. Hence, in single-firm projects the effectiveness of team meetings and of an influential project manager tend to be limited, whereas these project-level integration mechanisms are especially useful in multi-firm projects, for instance to define problems, to swiftly decide upon which solution to implement, and to coordinate and manage the implementation of solutions.

Next to the moderating effects for these integration mechanisms, it also appears for both single-firm projects and alliance projects that problem-solving speed is generally highest if connectedness and project management influence are limited (see Figure 9.2). In terms of connectedness this indicates that meetings in general appear to delay the problem-solving process, which suggests that it is more important for team members to spend their time on figuring out the details of problems and on implementing solutions than to discuss problems with their peers. In terms of project manager influence, problems on average tend to be solved relatively fast in projects that are managed by a manager who enjoys limited freedom vis-à-vis the management of the sponsoring firm(s). Hence, although strong project management is more important in alliances than in single-firm projects, in general this appears to reduce problem-solving speed. A possible is that an influential project manager reduces the autonomy of team members to fully apply their expertise to solve problems quickly. Conversely, if unforeseen problems arise in projects that require the input from managers outside the project, i.e. if the influence of the project manager is limited, then project members might in the mean time take actions themselves to solve those problems. In sum, connectedness and project management influence both have a negative effect on problem-solving speed, but both contribute more to the speed of problem solving in multi-firm projects than in single-firm projects.

In additional analyses we found that the two abovementioned moderating effects only hold for ownership integration in terms of the distinction between single-firm projects and multi-firm projects. These effects do not appear for ownership integration as judged by the number of investing firms. Hence, the decision to 'make' or to 'ally' for a NPD project is an important determinant of the way that project-level factors contribute to proficient problem solving. This also indicates that the decision to ally or not has more profound implications for the effectiveness of project-level mechanisms than decisions about the number of partners to innovate with.

***Limitations and future research***

This study has several limitations. First of all, we used single respondents. Hence we did not obtain data from multiple respondents and we therefore did no capture the view from partner firms if these were present in the project. Secondly, our measures of ownership integration do not include information about the actual division of investments among the partners in multi-firm projects. Hence, we cannot control for the effect that different types of alliances may have, such as differences between fifty-fifty alliances and alliances with an unequal division of investments between the partners (e.g. 80%-20%). Fifty-fifty alliances might for instance require more project-level integration mechanisms to align partners than asymmetric alliances. In future research it would be valuable to take this division of investments into account.

As another limitation, we did not investigate how our findings hold for different types of innovation. Future research is therefore needed first of all to replicate this finding and secondly to explore whether and how this finding is contingent upon other factors, such as the innovation's novelty (e.g. Chapter 3) or the type of problem (e.g. Chapter 8). We suspect that integration between team-members from different firms contributes positively to the team's overall problem-solving capability if these problems also affect members from these different firms (i.e. systemic problems across firm boundaries), but we expect it to hardly improve, if at all, the proficiency with which problems are solved that are autonomously related to team members from different firms. Future research is required in this regard.

Furthermore, our multi-level analysis is limited in the sense that we did not take into account the other dimensions of integration as discussed in Chapter 5, i.e. task integration, knowledge integration, and coordination integration. Regarding task integration, one or both of the partners in an alliance project might actually perform project tasks (i.e. single participation or dual participation; Gerwin and Ferris, 2004), which is likely to have consequences for the project-level structuring of the NPD process. Besides partners, task integration might also involve suppliers that will be compensated for their efforts. In this analysis we only focused on partner firms that also invested in the project. Task integration is therefore a more complex organizational dimension than ownership integration: ownership integration involves the division of project investments among alliance partners only, whereas task integration involves the division of labor among both alliance partners and suppliers.

Although we did not in this chapter include coordination integration as a separate variable, it is closely related to project-level integration mechanisms, such as free flow of information and connectedness. In the case of multi-firm projects, these project-level integration mechanisms contribute to the overall coordination integration between these partner firms to the extent that information exchange is between project members from the different firms rather than between members from the same firm. We lack the precise data however to indicate the extent of inter-firm information exchange.

Multi-level research in innovation management has only recently gained more attention (Gupta et al., 2007; Tiwana, 2008). Future research in this area is needed to improve our understanding of the way that firms organize innovation processes and how this influences a firm's (innovative) performance. This chapter has made a contribution to this field of research by showing how project-level integration mechanisms work differently in single-firm projects than in alliance projects. These differential effects especially appear to hold for problem-solving proficiency, which suggests that it is more appropriate to focus on the performance of processes within projects than on the ultimate performance of projects. These latter, aggregate performance indicators (e.g. project cost efficiency, project timeliness, and innovation quality) are less suitable to reflect the performance effects of a project's organizational form, because they are more likely to be influenced by factors that are outside of the scope of (project) managers.

***Managerial implications***

For managers, an interesting finding involves reach, i.e. the extent that project teams search for information in their environment. Alliances tend to use this more extensively than single-firm projects and rightly so. We find namely that extensive search for information contributes more to project speed in alliances than in single-firm projects. This suggests that Open Innovation in the development phase, if applied, needs to be applied extensively, i.e. firms should not only partner in NPD projects (at the firm level), but the NPD process within these alliance projects needs to be open as well (at the project level).

This study also shows that a project's firm-level organizational form and its project-level organizational form are especially complementary in their effect on problem-solving proficiency. Although limited integration on average appears to result in more proficient problem solving, once applied extensively it results in comparatively more proficient problem solving in alliances. Especially since extensive integration might be needed in alliances for other reasons than problem solving, such as task alignment, monitoring, etc., this is an important finding for managers. In addition, we found that the comparative benefit of integration mechanisms for problem solving in alliance projects does not depend on the number of partnering firms. Hence, a tentative conclusion is that the decisions of managers about how to structure and organize the NPD process should depend on whether the firm partners for the project or goes it alone.

# 10. Conclusions

## 10.1 Introduction

This chapter concludes this thesis. We do not intend to repeat in detail the summaries and the discussions reported at the end of each individual chapter. Instead we address several overall concluding remarks, reflections and discussions. We also point to some generic limitations of the thesis and indicate opportunities for future research. Finally, several managerial insights are presented.

## 10.2 Systemic innovation and systems integration

The central subject of this thesis is the organization of systemic innovation. Systemic innovation refers to product development activities that involve the change of multiple interdependent components. Unlike autonomous innovation, which refers to components that change independently, systemic innovation is for many firms the norm rather than the exception. This is for instance the result of increased efforts to develop products from multiple (new) technologies, such as mobile phones. The systemic nature of innovation, combined with its inherent uncertainty, makes it a challenging task to organize and manage this process as well as possible. This is why this thesis developed and tested several theories to explain the performance of new product development (NPD) projects. Of main concern are the performance implications of a project's organizational form. In addition, we have explicitly taken into account how these performance implications depend on the systemic nature of the innovation itself, which for instance depends on the innovation's technological novelty and its degree of interface change (see Figure 1.1).

Systemic innovation is especially prevalent in the development of (parts of) complex products, such as those in the converging and the technologically dynamic ICT industries (e.g. telecommunications systems and complex software products). These products consist of many components and subsystems that are typically highly interrelated. As a result, these components cannot be changed without requiring changes to other parts of the product. In this systemic context, it is a fundamental organizational challenge for innovating firms to develop, integrate, monitor, and renew product systems. Broadly defined, a firm's organizational and managerial capability to deal with these issues of systemic innovation can be labelled 'systems integration'. Chapter 3 pointed out that systems integrators, i.e. firms responsible for the coherent design and development of (complex) product systems, typically know more than they make to maintain deep architectural knowledge and strong coordination capabilities. We indicated that practices of Open Innovation help such firms to increase their knowledge boundaries, but at the same time we claimed that systems integrators need to be closed to integrate the various bodies of knowledge into deep architectural knowledge and to protect this knowledge. In this thesis we have addressed several aspects of the firm's capability to organize NPD projects and to deal with its systemic characteristics. Our main findings and contributions are briefly outlined below.

## 10.3 Scientific contributions

The main scientific contributions of this thesis are the following. First of all, Part 2 of this thesis adopts a configurational approach to the study of innovation management. More in particular, we investigate - mainly from the perspective of systems integrators - the organizational form of development projects. The organization of innovation is a multifaceted problem and many theories therefore relate to this topic. It can be no surprise therefore to find many studies that aim to integrate multiple bodies of literature (e.g. Brusoni et al., 2001; Hoetker, 2005; Hoetker, 2007; Tiwana and Keil, 2007; Tiwana, 2008; Wolter and Veloso, 2008), including transaction cost economics, the resource-based view, social network analysis, the alliance literature, organization theory, knowledge management, and product modularity. What characterizes most of these studies is the view that each explanatory concept (such as tie strength, modularity, coordination intensity, etc.) is expected to be related directly and in a linear way to the performance of firms or of the innovation effort itself. Hence, and as outlined in Chapter 2, it is as if these theories compete in terms of their individual explanatory power. Instead, Part 2 of this thesis adopts a configurational approach to the study of the organization of innovation, which considers the joint effect of multiple explanatory factors.

More specifically, Part 2 focuses on the involvement of systems integrators in development projects. For instance, to what extent should they finance these projects themselves or with partners? To what extent should they perform these projects? To what extent should they aim to fully understand the technologies involved in these projects? We argue that the answers to questions such as these depend on the specific characteristics of the innovation, and that these questions should be dealt with jointly rather than one by one. To develop our model, we first of all identified in the literature four distinct but related organizational dimensions (Chapter 5): ownership integration, coordination integration, task integration, and knowledge integration. Although these four dimensions have been indentified in various existing studies, no studies have considered all four of them simultaneously. As a result we were able to more comprehensively conceptualize a firm's organizational form for development projects. With these four dimensions as basic building blocks, we used existing theoretical arguments to propose a configurational model that outlines appropriate organizational forms for six different types of component development projects. These organizational configurations range from fully within the firm to fully external to the firm, with various specific organizational configurations in between. Subsequently, we refined this model based on a case study research for the cases that were analyzed quantitatively in Chapter 4. This resulted in the construction of tentative middle-range theories that explain multivariate fit (see Figure 5.5).

These tentative configurations for instance suggest the existence of several equifinal organizational forms, which is logically impossible in the traditional bivariate conceptualization of fit. We also find support for several of the original theoretical arguments. For example, several replications showed the appropriateness to use external innovation for the development of incremental and modular innovations. Also, we contribute to the systems integration literature by showing in detail (based on the rich insights from within-case analyses) how system firms realize systems integration coordination (Brusoni et al., 2001). They appear to know more than they make as a result of project monitoring and the selectively execution of project tasks (such as basic design and product testing). We also found that systems integrators tend to collaborate and tend to rely on external innovators more often than expected, but in many cases they appeared to maintain some degree of control based on their extensive knowledge integration.

Furthermore, we found a ‘strong direct effect’ across the different types of innovation: interface problems typically occurred when limited coordination integration was employed under conditions of radical interface change. Hence, systems integrators need to extensively exchange information with component developers to effectively integrate component innovations when interfaces with these components are very new, i.e. when the innovation is systemic rather than autonomous. This replicates a central argument in the systems integration literature (Brusoni et al., 2001) and in organization theory and information-processing theory more in general (Thompson, 1967; Tushman and Nadler, 1978). Furthermore, we found that loosely organized projects (i.e. limited coordination integration in the face of stable, possibly modular interfaces) can be either organized within the firm (high task and ownership integration) or completely external to the firm (low task and ownership integration). This supports the idea that modularity not necessarily coincides with loosely coupled networks, but that loose coupling can just as well reside within the firm (Hoetker, 2006).

Chapter 6 (the final chapter in Part 2) focused on systems integration for the development of a very specific type of product system: inter-industry architectural innovations. These new product systems are created by the first-time combination of existing technologies that come from different industries. Here, the product system itself is the locus of change, which means that within the project multiple components have to be aligned to create a coherent product system. Just as Chapter 5, Chapter 6 resulted in the formulation of a tentative configurational model. Based on three within-case analyses Chapter 6 shows that close first-time collaboration between specialists helps to successfully combine and integrate technologies from different industries. Furthermore, to increase the likelihood of a successful development project, this is suggested to be complemented with for instance a leading shareholder or a dominant partner, because this simplifies collaboration as well as joint decision-making and problem solving. In most collaborative cases in Chapter 5 a mobile operator was present that acted as the dominant firm. Chapter 6 complements extant systems integration literature by showing how (i.e. in what kind of organizational configuration) systems integration can successfully proceed without the presence of an incumbent systems integrator with deep prior architectural knowledge about component interrelationships.

As a second major contribution, once firms have decided on the organizational form *of* NPD projects (Part 2), we have investigated in Part 3 of this thesis the management and the organizational form *within* NPD projects. What type of manager should be in charge of the project? To what extent should team members have freedom to make decisions? To what extent should a team be open for the input from suppliers and customers? More in particular, we investigate how factors such as these influence the ability of project teams to solve technical problems proficiently (in terms of solution quality, problem-solving speed, and problem-solving cost-efficiency), which is - as we show - critical for the performance of (systemic) development projects. Using survey data obtained from project managers of software development projects, we for instance find that it is very important for team members to communicate freely among each other.

All in all, the findings from Part 3 of this thesis increases our understanding of the new product development process (Brown and Eisenhardt, 1995) and particularly complements the scarce literature about problem-solving in NPD (Sheremata, 2003; Atuahene-Gima, 2003; Gouel and Fixson, 2006). In terms of problem solving we extend Sheremata's existing model with several important moderating variables (problem frequency and the extent that problems are systemic rather than autonomous). We for instance find that the type of problem matters. Systemic problems involve problems with multiple, interrelated components, whereas autonomous problems are related to individual components. We find that different organizational project characteristics, such as decentralization and the search for external information, contribute differently to a team's problem-solving proficiency to the extent that projects are confronted with one type of problem rather than the other. Systemic problems are for instance solved relatively fast in the presence of a powerful project leader. In terms of reach we found an interesting trade-off.

Furthermore, our empirical study served as a replication of the first empirical test by Atuahene-Gima (2003), but for several variables it also involved the first empirical test (i.e. problem-solving proficiency and project cost efficiency). Furthermore, we showed the added value of checking for curvilinear effects using polynomial regression analysis (Edwards, 1993). This resulted in several interesting insights. For instance, if a project's problems are mostly systemic in nature we found that a medium degree of reach (i.e. search for external information) results in optimal solution quality. By obtaining a medium degree of relevant knowledge from their environment teams prevent the negative consequences of over-search (Laursen and Salter, 2006). At the same time the limited effort to engage with their environment allows teams to assimilate and to integrate the external knowledge and their internal expertise into high-quality architectural knowledge. Effective systems integration therefore requires organizational forms that are simultaneously open and closed. This also supports the idea outlined in Chapter 3 that architectural knowledge is scarce and that internal integration of external component knowledge is required to generate high-quality architectural knowledge. The idea of medium reach (which expands the firm's knowledge boundary) and the internal development of high-quality architectural knowledge is also in line with the notion of systems integrators as 'firms that know more than they make' (Brusoni et al., 2001). This also fits our finding in Chapter 5 that systems firms tend to know more than they make based on external project monitoring and selective task integration.

A third contribution of this thesis involves our investigation of cross-level moderators. The organizational form of NPD projects is typically studied for single-firm projects, whereas NPD alliances are often studied in terms of the degree of vertical integration (e.g. contractual alliances, minority shareholdings, joint-ventures). Limited evidence exists about how different project organizations perform in different firm-level settings (Gerwin and Ferris, 2004; Tiwana, forthcoming). In Chapter 9 we are one of the first to study how the organization within NPD projects is more or less effective in single-firm projects than in alliance projects. We for instance find that firm-level differentiation (as a result of alliance projects) contributes more strongly to problem solving proficiency if it is complemented by project-level integration mechanisms. This suggests that the differentiation potential of alliances is more likely to be realized if the actual collaboration process is organized to closely integrate and align partners. This is also the logic underlying the proposed organizational configuration for the development of inter-industry architectural innovations in Chapter 6. More in general, this finding suggests that it is important to consider the multiple levels of organizational forms in order to fully understand the complementarity of integration and differentiation, which is the goal of many studies (Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Weick; 1976; Gulati et al., 2005; Sheremata, 2000; Brusoni et al., 2001).

## 10.4 Limitations and opportunities for future research

Some overall limitations and opportunities for future research are the following. First, the unit of analysis throughout this thesis has been individual new component or new product development projects. This means that we did not investigate how systems integrators organize simultaneously multiple development projects and how projects are for instance integrated in an overarching project. Chapter 5 does address how different component development projects require different organizational forms, but we did not investigate how systems integrators manage and organize portfolios of development projects. This would for instance address the question how systems integrators are able to meet simultaneously different organizational requirements, such as ambidexterity (Tushman and O'Reilly, 1997). Furthermore, we paid little attention to project management over time. Most projects were viewed as static in terms of their contingencies and their organizational forms, which means that we did not investigate processes of change to achieve and maintain fit during the development process. This would for instance allow us to investigate how teams deal with technical problems once they occur.

Secondly, the particularities of our empirical settings (mobile application development and web application development) have to be kept in mind when interpreting the results reported in this thesis. Future research is needed not only to increase our confidence in our findings in this particular setting, but also to see whether and how they hold in other empirical settings. Furthermore, we should note that these ICT industries - at the time of our data collection - witnessed fast technological changes. Particularly the mobile telecommunications industry was in a state of flux. It was still very uncertain at the time whether and how mobile Internet services would take off. Many efforts were made to develop innovative applications to attract new users (Chapter 4 and 5), which for instance included initiatives to collaborate across traditional industry boundaries (Chapter 6). Also the sector of web application development (Chapters 7, 8, and 9) witnessed rapid technological change in the period of our study. Internet applications are becoming increasingly advanced and complex, with great demands to align and customize many different technologies and to integrate prior technologies and systems. Hence, systems integration was a critical challenge in both empirical settings.

We can expect that different phases of the industry life cycle coincide with different involvement of systems integrators in the development of new components and complementary products. For instance, the incentives for operators to generate installed base are likely to be less in mature industries (Chapter 4). Furthermore, technologies might become more standardized and open over time (Chapter 3), thus resulting in more external innovation and possibly in the emergence intermediary systems integrators, i.e. actors that take over systems integration activities from systems integrators (Chapter 5). It would for instance be interesting to investigate this phenomenon of intermediate systems integration in future research from the perspective of the vertical disintegration of markets (Jacobides, 2005; Jaspers et al., 2007).

Thirdly, in terms of measurement, it has to be acknowledged that subjective measures were used. Hence, common method bias might have influenced our results, although we have reasons to believe that this is limited (Chapter 9). We must also stress that our studies aim to explain the respondents' personal satisfaction with how well projects met their objectives. These objectives might however vary from firm to firm and from project to project, and for individual projects these objectives might change over time. Furthermore, differences are likely to exist between project managers about how easily they are satisfied with the performance of teams. We did not control for this. A common assumption is that error in this regard is cancelled out over multiple projects, but we cannot rule out any particular bias in this regard. However, our within-case analyses in Chapter 5 and Chapter 6 suffer less from this problem, because the qualitative insights allow us to better understand project outcomes.

Fourthly, in this thesis we predominantly focused on the development phase of the innovation process. This means that we pay little attention to the commercialization and the marketing of new components and product systems, and to the market performance of innovations. However, we did take into account how several strategic considerations related to the commercialization phase can influence the organization of development projects. In Chapter 4 we for instance considered the urgency of mobile operators and external complementors to acquire an early group of users and how this influences the relative involvement of these actors in the development phase. In other chapters we found evidence as well that commercial and strategic issues influence the organizational form of development projects. Incumbents for instance turned down the opportunity to participate in the new product development initiative of a new entrant because of competitive reasons (Chapter 6), and for strategic reasons small, external firms were very willing to invest in development projects that were initiated by operators (Chapter 5). Future research on the organization of NPD projects could take into account more explicitly how organizational forms are influenced by market and strategic considerations.

For instance, firms may purposefully develop systemic innovations to seek competitive advantage, such as by creating a proprietary, customized product system, or by repositioning its core technologies within a larger product system (e.g. Adner, 2006). In addition, collaborative development projects might be initiated for the sheer purpose to discover interdependencies and complementarities that were unknown before (Pisano, 2006). It was not an explicit aim to incorporate these issues in our analyses. Neither did we

Fifthly, the notion of multi-firm systems integration as presented in Chapter 6 is not only relevant for the development of inter-industry architectural innovations, as it also applies to the design and development of next-generation technologies and standards, such as the next-generation of DVD technologies. The competing Blu-ray and HD DVD technoligies have each been developed in a large consortium. Such highly complex and large-sized projects were not included in our study, but we can expect that issues of joint decision-making, coordination, and differentiation are crucially important in these settings. In addition, inter-firm relationships will be less cooperative as the many different participants have partly overlapping skills and intend to compete after the commercialization of their joint standard. Systems integration is therefore a particularly strategic, political, and complex challenge in such settings. It would be interesting to study these extreme projects from a systems integration perspective. A relevant stream of literature in this regard is social network analysis, which allows the investigation of different network structures in terms of the positions of network participants and the nature of their ties (e.g. Tiwana, 2008).

Sixthly, the chapters on problem solving (Chapter 7, 8, and 9) adopt the traditional bivariate approach to investigate fit. Using regression analyses we investigated several interaction effects, but we did not yet explore configurations of the different differentiation and integration mechanisms. A common approach would be to use cluster analysis to derive profiles of project structures within the subset of high-performing projects. Next, profile similarity indices (Chapter 2) can be used to investigate for the remaining projects whether deviation from high-performing project profiles reduces performance. Another approach would be to search for project configurations that are sufficient but not necessary for high project performance using Boolean algebra (e.g. Fiss, 2007). Both approaches offer ways to develop middle-range theories (see Chapter 2) for configurations of project-level organizational mechanisms. This could help to generate a better understanding of the proposed complementarity between differentiation and integration mechanisms (Sheremata, 2000; Tiwana, forthcoming). This would also be of value to the systems integration literature, because this also heavily draws on this complementarity (e.g. Brusoni et al., 2001). Finally, a further way to refine the analyses in Chapter 8 and Chapter 9 would be to investigate polynomial models of fit as the ones applied in Chapter 7.

Finally, given the scarcity of multi-level research on the organization of innovation, many opportunities exist to pursue this type of studies in the future (Gupta et al., 2007). Chapter 9 adopted an explicit multi-level perspective, but opportunities also exist to investigate how the four dimensions of integration relate to the various project-level organizational mechanisms. Other chapters implicitly addressed this to some extent. Chapter 6, for example, focused on project-level processes (such as coordination and architectural knowledge creation) for different firm-level settings in terms of ownership integration. Furthermore, Chapter 3 illustrated how various lower-level Open Innovation mechanisms contribute to higher-level organizational dimensions, such as knowledge integration. This is closely related to a recent study by Tiwana and Keil (2007), who have shown how the presence of peripheral knowledge, i.e. knowledge integration of outsourced activities, influences the performance of outsourcing relationships for different types of control. The application of peripheral knowledge by means of extensive process control reduces the autonomy and the incentives of external actors and therefore reduces performance. In contrast, extensive peripheral is particularly effective for output control, because this helps to specify and enforce prespecified outcomes, such as milestones. Building upon these findings, and complementing them with the studies in this thesis, future research could for instance address how the application of process control and output control differ for single-firm projects and multi-firm projects.

## 10.5 Managerial implications

This thesis provides insights that help managers to organize and manage new product development (NPD) projects. These projects often fail to meet quality, budget, and time objectives. This especially holds true for systemic innovation projects, i.e. projects that involve the change of numerous highly interrelated components. Two issues are of particular managerial concern. First of all, this concerns whether firms should be involved in NPD projects in the first place, and if so, to what extent and in what type of projects? To address this issue, this thesis presents a model that proposes, for different types of NPD projects, one or more organizational forms that contribute to project performance. This model helps to make integrative decisions about how to organize innovation projects in terms of legal ownership, active task involvement, coordination intensity, and knowledge management. Supported by case study evidence, this tentative model indicates that project performance benefits from organizational forms that carefully combine these organizational elements to match the project's technical characteristics.

Furthermore, the four organizational dimensions included in this model can be used for other purposes, such as the design of buyer-supplier relationships (Jaspers and Van den Ende, 2006). The four dimensions are also useful as a tool to assess a firm's ongoing buyer-supplier relationships and NPD projects. It helps to ask questions such as: do we know enough of the technologies involved? If we invest in learning capabilities, does that allow us to rely more extensively on outside suppliers and partners? Should there be more knowledge overlap with our suppliers? Etc.

Secondly, after a firm has decided to perform a development project, the question becomes how to organize and manage these projects. What type of manager should be in charge of the project? To what extent should team members have freedom to make decisions? To what extent should a team be open for the input from suppliers and customers? More in particular, this thesis shows how project-level factors such as these influence the ability of project teams to solve technical problems, which is - as we showed in Chapter 8 - critical for the performance of (systemic) development projects. For instance, in our empirical setting of small software development teams, free flow of information appeared to have a strong positive effect on problem-solving proficiency. In addition, we find that the frequency of problems and the type of problem matter. Namely, a different project organization is needed for teams that are confronted with problems that affect many of a product's components (systemic problems) than for teams that mainly have to solve problems with individual components (autonomous problems). Systemic problems are for instance solved relatively fast in the presence of a powerful project leader.

In addition, we found a strong trade-off for the extent that teams reach outside to collect information. Although reach helps to improve the quality of autonomous solutions, this is at the same time a very costly problem-solving tactic. Furthermore, especially medium levels of reach are helpful to generate high-quality solutions for systemic problems: extensive reliance on the firm's environment appears to contribute less to the development of high-quality architectural knowledge than medium external search. Open Innovation therefore appears to have clear limits in the context of systemic innovation. Firms need to be somewhat open to collect new ideas and information, but at the same time they need to develop internally a detailed understanding of their own product architectures.

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# Samenvatting (Dutch summary)

Systemische innovatie betreft de ontwikkeling van producten waarbij meerdere componenten veranderen die onderling sterk samenhangen. In tegenstelling tot autonome innovatie, dat betrekking heeft op componenten die onafhankelijk van elkaar veranderen, is systemische innovatie voor veel bedrijven eerder regel dan uitzondering. Dit komt bijvoorbeeld door de toegenomen inspanningen om producten te ontwikkelen, zoals mobiele telefoons, die uit verschillende (nieuwe) technologieën bestaan.

Het systemische karakter van innovatie, in combinatie met haar inherente onzekerheid, maakt het een grote uitdaging om dit proces zo goed mogelijk te organiseren en te managen. Dit proefschrift ontwikkelt en test daarom verschillende theorieën om de prestaties van productontwikkelingsprojecten te verklaren. Het belangrijkste aandachtspunt wordt hierbij gevormd door de manier waarop deze projecten zijn georganiseerd. Dit proefschrift presenteert en verfijnt bijvoorbeeld een configuratietheorie voor de integratie van componentontwikkelingsprojecten door systems integrators. Deze bedrijven zijn verantwoordelijk voor het coherent ontwerpen en ontwikkelen van (complexe) productsystemen, ofwel systeemintegratie. De theorie stelt dat systems integrators hun producten verbeteren door middel van zorgvuldige combinaties van projectinvesteringen, taakverdeling met leveranciers, kennismanagement en coördinatie-intensiteit.

Dit proefschrift test ook de mate waarin de organisatie van ontwikkelingsprojecten bijdraagt aan het vermogen van productontwikkelingsteams om technische problemen op te lossen. De resultaten laten zien dat systemische problemen anders georganiseerde teams vereisen dan autonome problemen. Systemische problemen worden bijvoorbeeld relatief snel opgelost wanneer het project wordt aangestuurd door een sterke manager. Daarnaast vinden we dat voor systemische problemen kwalitatief hoogwaardigere oplossingen worden gevonden naarmate meer inspanningen worden verricht om extern informatie te verzamelen. Dit geldt echter maar tot op zekere hoogte: naarmate meer externe informatie wordt gezocht zwakt dit effect af en gaat het de kwaliteit van oplossingen zelfs negatief beïnvloeden.

# About the author

Ferdinand Jaspers was born in 1978 in Breda, the Netherlands. In 1997 he finished his pre-university education in Oosterhout (Sint-Oelbert Gymnasium). In 2002 he completed his study Business Administration (Strategic Management) at the Rotterdam School of Management, Erasmus University. After his graduation Ferdinand joined this same school as a scientific researcher in the department Management of Technology and Innovation. In 2004, with the support of the Erasmus Research Institute of Management, he became a Ph.D. candidate within this department. His research focuses on the management and the organization of innovation. During his time as a Ph.D. candidate, he taught twice the master elective Innovation in High Tech Industries.

Ferdinand presented his work at numerous academic conferences, such as the Academy of Management Meeting (2006, 2007, 2008), the 2008 EGOS Colloquium, the International Product Development Management Conference (2004 and 2005), the R&D Management Conference (2005) and the Annual IMP Conference (2005). His work has appeared in or is forthcoming in Technovation, Industrial Marketing Management, Technology Analysis & Strategic Management, the Journal of Purchasing and Supply Management, and the International Journal of Technology Management. Ferdinand currently works as an assistant professor at RSM's Centre for Entrepreneurship.

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## ORGANIZING SYSTEMIC INNOVATION

Systemic innovation refers to product development activities that involve the change of multiple interdependent components. Unlike autonomous innovation, which refers to components that change independently, systemic innovation is for many firms the norm rather than the exception. This is for instance the result of increased efforts to develop products from multiple (new) technologies, such as mobile phones. The systemic nature of innovation, combined with its inherent uncertainty, makes it a challenging task to organize and manage this process as well as possible. This is why this thesis develops and tests several theories to explain the performance of new product development (NPD) projects. Of main concern are the performance implications of a project's organizational form.

This thesis, for instance, proposes and refines a configurational theory about the integration of component development projects by systems integrators. These firms are responsible for the coherent design and development of (complex) product systems, i.e. systems integration. The theory predicts that systems integrators carefully combine project ownership, supplier involvement, knowledge management, and coordination intensity to improve their products. This thesis also tests to what extent the organization of NPD projects contributes to the capability of NPD teams to solve technical problems. The results indicate that systemic problems require differently organized teams than autonomous problems. For instance, systemic problems are solved relatively fast in the presence of a powerful project manager. In addition, we find that search for external information helps to generate high-quality solutions for systemic problems, but only to a certain degree. After that, this effect turns negative.

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Tel. +31 10 408 11 82
Fax +31 10 408 96 40
E-mail info@erim.eur.nl
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Design & layout: B&T Ontwerp en advies (www.b-en-t.nl) Print: Haveka (www.haveka.nl)