Organizational Forms for Innovation in System Industries: A Typology Test with Case Studies on the Development of Mobile Telecom Applications

Ferdinand Jaspers
RSM Erasmus University, Rotterdam, The Netherlands, fjaspers@rsm.nl

Jan van den Ende
RSM Erasmus University, Rotterdam, The Netherlands, jende@rsm.nl

Abstract

System industries deliver product systems that are composed of technologically diverse components. Over time product systems evolve by innovations that cause major or minor changes to the system's architecture, interfaces and components. We take the perspective of the product system firm, the firm that designs, integrates and commercializes the product system. Contingent on the degrees of change to the product system, the firm is faced with specific requirements in terms of coordination, appropriation and learning. The organizational form for the innovation process has to provide the firm with the capacity to match these requirements. In this study the organizational form is conceptualized as a multidimensional construct. Based on a review of the literature we identify four organizational dimensions and we build a typology that proposes distinct organizational configurations for different types of innovation. These configurations show that a one dimensional conceptualization of the organizational form based on the level of vertical integration is insufficient to fully understand how to organize innovation processes in a product system.

Next, using a multiple case study design we put the typology to a first empirical test. Using a pattern matching approach we systematically compare observed organizational forms with expected organizational forms. We hypothesize that configurational fit corresponds to high project performance and that configurational misfit corresponds to lower project performance. The case studies involve development projects of mobile telecommunications applications that were selected using theoretical replication logic. The results provide considerable support for the typology developed in this paper.

Keywords: organizational form, innovation, product systems, system industries, configurations, typology, case studies, mobile applications, pattern matching.

Introduction

An increasing number of products can be considered systems that are composed of multiple, functionally interrelated components or subsystems (Prencipe, 1997). These ‘product systems’ are central to ‘system industries’ like the computer, the aviation and the telecommunications industry. Innovation in system industries is a complex matter: many technologically different and interdependent components can be involved, which have to be integrated into a working system (Brusoni et al., 2001). Furthermore, since few product system firms (e.g. Bonaccorsi et al., 1999) produce all components themselves, cooperation with other firms is often a necessity. As a result, the product system firm faces the challenge to design organizational solutions for its innovation efforts that allow him to deal effectively with the characteristics of those activities. Innovation is a key element in system industries. First of all, innovation pertains to the development and commercialization of product systems themselves. Here, lengthy negotiations with competitors and standardization bodies might be required to set the ‘de jure’ industry standard. In other industries alternative systems might compete head to head to set the ‘de facto’ dominant design. Secondly, and the topic of this study, innovation pertains to the improvement of product systems once they are introduced in the market and their basic architecture is set. Product system firms, i.e. the firms that design, integrate and commercialize product systems, can achieve competitive advantage by innovating on the component and interface technologies that constitute their product. Mobile network operators for example aim to create value by developing new or improved versions of subsystems as diverse as network technologies, communication protocols, handsets, portals, and applications.

Many studies in the field of innovation management implicitly or explicitly address how to organize for the innovation in system industries. Most of these studies are conceptual in nature and use case studies for exploratory and explanatory reasons (e.g. Chesbrough and Teece 1996, Sanchez and Mahoney 1996, Prencipe et al. 2003). An integrative framework and empirical tests are lacking however. The aim of this study is to add to our understanding on the organization of innovation in system industries by developing a comprehensive typology for the organization of innovation. In addition, we also put this model to a first empirical test to increase our confidence in the typology. We will do so by a pattern matching analysis (Yin, 1994) of case studies on the development of mobile telecommunications applications. In this study we first identify key characteristics of innovation in system industries. This results in six types of innovation. Secondly, we discuss the organizational requirements as a result of innovation for the product system firm in terms of appropriation, coordination and learning. We adopt the contingency perspective that innovation performance depends on the extent that the organizational form matches the requirements posed by the specific innovation project. The next section introduces four organizational dimensions. Based on these dimensions we subsequently propose a distinctive organizational configuration for each of the six types of innovation. Next we discuss our methodology to put this model to a first empirical test. This is followed by the results from the case studies. Finally, we conclude with a discussion and conclusions. We also make suggestions for future research.

Innovation in System Industries

System industries create value by combining components or subsystems into architectures that deliver a specific function (Ulrich, 1995). There is considerable research on product systems. Among others Miller et al. (1995), Hobday (1998) and Prencipe et al. (2003) study ‘complex product systems’ or ‘CoPS’. Miller et al. (1995) describe CoPS as large scale, durable goods consisting of multiple, customized components and subsystems. Examples of CoPS are airplanes, telecom networks, electricity networks and chemical process plants. In these markets usually only a few product system firms face a small number of large buyers, e.g. airlines and telecom operators. Product system firms require deep knowledge on a range of subsystems and interface technologies to integrate and validate the system and to control the development of new subsystems. Because of the importance of these CoPS to their businesses, buyers are typically highly involved in the innovation process. Not all product systems fit the characteristics of CoPS though. Mobile phones and automobiles for example have a large number of buyers, but they do involve products that are composed of multiple, technologically distinct subsystems. To cover these product systems as well, we broadly define a product system as an architecture that links technologically distinct components into a functional whole. This definition identifies three important elements of product systems: the architecture, the components, and the linkages or interfaces between those components.

In practice, product systems are often structured hierarchically, meaning that they are composed of subsystems that are themselves also composed of subsystems (Simon, 1962). Therefore, what is considered a system at one level of analysis is a subsystem at the next. The mobile phone for example is a subsystem of the larger mobile telecommunications system, which includes transmission stations, antennas, switches, etc. In its own, the mobile phone is system composed of among others a display, a SIM card, and an antenna. At the lowest level of analysis systems consist of elementary parts that cannot be subdivided any further (Simon, 1962). Therefore, what to consider a product system and what a subsystem is a matter of definition. Many empirical studies use inconsistent definitions however as they develop hypotheses for the system as a whole and collect data at the subsystem level (Gatignon et al., 2002). This study explicitly focuses on innovations that affect the product system's components and the interfaces between them.

The distinction between radical and incremental innovation is very common in the innovation literature. Radical innovation reflects the development and commercialization of a new technology. Over time incremental innovations reinforce the technological trajectory started by the radical innovation (Dosi, 1982). Radical innovation is characterized by high technological and market uncertainty, whereas the uncertainty for incremental innovations is limited because most technical problems have been resolved and the preferences of users are well-known. Radical innovation is typically associated with the development of new systems. In line with Henderson and Clark (1990) we apply it to describe innovations that create new component technologies and component interfaces for existing product systems. These innovations are also characterized by high technological and market uncertainty, but only relative to the uncertainty for the system as a whole. In contrast, incremental innovations reflect innovations that reinforce a product's existing component technologies and interfaces.

Henderson and Clark (1990) move beyond the common distinction between radical and incremental innovation as they also consider modular and architectural innovation. Modular innovation pertains to technologically new components that can be integrated into the system using existing interfaces. As long as these interfaces are adhered to, components can be based on distinct and new technologies and still be compatible with the rest of the system (Schilling, 2000). The term 'architectural innovation' implies that it affects the product system's architecture to a certain extent. We should make a clear distinction however between a system's architecture and its interfaces. The architecture is the *design* of the product system that defines which subsystems constitute the system and how they are interconnected by means of interfaces (Ulrich, 1995). A product system is therefore actually built from components and interfaces. On the one hand, radical change to a system's architecture can leave its interfaces unaffected. In the PC industry for instance a range of components can be 'mixed and matched' into architectures with different functionality and cost characteristics using stable interfaces (Baldwin and Clark, 1997). On the other hand, substantial change to a system's interfaces not necessarily results in a fundamentally different architecture. Strictly speaking therefore, architectural innovation pertains to changes in the design of the entire system, with major or minor consequences for its components and interfaces. In this paper we use the term 'architectural innovation' in a more narrow sense, referring to innovations with minor consequences for the component technologies involved, but with radical change to the way components are linked.

Figure 1. Types of innovation affecting a product system's components and interfaces

	Incremental Core Component Change	**Incremental Peripheral Component Change**	**Radical Component Change**
Incremental Product Interface Change	Incremental Innovation for Core Components	Incremental Innovation for Peripheral Components	Modular Innovation
Radical Product Interface Change	Architectural Innovation for Core Components	Architectural Innovation for Peripheral Components	Radical Innovation

Based on Henderson and Clark (1990) and Teece (1996).

Henderson and Clark focus on the situation that the components affected by innovation are the firm's own components. Especially in system industries it's very plausible however that the firm does not produce every subsystem internally. Teece (1996) proposes a model that includes this possibility, as he considers the 'locus of existing capabilities'. Existing technologies are either owned by the firm itself or by other firms. This distinction largely corresponds to the distinction between peripheral and core components made by Gatignon et al. (2002). Core components are crucial to the performance of the product system and tightly coupled with other components. Typically, these components are maintained within the firm as they are difficult to procure in the market as a result of their asset specificity. In contrast, peripheral components are loosely coupled and their strategic importance is limited. Since these existing capabilities are based on mature technologies and involve low levels of uncertainty and asset specificity, they are generally readily available in the marketplace. By combining the four types of innovation as identified by Henderson and Clark (1990) with the distinction between core and peripheral components, we are able to identify six different types of innovations that could affect a product system (see Figure 1).

Organizing for Innovation: Considering Multiple Dimensions

Above we identified six distinct types of innovations affecting a product system. A key question for scholars and managers of system firms is how to organize for these different types of innovation? Although many authors indicate that the organizational form is a multidimensional construct (e.g. Teece, 1996), few studies incorporate this in their models. Often the organizational form is represented by the level of vertical integration. Inspired by industrial organization and transaction costs economics Chesbrough and Teece (1996) for instance assign make, buy, or ally strategies to different types of innovation. The level of vertical integration as a one-dimensional proxy for the organizational form is also common in the literature on alliances. Many studies for example focus on the distinction between equity and non-equity alliances (e.g. Gulati and Singh, 1998). Here, we aim to conceptualize the organizational form as a multidimensional construct. Based on a review of the literature, we propose that distinctive organizational forms arise if the product system firm is integrated to greater or lesser degrees with respect to the following four dimensions:

(1) *Coordination integration*: the extent that the firm coordinates the innovation process;
(2) *Ownership integration*: the extent that the firm controls the innovation process;
(3) *Task integration*: the extent that the firm performs the innovation activities;
(4) *Knowledge integration*: the extent that the firm acquires in depth knowledge on the innovation.

Robertson and Langlois (1995) point out that ownership integration and coordination integration are related, since ownership ensures that the firm has the authority to install coordination mechanisms between related sets of activities and to monitor their performance in practice. High levels of both coordination and ownership integration correspond to internal organization or hierarchy, whereas low levels of coordination and ownership integration reflect typical arm's length relations. Both dimensions can also take on distinct values however (Robertson and Langlois, 1995). On the one hand, independent firms in a network (i.e. low ownership integration) might develop extensive, hierarchy-like coordination mechanisms between them (i.e. high coordination integration). On the other hand, business units within a single holding company (i.e. high ownership integration) might coordinate their activities through the market mechanism (i.e. low coordination integration). In contrast to the assumption in many studies that vertical integration is required to facilitate the exchange of knowledge (e.g. Afuah, 2001), Hillebrand and Biemans (2004) show that information might flow more easily across organizational boundaries than within the firm itself. Hence, ownership integration is not a prerequisite for effective information exchange, or as Gulati et al. (2005, p.419) put it: *"Put more strongly, incentives, sanctions, monitoring, rewards, and punishments can help to achieve cooperation but are not sufficient to achieve coordination (Gulati and Singh, 1998)."* In sum, ownership integration considers appropriation concerns alignment of interests to ensure cooperation, whereas coordination integration refers to inter-unit information exchange to deal with the challenge to align tasks under the assumption of bounded rationality (Gulati et al., 2005). Dependent on the level of ownership integration coordination integration reflects information exchange between units of the focal firm (high ownership integration), between units of the focal firm and units of partner firms (medium ownership integration), or between internal units and units of suppliers (low ownership integration).

In addition, ownership integration is separable from the level of task integration: a single investing firm (high ownership integration) can for example source the detailed design and development work on a subsystem from an independent supplier (low task integration). Task integration, however is conceptually related to knowledge integration. Firms can acquire knowledge in many ways when faced with a high need for knowledge integration. An obvious learning mechanism is learning by doing. Simply by performing R&D activities and market experiments firms can reduce technological and market uncertainty. Hence, the level of knowledge integration is equal to or exceeds the level of task integration (Brusoni et al., 2001). Firms can also learn from external sources. Different actors in the firm's environment, such as universities, firms from other industries, and also competitors, might possess or develop knowledge relevant to the innovation process. The organizational challenge is to identify those outside actors and to craft relationships with them. A possible solution is simply to hire external expertise. Other mechanisms to develop in-depth knowledge on outsourced components (i.e. low task integration) are career development policies, extensive documentation of technological information, internal training programs and incentive schemes (Takeishi, 2002). In general, more uncertain innovation efforts require organizational forms that generate and acquire a larger amount of information from a wider range of sources to be able to innovate effectively.

Coordination integration and knowledge integration are also related. Coordination integration refers to the extent that the system firm coordinates information on the visible design rules (Baldwin and Clark, 1997) of the relevant components, while knowledge integration deals with the degree that the firm acquires detailed knowledge of the component's hidden design rules (Baldwin and Clark, 1997). Coordination integration serves the purpose to align components and to resolve interdependencies and requires information on the system's visible design rules. Knowledge integration is required when a gap exists between the information required and the information possessed. Knowledge integration facilitates learning on the system's hidden design rules and as such facilitates the development of visible design rules required for coordination integration. Hence, knowledge integration facilitates coordination integration.

Considering organizational forms as configurations or ideal profiles (Doty and Glick, 1994) of these distinct, but related *dimensions of integration* improves our understanding of the organization of innovation and helps us address the specific challenges of innovation in system industries. Below we elaborate on each of these organizational dimensions. Based on a review of the literature we formulate propositions linking each organizational dimension to the different types of innovation. The next section proposes distinct organizational profiles or combinations of these four dimensions of integration for the six types of innovation.

Coordination Integration

To increase the explanatory power of studies on how to organize for innovation Robertson and Langlois (1995) identify ownership integration and coordination integration as two dimensions of vertical integration. These two dimensions discriminate between the conceptually distinct organizational challenges of appropriation and coordination (Gulati and Singh, 1998). Robertson and Langlois (1995) consider the level of coordination integration as the intensity of information exchange between activities. At a minimum - and applied to a product system context - there is no arrangement for information exchange between the component that is subject to technological change and other elements of the product system. At a maximum, numerous coordination mechanisms are installed to deal with significant quantities of information exchange between subsystems.

Tushman and Nadler (1978) view the coordination problem from an information processing perspective. According to them there needs to be a match between the information processing requirements as a result of the level of task interdependence and the information processing capacity of the organizational form. In general, the higher the level of interdependence, the more elaborate the set of coordination mechanisms should be (e.g. Thompson, 1967). The level of interdependence is highly dependent on an innovation's degree of interface change. On one extreme, integral product architectures consist of highly interdependent components. Even minor changes to a subsystem have significant and largely unpredictable implications for all interrelated subsystems and possibly for the product architecture as a whole (Schilling, 2000). Such radical interface changes or 'systemic innovations' (Chesbrough and Teece, 1996) require extensive information exchange between the affected subsystems to ensure the integrity of the system (Berggren and Bengtsson, 2004; Prencipe et al., 2003). Insufficient coordination from the side of the product system firm is likely to result in project delays and possibly in system-wide malfunctions, because suppliers tend have insufficient knowledge.
On the other extreme, systems with a modular designs consist of loosely coupled components that can be easily decomposed and recombined without the need to adjust components and interfaces. Furthermore, when the interfaces or 'visible design rules' of a modular system are available to the entire industry, independent firms can specialize themselves in the detailed design or 'hidden design rules' of component technologies (Baldwin and Clark, 1997). The system's interfaces serve as an embedded coordination mechanism that facilitates the specialization of labour without much information exchange and managerial effort (Sanchez, 1995). Chesbrough and Teece (1996) refer to this type of innovation as 'autonomous innovation', indicating that the innovation reinforces existing

interfaces and that it can be executed in 'self-contained' units (March and Simon, 1958) independent from the rest of the system. From an information-processing perspective (Galbraith, 1977 and Tushman and Nadler, 1978), a low level of coordination integration is sufficient to maintain an integrated system. A high level of coordination would result in excessive flows of information throughout the system and in excessive management attention, resulting in higher costs, superfluous conflicts and in the waste of valuable time. These considerations result in the following general rule for the design of organizational forms:

Proposition 1: Incremental product interface change requires a low level of coordination integration, while radical product interface change requires a high level of coordination integration to achieve high project performance.

Ownership Integration

Ownership integration refers to the extent that the firm controls the innovation process. We assume that the firm's investments in the innovation effort determine its level of decision-making authority and property rights over the innovation output. At a maximum, the product system firm is the single owner of the innovation effort. Internal innovation projects are an obvious example. At a minimum, the innovation process takes place without any ownership from the product system firm. This is the case when independent component suppliers innovate on their own or jointly. In between these extremes, medium levels of ownership integration indicate that the product system firm shares ownership and therefore decision-making power with one or more partners, for instance in a joint venture. This also means that the firm is entitled to only part of the returns on innovation.

Whereas coordination integration addresses the organizational challenge of information-processing requirements, ownership integration helps the firm cope with appropriation concerns (Gulati and Singh, 1998). Appropriation refers to the extent that innovators are able to capture a fair share of the profits from their innovations. Transaction costs economics (e.g. Williamson, 1985) identifies situations where appropriation proves difficult in arm's length relationships. Under assumptions of opportunism and bounded rationality, the specificity and uncertainty of activities makes it difficult to write and enforce contracts, thus increasing the appropriation concerns. Highly asset-specific investments, i.e. investments that can only be redeployed with considerable loss in value, increase the risk of hold-up strategies, making buyer and supplier firms more hesitant to commit themselves to the transaction as their each ex post bargaining position gets weaker. Reliance on arm's length relationships could therefore result in underinvestment and in innovation opportunities being wasted. A high level of ownership integration ensures the owner that opportunities to create value are pursued and that hold-ups will not occur. In addition, highly uncertain innovation activities increase the chances for redesigns and decision-making conflicts among partners. As a result, a sufficient degree of decision-making power is needed to prevent costly and time-consuming disputes and contract renegotiations (Tadelis, 2002). Put differently, increasing appropriation concerns require a higher level of ownership integration to be able to install an increasing number of safeguards and hierarchical controls (e.g. Gulati and Singh, 1998) which facilitate the innovation process and ensure the firm a fair share of the returns.

In system industries the innovation process often requires the involvement of buyers, suppliers and/or competitors to access their expertise (e.g. Miller et al. 1995). As a result of their involvement these partners can acquire information on the firm's proprietary technologies. This causes considerable appropriation concerns under the risk that these partners use this strategic information opportunistically. Contracts are no solution for such information spillovers due to the inherent difficulty to transact information (Arrow, 1962). For situations of weak appropriability Teece (1986) therefore proposes to internalize the innovation effort and to reduce the dependency on outside actors. Since core components are likely to be based on highly specialized and strategically important technologies, we formulate the following proposition:

Proposition 2a: Innovations to core components require a high level of ownership integration, while innovations to peripheral components require a low level of ownership integration to achieve high project performance.

Many studies (e.g. Teece, 1996; Afuah, 2001; Brusoni et al., 2001) suggest that radical innovations be executed within the firm. Radical innovations are surrounded by high levels of uncertainty for both the underlying component technologies as well as the interfaces. These characteristics are likely to make it unattractive for other firms to initiate radical innovations. These projects are very risky and are likely to be specific to the larger system. Moreover, successful completion of the project requires in depth knowledge of the system's interfaces, which most other firms are lacking. Product system firms therefore should aim to control these innovations, since these innovations are likely to have dramatic implications for the product systems. A high level of ownership integration means that the firm has the power to initiate the innovation in the first place and the decision-making power to control its evolution. In addition, high ownership means that the firm possesses the exclusive rights to the innovation and to its underlying technologies.

Proposition 2b: Radical innovations require a high level of ownership integration to achieve high project performance

Finally, it's hard to propose a specific level of ownership integration for modular innovations (e.g. Teece, 1996). Brusoni et al. (2001) argue that the contractual relation between the system firm and potential suppliers should depend on the strategic importance of the subsystem and/or the difficulty to write contracts. Modular innovation of a peripheral component provides suppliers with high-powered incentives, since they do not run the risk of a hold-up strategy by the system firm. This innovation is likely to involve low asset specificity and can thus be governed by arm's length relationships. Under conditions of medium to high levels of asset specificity however, commitment from the system firm might be required to initiate the innovation. A high level of ownership integration seems appropriate if core technologies are involved and if conflicts are likely to arise about what decisions should be made. Here, however, we argue that system firms should in general refrain from trying to control modular innovation projects. Since modular innovations reinforce the existing product interfaces there is less need for the firm to exercise decision-making power over these innovations. Facilitated by the embedded coordination provided by the established interfaces, it is better for the firm to let others take the risks in these highly uncertain component development activities. Furthermore, system firms generally have a strong position in complementary assets, which allows them to extract part of the value from external innovations (Teece, 1986).

Proposition 2c: Modular innovations require a low level of ownership integration to achieve high project performance

Task Integration

Task integration refers to the division of labour of the tasks in an innovation project (e.g. Von Hippel, 1990) and is defined as the extent that the product system firm performs the innovation activities itself. A high level of task integration means that the firm performs most or all of the activities required to bring about the innovation, i.e. specifying the design for the innovation, developing the innovation, testing it, and integrating it into the product system. A low level of task integration refers to the situation where the innovation activities are carried out by external firms, such as suppliers or strategic partners. When the firm performs all tasks this means that the firm acquires all new knowledge that is being generated during the innovation process. At the same time, this also prevents existing strategic information that is used in the process from being absorbed and exploited by others. A higher level of task integration thus serves appropriation purposes by excluding other firms from participation in the innovation process. Since appropriation concerns are high for innovations involving core components and low for innovations involving peripheral components, we formulate the following proposition:

Proposition 3a: Innovations to core components require a high level of task integration, while innovations to peripheral components require a low level of task integration to achieve high project performance.

Whereas a high level of task integration facilitates the development and protection of core competencies (e.g. Prahalad and Hamel, 1990), at the same time it limits the firm's capacity to learn from external sources and to benefit from the idiosyncratic learning processes at specialized suppliers (e.g. Robertson and Langlois 1995). This learning dilemma (John et al., 2001) is especially acute for radical innovations. These highly unpredictable innovations require a continuous stream of the latest information from various sources and are also likely to involve new and sensitive technological knowledge. Here we argue that system firms should perform as much tasks as possible in radical innovation projects to learn about and manage the implications for the system as a whole (Brusoni et al. 2001). In addition, if the risk of opportunistic behaviour is limited and when information can be easily transmitted, the firm should seek as much cooperation from external sources as possible.

Proposition 3b: Radical innovations require a high level of task integration to achieve high project performance.

Finally, for modular innovations, we follow Brusoni et al. (2001) by suggesting that modular innovations require a low level of task integration. This type of innovation produces completely new component technologies, but with limited adjustments to system interfaces. The latter makes it possible for system firms to rely on trial and error at specialized suppliers for the new module creation.

Proposition 3c: Modular innovations require a low level of task integration to achieve high project performance.

Knowledge Integration

Knowledge integration is defined as the extent that the firm possesses and acquires in depth knowledge on the component and interface technologies involved in the innovation process. A high level of knowledge integration indicates that the firm absorbs all the information that is being generated during the innovation process. A low level of knowledge integration indicates that the firm neither develops this knowledge internally nor absorbs it from external sources. Decision-makers in radical innovations processes generally lack the information to complete tasks (Galbraith, 1977) as they have no clue about the possible outcomes of alternative courses of action (March and Simon, 1958). As a result, there is a high need for generating and acquiring new information. In contrast, incremental innovations to peripheral components involve little uncertainty and consequently require limited organizational learning. For incremental changes to core components however, system firms need to integrate this knowledge, because even minor changes to core components can be important for the performance of the system and the competitiveness of the firm.

Some authors suggest that modularity coincides with loosely coupled organizations, i.e. with each firm operating autonomously and specializing in a specific subsystem (e.g. Ulrich 1995, Sanchez and Mahoney 1996). Brusoni and Prencipe (2001) however indicate that product system firms acquire knowledge on external subsystems and on interfaces for the purpose of systems integration. By knowing more than it actually does, i.e. when the firm's knowledge boundary (i.e. the level of knowledge integration) exceeds its production boundary (i.e. the level of task integration), the 'systems integrator' firm is able to integrate the subsystems, to monitor the consistency of the product system and to control the evolution of the product system architecture (Brusoni et al, 2001). The greater the changes to component technologies and interfaces, the greater the levels of uncertainty, and the larger the need for the product system firm to acquire knowledge about these changes in order to maintain a coherent product system and to monitor whether the component evolves from a peripheral to a core component. Hence, knowledge integration is particularly essential for architectural and modular innovations. Even while modular innovations reinforce existing interfaces, uneven rates of technological change for one component might have implications for the performance of other components and for the criticality of the component itself.

Proposition 4: Except for incremental innovations for peripheral components, all types of innovation require a high level of knowledge integration to achieve high project performance.

Figure 2. Typology of organizational configurations (illustrations in italics; L =Low, M =Medium, H =High)

	Incremental Core Component Change	**Incremental Peripheral Component Change**	**Radical Component Change**
Incremental Product Interface Change	Coordination: L Task: H Ownership: H Knowledge: H *Autonomous Internal Project*	Coordination: L Task: L Ownership: L Knowledge: L *Outsourcing to Suppliers*	Coordination: L Task: L Ownership: L Knowledge: H *Alliance or Joint Venture*
Radical Product Interface Change	Coordination: H Task: H Ownership: H Knowledge: H *Integrated Internal Project*	Coordination: H Task: L Ownership: L Knowledge: H *Network*	Coordination: H Task: H Ownership: H Knowledge: H *Integrated Internal or Joint Project*

Organizational Configurations for Innovation

The central proposition made by contingency theorists (e.g. Donaldson, 2001) states that a better match or fit between task characteristics and the organizational form improves performance. Each of the six types of innovation to product systems confronts the innovating firm with unique requirements. The organizational form for the innovation has to provide the firm with the capacity to deal with those requirements as good as possible. As argued above we propose that distinctive organizational forms arise if the product system firm is integrated to greater or lesser degrees in terms of the four dimensions of integration. These organizational dimensions can be combined into a range of organizational configurations with a corresponding variation in organizational capabilities. On one extreme, the firm has tight control over the innovation process, performs all tasks, extensively coordinates the development effort and possesses in depth knowledge on the technologies involved. On the other extreme, the firm has no control over the innovation process, performs no activities and absorbs no new knowledge, and is not involved in the coordination the innovation effort. Besides these two extremes of fully integrated and disintegrated organizational forms, a range of hybrid solutions is possible. Below, based on the propositions of the previous section, we construct a typology of internally consistent configurations or theoretical ideal profiles (Doty and Glick, 1994) for each the six types of innovation (Figure 2). Below we first discuss these ideal profiles more in detail. Next, we move on to test the central hypothesis underlying the typology:

Hypothesis: *A perfect fit between an innovation's ideal and observed organizational configuration coincides with high project performance, while extreme misfit between an innovation's ideal and observed organizational configuration coincides with low project performance.*

Incremental Innovation for a Core Component

Incremental core component innovations reinforce the component's interfaces with the rest of the product system. From an information-processing perspective, a low level of coordination integration is sufficient for this autonomous innovation (proposition 1). This type of innovation also reinforces the underlying technologies of a core component. To bring about this innovation in the first place and to control the evolution of these crucial and highly idiosyncratic capabilities a high level of ownership integration by the product system firm is proposed (proposition 2a). The firm should also perform most or all activities internally (high task integration), because the firm's own employees are most suited to perform the innovation activities efficiently. If external firms would perform the incremental adjustments, we can expect their lack of detailed knowledge to result in less efficient problem-solving (proposition 3a). A high level of task integration automatically implies a high level of knowledge integration, which is required to prevent spillovers of sensitive information (proposition 4). In sum, we propose a low level of coordination integration combined with high levels of ownership, task and knowledge integration. An example of an organizational form that resembles this ideal profile would be a firm's independent, autonomous organizational unit or project team staffed with its own employees.

Architectural Innovation for a Core Component

Architectural innovations refer to the creation of new or radically altered interfaces. As a result, the level of coordination integration should be high to adjust all affected components (proposition 1). Insufficient coordination integration can be expected to result in suboptimal performance or even product failures as a result of misaligned subsystems. Next to radical change to the system's visible design rules, architectural core component innovations involve incremental change to the hidden design rules of core components. In line with the reasoning for incremental core component innovations, we propose that the product system firm is best positioned to perform and finance the innovation process himself (propositions 2a and 3a) and to absorb the knowledge generated in this innovation process. The latter is especially relevant since the firm has a great interest to learn about and identify interdependencies, and to be able to actually implement the innovation in the larger product system (proposition 4). In sum, architectural core component innovation requires high levels of integration on all four dimensions. An integrated internal project is a good example of this configuration, where 'integrated' means that all internal units with knowledge on the affected components are involved in a single, highly coordinated organizational setting.

Incremental Innovation for a Peripheral Component

The requirements to align the innovation and the rest of the product system are negligible for incremental innovations. Hence, the requirements for coordination integration are low (proposition 1). Furthermore, the high-powered incentives of the market are particularly effective to bring about improvements to peripheral components that are readily available in the market place. A low level of ownership integration therefore suffices (proposition 2a). Appropriation concerns are limited for these generic assets, and the external owners of the relevant capabilities are best positioned to incrementally improve their own assets, making a low level of task integration appropriate (proposition 3a). In addition, since this type of innovation is surrounded by low levels of uncertainty, it is unlikely to fundamentally affect the performance of the product system. Hence, there is no need for the product system firm to acquire in depth knowledge on these innovations (proposition 4). The organizational configuration for external incremental innovations is to 'outsource everything and anything' (Teece

1996, p.218), i.e. low levels of integration on all four dimensions are proposed. These innovations can therefore best be financed and performed by independent, specialized suppliers.

Architectural Innovation for a Peripheral Component

Architectural innovations involve radical interface change. Hence, coordination integration should be high (proposition 1). In contrast, ownership and task integration can be limited for peripheral components (propositions 2a and 3a). Since incremental changes are required to generic component technologies, the system firm can let others finance and perform these low-risk activities. In this way the firm benefits from specialized and differentiated learning at supplier firms. Finally, the level of knowledge integration should be high in order for the system firm to retain system integration capabilities (proposition 4). All in all, architectural peripheral component innovations require high coordination and knowledge integration and low ownership and task integration. An inter-organizational network fits this ideal organizational configuration. Here, the system firm shares ownership with a other firms that possess the relevant capabilities. As a key player in the network the system firm is able to coordinate the innovation effort and to acquire in-depth knowledge of the architectural change, while leaving most tasks and investments to external firms. This is also in line with Chesbrough and Teece (1996) who argue that firms should ally 'with caution' for this type of innovation. We are more precise however in what is meant by 'being cautious': the firm should maintain and develop in-house knowledge on the architectural innovation that is performed by external actors, i.e. the firm's knowledge boundary should exceed its production boundary (Brusoni et al., 2001). The integration of knowledge next to the outsourcing of the respective activities increases the firm's ability to negotiate contracts with suppliers and monitor their performance (Bradach and Eccles, 1989). An internal unit that cooperates with the supplier for example ensures a higher level of knowledge integration and enables the firm to continue the project internally if the relationship with the supplier suddenly ends (Pisano, 1991).

Modular Innovation

Modular innovation pertains to the development of a component based on entirely new technologies. As a result, this is a highly uncertain development task. The new module operates within the limits of existing interfaces however, and can thus be integrated into the product system without much coordination effort (proposition 1). These limited architectural consequences also mean that there is less need for the firm to control this type of innovation projects. A low level of ownership integration could also mean that the firm benefits from the risk-taking and innovative behavior of external actors (proposition 2c). Next, a low level of task integration enables the firm to benefit from the idiosyncratic learning process within specialized suppliers (proposition 3c). Finally, the firm should try to develop in-house knowledge on these new technologies however to be able to integrate these new components in the product system and to learn about the evolution of the product system (proposition 4). By combining the distinctiveness of low task integration with the responsiveness of high knowledge integration, the firm retains systems integration capabilities (Brusoni et al., 2001). Hence, the organizational configuration for modular innovation consists of low coordination and task integration, high knowledge integration, and an unspecified level of ownership integration. Several authors (e.g. Teece 1996, Brusoni et al. 2001) suggest that shared ownership, like in a joint venture, might be an appropriate solution for this type of innovation. This organizational form provides the firm with decision-making power and property rights in line with the medium level of risks it takes, it operates independent from the rest of the product system, and it allows the firm to benefit from the learning that occurs while the partner in the joint venture performs most of the activities.

Radical Innovation

Radical innovations involve highly unpredictable development work on radically new components and interfaces. As for architectural innovations, radical innovations require a high level of coordination integration (proposition 1). In addition the firm should also attempt to establish high levels of ownership, task and knowledge integration (proposition 2b, 3b and 4). This highly integrated organizational form provides the control mechanisms to overcome hold-up risk, to prevent information spillovers, and to absorb the newly generated knowledge so as to maintain a coherent system.

Methods

In the empirical part of this study we test the typology and the central hypothesis using data on development projects for mobile telecommunications applications. Examples of mobile applications are mobile games, location-based services, mobile office solutions, and mobile commerce applications. Mobile applications are very suitable for this study. First, they can be considered components/subsystems of the larger mobile telecommunications system, and they show sufficient variation in terms of the two main dimensions of our typology: the degree of interface change and the degree of component change. Second, the organizational forms for the development of mobile applications varies considerably in terms of the extent that a mobile network operator (i.e. 'the product system firm') integrates these projects. On the one hand we see operators performing projects internally. On the other hand we see other firms (e.g. financial institutions, game developers, news agencies, and start-ups) developing new services completely independent from operators. In between we find different degrees of integration (e.g. different types of alliances) between operators and third parties. In addition, by focusing on one empirical setting we are able to keep several factors constant.

We apply a multiple case study design. The unit of analysis in each retrospective case is a project executed in the Netherlands concerned with the development of a mobile application. We collected data on thirty mobile application development projects. To facilitate theoretical replication (Yin, 1994) the projects were selected to obtain distribution along the dimensions of interface change and component change. The projects cover a wide range of applications and technologies and also vary in terms of the organizational forms. The projects also cover the five Dutch mobile network operators. The use of multiple case studies increases our confidence in the results and allows us to make stronger theoretical generalizations (Yin, 1994).

Typically, project managers are the key informants for innovation projects. From each project performed in a single firm the project manager was interviewed. For most projects performed by multiple firms we interviewed only the project manager from one of the firms. At the project manager's company, each project manager first completed a questionnaire in the presence of the researcher. This allowed the researcher to clarify the questionnaire if necessary. Our presence also might have acted as a barrier to self-report bias. In the questionnaire we asked for the respondent's view on the performance of the project. In most cases it is difficult to get objective data, and if you do, it is generally difficult to compare these data across cases. To increase the number of participating firms and the richness of the data we deliberately proposed to keep the data anonymous. Next, after the completion of the questionnaire, the respondents were interviewed, semi-structured following the questionnaire outline. The interview allowed us to improve our understanding of the project. The researchers' prior experience in the mobile telecommunications industry facilitated the interviews and increased the richness of the data and also enabled us to build a questionnaire using wording familiar to the respondents. The interviews enabled us to validate the answers we obtained with the questionnaire, ensuring construct validity. We found no serious problems or diverging interpretations of key constructs. The field notes obtained during the interviews were converted into a detailed case report right after the interview. In some cases we contacted respondents afterwards to seek clarifications on data that appeared unclear. Letting informants review the case reports was not a standard procedure however, because the congruence between the survey data and the interview data was considered sufficient to ensure construct validity. The interviews were mostly conducted by a single researcher. To improve reliability, the first interviews were conducted by the two researchers together to become experienced with the method and to develop an agreed upon approach to follow.

To test the typology and its underlying hypothesis we conduct a pattern matching analysis (Yin, 1994). First, we categorize each of the thirty projects as one of the six types of innovation in the typology. From our sample of thirty cases we can allocate at least three cases to each of the six types of innovation. Next, we describe for each case the relevant organizational characteristics to get a picture of its multidimensional organizational form. Subsequently, we compare this observed organizational profile/pattern with the ideal profile as suggested by the typology for this project's type of innovation. Since it is difficult to formulate criteria to determine the precise degree of fit between the observed profile and the ideal profile, we select for each type of innovation the case that fits the ideal profile most and the case that shows the most extreme deviation (Burton, Lauridsen and Obel, 2002) from the expected profile. This practice is in line with the hypothesis and is in line with this study's theoretical replication logic (Yin, 1994). If multiple cases showed a more or less equal level of fit, the case with the lowest performance was selected for the 'perfect fit' case and the case with the highest performance was selected for the 'extreme misfit' case. This selection against the hypothesis increases the robustness of our analytic generalization (Yin, 1994). Finally, we describe the performance of each innovation project and analyze the relationship with its level of fit. For each type of innovation, i.e. within each cell, we expect the best-fitting case to be associated with strong performance, whereas the worst-fitting case is expected to be associated with weak performance. This section's discussion of our research design largely corresponds to the elements identified by Voss, Tsikriktsis and Frohlich (2002) to conduct case study research. Collectively these elements determine the quality of the case study design. To summarize this section on the case study design Table 1 presents an overview of our research design in terms of four common tests (Yin, 1994, p.34).

Table 1. Case study tests and tactics

Test	**Applied case study tactics**
External Validity	Use of replication logic in a multiple case study design
Construct Validity	Use multiple sources of evidence; Prior experience with the empirical field; Have key informants review case study reports.
Reliability	Case study protocol; Database of case descriptions
Internal Validity	Pattern matching; Selecting against the hypothesis

Measurement

To perform the pattern matching analysis as described above our research design employs qualitative data (obtained through the interviews) assisted by quantitative data (obtained through the questionnaire). The categorization of the cases into the six types of innovation was primarily based on the qualitative project descriptions. To determine a project's *degree of interface change* assistance was provided by quantitative data on the four-point scales measuring 'the degree of uncertainty regarding the interfaces to connect the application to the network' and 'the degree of standardization of the platform to which the application was connected.' This latter scale ranges from 'no standards' to 'highly standardized.' Usually, newly introduced networks employ tailor-made platforms, whereas over time standardized platforms emerge that manage the development and interconnection of applications. To rate a project's *degree of component technology change* assistance was provided by a measure on technological uncertainty ('uncertainty regarding the costs to develop this application'). Also for the distinction between *core and peripheral projects* we primarily draw on qualitative data. We follow Gatignon et al. (2002) who characterize core components as strategically important to the firm and/or tightly coupled to the larger system. During the interviews we assessed the strategic importance of the application to the operator. We could corroborate these findings using data on the questionnaire item asking for 'the urgency felt by the network operator to introduce this application quickly.' We hypothesize that operators experience high urgency for strategically important applications in order to quickly build a customer base. The extent of coupling, i.e. the number of interfaces between an application and the network, was determined based on the technical characteristics of the project. Some applications, such as voice services or person-to-person text messaging, involve applications that are integral parts of the mobile network, i.e. interconnected with many network elements. In contrast, peripheral applications are often connected to the mobile network, or in many cases to an application platform, through a single interface.

Besides using qualitative data, three organizational dimensions were also measured in the survey. *Ownership integration* and *task integration* are measured on a five-point scale asking respectively for 'the extent that the operator invested in the mobile application development project' and 'the extent that the operator performed the project tasks.' *Coordination integration* is measured on a four-point scale asking for 'how much time was spent on communication in the project.' *Knowledge integration* is assessed using qualitative interview data only.

Finally, our qualitative data on project performance were complemented by survey data. For each indicator we measure actual performance relative to expectations as perceived by the project managers on a five-point scale. The lowest score represents very disappointing performance, a medium score means that performance lives up to expectations, and the highest score indicates a performance level well beyond expectations. The items that form project performance ask for judgments regarding: meeting the time-to-market deadline; adherence to interim project deadlines; quality of the project; and budget performance of the project.

Results

In this section we analyze two case studies on mobile application development projects for each of the six types of innovation: first a project that resembles the innovation's ideal organizational form as much as possible, and secondly a project that deviates from this ideal type as much as possible.

Figure 3 provides an overview of the results from the case study pattern matching analysis. This figure presents the ideal or expected organizational pattern for each type of innovation as presented in the typology in Figure 2. Next to that it presents the actual organizational forms for the two cases. For each case the figure also indicates the match or the degree of fit between the expected and the observed organizational form, the performance for this project, and the extent to which the case supports the hypothesis. In total, for the perfect matches, we are able to include three perfect matches in our analysis (case 1, 5, and 9). These cases are indicated by a high degree of fit. Two cases (case 3 and 7) deviate from the ideal profile on only one organizational dimension, i.e. a medium to high degree of fit. Finally, for radical innovation (case 11) we find an organizational form that slightly deviates from its ideal profile on all four dimensions. This is indicated by a medium degree of fit.

Next to perfect matches, we also aim to include extreme misfits in the pattern matching analysis. We are unable to find exact opposites of the expected profiles however. This can be interpreted as support for our hypothesis. The hypothesized inconsistency and negative effects of extreme misfit might prevent such organizational forms from occurring in practice. Although we did not find extreme misfits, we did identify five cases with a low to medium degree of fit (cases 2, 4, 6, 8, and 12). These cases deviate from the ideal profile on at least two dimensions of integration. In addition, most of them are characterized by extreme misfit on two dimensions. Finally, case 10 deviates from its ideal profile on just one dimension, suggesting a medium to high degree of fit.

Overall, the case studies provide considerable support for the hypothesis that fit coincides with high project performance and that misfit coincides with low performance. Nine out of twelve cases provide strong support for the hypothesis. Three cases provided medium or mixed support for the hypothesis. These three cases (cases 6, 10, and 12) all pertain to cases that deviate from the ideal profile as much as possible. A possible explanation for these mixed results is that these cases do not reflect a situation of extreme misfit, which makes it difficult to draw conclusions based on these cases. The remainder of this section analyzes each case in more detail. Although the main aim of our research is to test the typology's hypothesis, the detailed insights from the case studies also allow us to touch upon each individual organizational dimension. This will be covered in the discussion section.

Figure 3. Pattern matching between ideal/expected organizational profiles and observed profiles

		Incremental Core Component Change			**Incremental Peripheral Component Change**			**Radical Component Change**		
		Ideal Profile	**Case 1**	**Case 2**	**Ideal Profile**	**Case 5**	**Case 6**	**Ideal Profile**	**Case 9**	**Case 10**
Incremental Interface Change	**Coordination**	**L**	L	L	**L**	L	L	**L**	L	L
	Task	**H**	H	M	**L**	L	L/M	**L**	L	L
	Ownership	**H**	H	L/M	**L**	L	M	**L**	L	L
	Knowledge	**H**	H	L/M	**L**	L	H	**H**	H	L/M
	Fit with Ideal		H	L/M		H	L/M		H	M/H
	Performance		=/+	-		=	-/=		=	+
	Support for H		H	H		H	M		H	M
		Ideal Profile	**Case 3**	**Case 4**	**Ideal Profile**	**Case 7**	**Case 8**	**Ideal Profile**	**Case 11**	**Case 12**
Radical Interface Change	**Coordination**	**H**	L	L	**H**	H	L	**H**	M	L/M
	Task	**H**	H	M/H	**L**	L	L	**H**	M	L/M
	Ownership	**H**	H	M/H	**L**	M	L	**H**	M	L
	Knowledge	**H**	H	L	**H**	H	L	**H**	M	L
	Fit with Ideal		M/H	L/M		M/H	L/M		M	L/M
	Performance		-/=	-		-/=	-		-	-/=
	Support for H		H	H		H	H		H	M

"L" = low; "M" = medium; "H" = high; "-" = below expectations; "=" = equal to expectations; "+" = beyond exp.

Incremental Innovation for Core Mobile Applications

CASE 1 involves the development of a mobile application that reinforces an operator's core SMS (short messaging service) facilities without any fundamental changes to the system's interfaces. In addition, this application was highly important to the operator because it was considered a potential 'killer application.' The project involves the development of a web-based SMS application, which allows the sender to submit a text message to a group of receivers. Next, each receiver can respond to the entire group with a single message. The organizational form for this project perfectly matches its expected profile. The project was performed internally by a mobile network operator with a low level of coordination integration, since the application was developed by an autonomous team that performed the project independently from the operator's daily operations. This team consisted of the operator's own employees and was fully financed by the operator (i.e. high levels of ownership and task integration). Because the firm's employees performed all the tasks in this project, the firm automatically absorbed the knowledge on this incremental innovation, implying a high level of knowledge integration. We expect this perfect match to correspond to high project performance. Supporting our hypothesis we find that, overall, the project lived up to the project manager's ex ante expectations. The project even exceeded his expectations for the quality of the service.

CASE 2 pertains to the improvement and commercialization of a network-specific platform. The platform facilitates a mobile personal assistant application, which allows businesspeople to contact a secretary in a call center for services like contact and diary management, dictating and reading-out e-mails, and providing traffic information. The organizational form for this project deviates substantially from its ideal profile. A mobile network operator developed this network-specific platform in the nineties, but never implemented it. In 2002 a spin-off from the operator started a project to update and commercialize the platform. In line with our expectations the degree of coordination integration between this project and other parts of the mobile network was low. However, where we expect high ownership integration, the operator actually had a low to medium level of ownership integration, since the independent spin-off firm possessed the exclusively license to improve the platform and to commercialize it. The operator did keep the patent for the platform though. Also, the level of task integration diverged from the expected high level of task integration. Technicians from the operator did make the required adjustments to the platform, but the design of new functionalities and also marketing and sales activities were carried out by the spin-off, implying a medium level of task integration. According to the spin-off the operator showed little interest in this project. Hence we assume that the level of knowledge integration does not exceed the operator's level of task integration.

The performance of this project was disappointing in terms of project costs, quality, and speed. Insufficient ownership and task integration seemed to contribute to this result. According to the spin-off, crucial platform adjustments were delayed due to a lack of commitment from the operator's technicians,. This caused a substantial and costly period of inferior platform performance. A higher level of ownership integration would have resulted in more incentives for the operator to make a success out of this project. In the current setting only the spin-off, who lacked the critical technical knowledge to adjust this network-specific platform, felt the incentives to create and appropriate value. The operator was assured of part of the revenues anyhow as a result of the license fee it received. Hence, the operator did not experience high-powered incentives to innovate faster and more efficient.

Architectural Innovation for Core Mobile Applications

CASE 3 has the objective to improve the core SMS infrastructure of a network operator so that it could support content messages like news and entertainment services next to only person-to-person communication. The main challenge in this project was to develop new interfaces between the SMS center (the subsystem responsible for routing text messages), the billing system, and the system that manages the content services. The organizational profile for this project is a perfect fit for three organizational dimensions. The operator performed the interface development tasks and fully financed the project. Hence, this project was highly integrated in terms of ownership and tasks, and therefore also highly integrated in terms of knowledge. We expect a high level of coordination integration, but the intensity of information exchange between the people working on the relevant subsystems was limited, because the creation of interfaces was initially perceived to be a fairly predictable task. The complexity of this task was underestimated however because of the high market uncertainty for this application. The operator put most effort in market research to learn about user preferences.

The time to market objective for this application was met, but the project failed to meet intermediate project deadlines and budget objectives. These results can be explained by the interface problems. The interface with the billing system performed poorly and the creation of the interface between the SMS center and the content management system proved more difficult than expected up front. The perceived low interdependence meant that the actors in this project hardly communicated. As a result insufficient knowledge was generated on the architectural implications of this innovation. Once the actual complexity of the task was recognized however, additional investments intensified the work on the interfaces. This response meant that the project was completed in time, although the project failed to meet intermediate deadlines and the original budget targets. In sum, this organizational solution shows fit in terms of three dimensions, but misfit in terms coordination integration. The latter appears to be sufficient to reduce performance.

CASE 4 pertains to an application consisting of highly standardized components. Its implementation into the operator's network however required the development of new interfaces. The application, which was highly important for the focal network operator, gives employees access to their corporate networks, e-mail, and calendar by means of a PDA (personal digital assistant) that is connected to a GPRS-enabled mobile phone using Bluetooth technology (a wireless solution to replace cables between communicating devices). GPRS (General Packet Radio Service) is an upgrade for GSM networks that allows faster (packet-switched) data transmission. The organizational setup for this project deviates substantially from the expected organizational profile. An alliance was created between the operator, a hardware firm, and a software firm to share the tasks and investments. The partners together designed the application and supplied the components to build the service, but in practice the operator performed more tasks and was a larger investor than agreed up front. The level of coordination integration between the firms was low because a low level of interdependence was anticipated between the standard components. This also meant that the level of knowledge integration was limited, i.e. the operator did not posses/develop in depth know how of the suppliers' components.

The implementation of the application into the operator's network appeared to be more difficult than expected however. Problems with the interfaces caused numerous, substantial redesigns. The organizational form was not very well suited to this degree of architectural change. Communication between the partners proved to be difficult, because of the different specializations involved (telecommunications, hardware, software) and because the operator's partner firms felt no responsibility for the success of the project and were reluctant to commit themselves. According to the operator's project manager this organizational form was not a suitable design. During the project it turned out to be very difficult to incorporate the initial alliance agreement in a formal contract. According to the project manager it would have been better for the operator to fully integrate this project, meaning that the partner firms would act as arm's length suppliers. This would have provided clarity right from the beginning and would have ensured the cooperation of the suppliers. In line with our expectations, performance for this project was very disappointing. The initial time-to-market objective was exceeded with almost a year and the costs were much higher than expected. A higher level of coordination integration and ownership integration could have resulted in more communication between the partners and in more decision-making power for the operator. Because of its limited in-depth knowledge, the operator lacked the capacity to identify and coordinate interface changes.

Incremental Innovation for Peripheral Mobile Applications

CASE 5 is selected from three projects that all perfectly match the ideal profile. We selected this case because the quantitative data show that this case has the lowest performance of the three. This case is about a mobile application that is based on standard components and interfaces. Independent from a telecom operator a start-up firm developed a text messaging platform and to exploit this asset it developed a mobile dating application. Users register themselves on a website and based on user characteristics the application suggests several matches, allowing matched users to start exchanging text messages. According to the project manager internal development at the start-up without any involvement from a mobile network operator was a very appropriate organizational solution. The project performed according to the firm's objectives. This supports our hypothesis.

CASE 6 involves the development of a mobile version for an existing ticket-based lottery using standard SMS technology. Whereas we expect no involvement from an operator at all, the lottery firm and a network operator agreed to share investments and decision-making power for this project. These partners were also involved in the design of the mobile lottery, but they hired a firm specialized in the development of Internet applications to do the actual development work. Hence, the organizational form is characterized by a medium level of ownership integration and a low to medium level of task integration. The level of coordination integration is low since this application could be developed autonomously. The operator did integrate detailed knowledge on this application however, because of its involvement in the design of the service and its participation in the weekly meetings with the other two firms. Learning for reasons of systems integration was not the main objective for the participation of the operator however, which was to improve its innovative image in the market. Despite higher degrees of integration than hypothesized, the project performed according to plan and was completed somewhat before the project deadline. According to the project manager from the application development firm it was very difficult however to deal with and to report to two principals. Especially interactions with the operator were time-consuming and duplicated much of the interactions between the application developer and the lottery firm. This indicates that higher than expected integration reduces project efficiency and timeliness. In sum, we find mixed support for our hypothesis.

Architectural Innovation for Peripheral Mobile Applications

CASE 7 is an application that relies on standard technologies, but which required several new interfaces to be implemented. The application allows security personnel to select several predefined messages from a menu in their mobile phones to update their status in less time and with higher accuracy. These messages are transmitted using SMS technology. Characterizing its peripheral nature, this application was developed for a market niche and therefore had a limited potential to increase the operator's texting revenues. In addition, the operator's project manager pointed out that the operator aimed to substitute these texting services by services based on GPRS.

The application was developed jointly by an IT firm specialized in the security industry and a mobile operator. The firms equally shared investments and risks (medium ownership integration). The IT firm performed most tasks (low task integration) and acted as the project leader, but both firms cooperated on the development of the interface that had to be developed between the operator's text messaging system and the computer system of the application developer. During the project the partners communicated in-depth and very intense. This served multiple purposes. First of all, it resulted in high knowledge integration. This was needed for the operator to assess the application's technical and security implications. The application had to be installed onto the mobile phone's SIM card, which the operator regarded a sensitive issue. Intense communication facilitated decision-making within the operator, but critical decisions still went all the way up in the operator's hierarchy, causing considerable delays to the project. Secondly, it facilitated high coordination integration, because it allowed the transfer of the operator's knowledge regarding access to the SIM cards to facilitate the development of the interface by the IT firm.

This organizational form largely corresponds to the expected configuration. As expected, most of the development tasks were performed outside the operator. In addition the project was characterized by high coordination integration and knowledge integration, meaning that the level of knowledge integration exceeded the level of task integration. Only the actual level of ownership integration (medium) exceeded the level that was expected (low). Overall, the project performed in line with expectations. The project was significantly delayed however due to the decision-making process within the operator, but performed well with respect to efficiency and quality. The operator's medium level of ownership did not appear to contribute to its control over the project, since it was in a powerful position anyway as a result of its control over the required inputs to this project (i.e. access to the SIM cards). Any risks were further mitigated by the high level of knowledge integration. Hence, there are no indications that medium ownership integration was necessary for reasons of control over the innovation effort. Possibly the application developer was unable to finance this service alone, requiring the operator to make some investments. In sum, this case seems to support our hypothesis.

CASE 8 concerns the development of a WAP-version of an existing electronic directory service. WAP (Wireless Application Protocol) is a technology that facilitates mobile Internet type of services. The task to make the directory database available using – at the time – new WAP technology was highly unpredictable. The project was started after a mobile network operator asked the directory firm to make its application available through its WAP portal. Subsequently the operator was not involved in the development process however, whereas we would expect to find high degrees of coordination and knowledge integration. The quantitative data indicate that the project was cheaper than expected, but performed well below expectations in terms of project duration and the quality of the service. The directory firm possessed no knowledge of mobile telecommunications and amongst others experienced difficulties to adapt its application newly emerging mobile handsets. The operator did not attempt to coordinate these interface difficulties for the new WAP technology. In addition, from the qualitative data we learn that the directory firm accepted from the start that this would be a low performing project, because at the time the firm's main emphasis was on the development of an Internet application. These very low objectives strengthen the support for our hypothesis.

Modular Mobile Application Innovations

CASE 9 is a mobile office solution based upon highly uncertain component technologies. It uses fairly predictable interface however. Using a GPRS connection this application enables employees to access their corporate network and email from their laptop computer. The organizational form for this project is perfectly in line with the expected configuration. An IT service provider developed this application and offered it to its own consultants in a pilot study to gather 'market information.' To facilitate this pilot study the operator made a small contribution by providing the SIM cards, but it was the IT firm who made most investments (i.e. low ownership integration) and performed most tasks (i.e.

low task integration). The level of coordination integration between the operator and the IT firm was also low, because of the low need to resolve interdependencies between the application and other network elements. Despite this limited information exchange, the project was characterized by high knowledge integration because the operator got access to the lessons learned from the project. The operator wanted to incorporate these into its own mobile office development project. Despite some minor technical problems and delays, this project lived up to expectations. Hence, this project supports our hypothesis and also shows that the knowledge boundary exceeds its production boundary.

CASE 10 is based on a new technology to create small videos suitable for mobile devices from a live television stream. This application allows mobile users to receive small videos showing the latest goals from football matches. As soon as a goal is scored subscribers are alerted by a text message. A subscriber then has the option to download the video to its mobile device. Videos are transmitted to the user's device using a GPRS network. This application is developed by a firm with less than twenty employees. It financed and performed the development of this application all by itself. Without much communication with the operator, the firm connected the application to the operator's network. The operator did not attempt to learn from this project by being involved in the project or by staying in close contact with the application developer, suggesting a low level of knowledge integration. As a configuration, this organizational form corresponds to full disintegration on all four dimensions. This means that it shows a misfit on the dimension of knowledge integration, which we expect to be high in this case. According to the project manager the project performed much better than he had expected up front. The project manager believed that this organizational solution - no involvement from the network operator - was the only viable way to develop this service. According to him operators are more concerned with selling mobile connections than with the development of new applications. In sum, misfit of knowledge integration does not seem to correspond to disappointing performance and therefore disconfirms our hypothesis. The operator did have access to some key performance indicators however, since it was the exclusive provider of network services for this new application, i.e. the operator sends the alert messages and takes care of billing. Hence, the actual level of knowledge integration is higher than the interview results suggest and more in line with our expectations. This makes it difficult to draw conclusions based on this project because we can not consider it to be an extreme misfit for modular innovation. This case provides mixed support for our hypothesis.

Radical Mobile Application Innovations

CASE 11 involves the development of a WAP-based mobile banking service. This is a radical innovation since a new IT application system had to be developed for this service as well as a new interface to establish a real-time link between the operator's billing system and this new banking application. The project was performed in an alliance between an operator and a retail bank. Each partner performed the tasks related to their own core capabilities. The retail bank contributed more financial resources to the project than the operator. Decision-making power resided at two project managers, one from each firm. The employees of both firms were collocated and in the early phase of the project there was intense information exchange regarding the design of the service and the development of the interface. In later stages each firm performed its tasks at its own office as much as possible. In sum, whereas the typology proposes a highly integrated organizational form, this case shows medium levels of integration in terms of ownership, tasks, coordination and knowledge. This means that the operator is somewhat integrated on all four dimensions, but substantially less than expected. This contributed to very disappointing results, since these actual levels of integration were unable to cope with the high levels of technological and architectural uncertainty. This telecommunications application was unable to meet the strict security requirements of the financial industry, which required a major technological redesign. In addition, the quality of the service was well below expectations as well as this application's time to market and costs.

CASE 12 is a location-based service that uses GPS and GPRS technologies to provide navigation services based on the latest traffic information. This application required the development of new hardware and software to be installed in the car, as well as a new interface with a mobile network. This radical innovation is developed independently by a motorists' association. At first a network operator wanted to participate in the project, but the motorist's association wanted to take the time to develop a high-quality service. As a result, the only involvement from this operator was to assist in the development of the interface to be able to test the service. This means that the operator was disintegrated in terms of ownership and knowledge. Because of its involvement in the interface tests, the operator performed some tasks and was involved in some coordination with the motorist association's project team. Although this project was very costly and time-consuming, it did produce a high-quality service according to the project manager from the motorists' association. Hence, this case shows reasonable performance despite large deviation from the ideal profile for radical innovations. Shortly after the commercialization of this service however and after the interview with the project manager, the motorists' association cancelled this very expensive application and withdrew from the navigation market altogether. According to the motorists' association this decision was taken as a result of amongst others the difficulty to innovate for this radically new type of application. In sum, our conservative conclusion is that this project provides mixed support for the hypothesis.

Conclusion and Discussion

This study addresses organizational forms for innovations that affect the components and interfaces of product systems. Our approach shows that the organization of innovation is a complex issue, which cannot be solved by addressing the level of vertical integration only. We identified six types of innovation based on the degree of interface change, the degree of component change, and the extent to which existing components are core/peripheral. We claim that each type of innovation confronts the firm with different requirements in terms of appropriation, coordination and learning. The product system firm should employ specific organizational forms for each type of innovation that provides the capacity to match these requirements. We conceptualize the organizational form as a multidimensional construct of distinct, but related dimensions of integration. Based on a literature review this study constructs a typology of theoretical ideal organizational configurations. Next, we use case studies to put the typology to a first empirical test. Our aim is not to statistically generalize to a population using a random sample, but instead we aim to generalize to the theory (Yin, 1994). To enable this analytic generalization we selected cases from a larger set using theoretical replication logic (Yin, 1994). This maximized the organizational variation for each type of innovation by focusing as much as possible on organizational forms that either perfectly match the relevant ideal profile or constitute an extreme misfit. Based on configurationalism we hypothesize that a perfect fit between an innovation's ideal and observed organizational configuration coincides with high project performance, while extreme misfit between an innovation's ideal and observed organizational configuration coincides with low project performance. Overall, the case studies provide considerable support for the hypothesis. Nine out of twelve cases provide support for the hypothesis. Three cases provide medium or mixed support. These latter cases do not reflect extreme misfit however, which is a limitation of this study. This can also be interpreted as support for our hypothesis however. The hypothesized negative effects of extreme misfit might prevent such configurations from occurring in practice. Further research is needed to find and analyze cases that better reflect extreme misfit.

Although our main aim is to study the relationship between configurational misfit and performance, a cross-case analysis based on our qualitative data allows us to touch upon the propositions for the individual organizational dimensions. This leads to some interesting insights that increase our confidence in the typology. In line with our expectations for coordination integration (*proposition 1*) we find that coordination integration is low for all innovations with incremental interface change. Coordination integration takes on a high value in only one case with radical interface change however (case 7). As we would expect, in four cases (case 3, 4, 8, and 11) we find evidence that insufficient coordination integration caused architectural problems and as a result project delays and extra costs. In case 3 the operator did possess all relevant in-depth knowledge on the component technologies involved, but insufficient coordination of this knowledge still caused architectural problems. In this particular case the operator underestimated architectural uncertainty as a result of its emphasis on resolving market uncertainty. In addition, case 6 also shows the importance of market-related factors as drivers for the organizational form. Our typology mainly focuses on uncertainty and interdependence as a result of technological change however. In another study (Van den Ende and Jaspers, 2004) we did address market-related contingency factors as well as commercial performance next to technological change and project performance. In that paper we included the urgency for a network operator to build a customer base as a driver for ownership integration of mobile service development projects. In a regression analysis on the same dataset we found that ownership misfit significantly explains the commercial performance of mobile service development projects. Hence, our typology here is limited in the sense that market-related contingency factors and performance indicators are omitted. Another difference between both studies is that this study employs a configurational approach, whereas Van den Ende and Jaspers (2004) is more in line with conventional contingency theory. Both studies however determine ideal profiles theoretically.

For ownership integration (*propositions 2a, b, and c*) we find one case that is characterized by an exact opposite value than expected (case 12). For this case we expect high ownership integration, but instead we find a firm attempting to innovate without any involvement from a network operator. In the end this firm was incapable of managing the high levels of uncertainty in this project. In addition, case 2 and 4 seem to support the idea that insufficient ownership integration negatively impacts project performance as a result of insufficient incentives to innovate. In addition, two cases show a higher than expected level of ownership integration. For case 6 this was to improve its reputation in the market, i.e. a market-related factor which is - as explained above - outside the scope of this paper. For case 7 we found no obvious reason or benefit for this apparently excessive level of ownership.

Overall, all cases are very much in line with our expectations regarding task integration (*propositions 3a, b, and c*), i.e. we find no extreme misfit regarding task integration. Case 12 however involves a firm performing most of the tasks himself, whereas we would expect an operator to perform most tasks. We find low performance for this project. Case 6 is characterized by excessive task integration. It wasn't shown however that the operator was more proficient in performing these tasks than the specialized supplier. The cases that aimed to reflect situations of perfect fit support *proposition 4* in that only the incremental peripheral component innovation (case 5) is characterized by low knowledge integration. In addition, we find support for the claim by Brusoni et al. (2001) that knowledge integration should exceed task integration for modular and architectural innovation (case 7, 9 and 10).

In addition to further research to identify extreme misfits and to study their performance implications some other avenues for future research can be specified. To further increase our confidence in the typology, future research could involve a large sample, survey-based study - using more precise measures of fit (e.g. Euclidean distance measures, see Doty and Glick, 1993) - to investigate whether a systematic effect exists between the degree of fit and performance. In line with Venkatraman and Prescott (1990) multiple tests will have to be employed to test the proposed negative relationship between the degree of deviation or misfit (Burton et al., 2002) and performance. An important element in such tests might be to distinguish between excessive and insufficient organizational capabilities (e.g. Reuer and Arino, 2002), since both can be assumed to have different performance implications. Excessive coordination integration for example can be expected to delay the project and to increase its costs, whereas insufficient coordination can be expected to reduce the innovation's quality. Hence, multiple performance indicators need to be employed to assess the performance implications and trade-offs of different organizational forms. As indicated, future research could also attempt to include market-related contingency factors in the typology.

Finally, for managers the typology shows that choosing the right level of vertical integration is insufficient to effectively innovate in terms of coordination, appropriation and learning. Dependent on the features of each innovation firm's should carefully design their organizational forms from multiple dimensions of integration. Focusing on fit for just one organizational dimension is insufficient to fully understand the complexity of managing innovation in system industries. The policy implications from this study first of all indicate that innovations affecting a system's interfaces and components are a major driver for the creation of value and the diffusion of system innovations. A system's technological trajectory is surrounded by challenges in terms of appropriation, coordination within and across firm boundaries, and learning. The level of vertical integration, a dominant concept in competition policymaking, is insufficient to act as a driver for innovation in the long term. Successful innovation along a system's technological trajectories is a learning and coordination challenge as much as it is a matter of sheer ownership and market power.

References

Afuah, A. (2001). Dynamic Boundaries of the Firm: Are Firms Better Off Being Vertically Integrated in the Face of Technological Change?, Academy of Management Journal, 44, 6, pp. 1211-1228.
Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention, in The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton University Press.
Baldwin, C.Y. and K.B. Clark (1997). Managing in an age of modularity, HBR, Sep.-Oct., 84-93.
Berggren, C. and Bengtsson, L. (2004). Rethinking Outsourcing in Manufacturing: A Tale of Two Telecom Firms, European Management Journal, 22 (2), 211-223.
Bonaccorsi, A., Pammolli, F., Paoxli, M., and Tani, S. (1999). Nature of innovation and technology management in system companies, R&D Management, 29 (1), 57-69.
Bradach, J.L. and Eccles, R.G. (1989). Price, authority, and trust: From ideal types to plural forms. Annual Review of Sociology, 15, 97-118.

Brusoni, S. and A. Prencipe (2001). Technologies, Product, Organisations: opening the black box of modularity, Industrial and Corporate Change, 10 (1), 179-205.
Brusoni, S., Prencipe, A. and Pavitt, K. (2001). Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make? ASQ, 46, 597-621.
Burton, R. M., Lauridsen, J. and Obel, B. (2002). Return on assets loss from situational and contingency misfits. Management Science, 48, 1461–1485.
Chesbrough, H.W. and Teece, D.J. (1996). When is Virtual Virtuous? Harvard B.R., 74 (1), 65-73.
Donaldson, L. (2001). The contingency theory of organizations. Sage Publications, Thousand Oaks.
Dosi, G. (1982). Technological paradigms and technological trajectories; A suggested interpretation of the determinants and directions of technical change. Research Policy, 11, 147-162.
Doty, D.H. and Glick, W.H. (1994). Typologies as a unique form of theory building: toward improved understanding and modelling. Academy of Management Review, 19 (2), 230-251.
Galbraith, J. R. (1977). Organization Design. Addison Wesley, New York
Gatignon, H., Tushman, M.L., Smith, W. and Anderson, P (2002). A Structural Approach to Assessing Innovation: Construct Development of Innovation Locus, Type, and Characteristics. Man. Science, 48, Summer, 103-1122.
Gulati, R. and Singh, H. (1998). The Architecture of Cooperation: Managing Coordination Costs and Appropriation Concerns in Strategic Alliances. Administrative Science Quarterly, 43, 781-814.
Gulati, R. Lawrence, P.R. and Puranam, P. (2005), 'Adaptation in Vertical Relationships: Beyond incentive conflict', Strategic Management Journal, 26, 415-440.
Henderson, R.M. and Clark, K.B. (1990). Architectural innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Science Q., 35, 9-30.
Hillebrand, B. and Biemans, W. G. (2004). Links between Internal and External Cooperation in Product Development: An Exploratory Study. Journal of Product Innovation M., 21 (2), 110-122.
Hobday, M. (1998). Product complexity, innovation and industrial organisation, Res. Pol., 26, 689-710.
John, C.H., Cannon, A., and Pouder, R. (2001). Change drivers in the new millennium: implications for manufacturing strategy research. Journal of Operations Management, 19, 143-160.
March, J.G. and Simon, H.A. (1958), Organizations. New York: John Wiley.
Miller, R., Hobday, M., Leroux – Demers, T. and Olleros, X. (1995). Innovation in complex systems industries: the case of flight simulation. Industrial and Corporate Change, 4 (2), 363-400.
Pisano, G.P. (1991). The Governance of Innovation: Vertical Integration and Collaborative Arrangements in the Biotechnology Industry. Research Policy, 20, 237-249.
Prahalad, C.K. and Hamel, G. (1990), The core competence of the corporation. Harv. B. R., May-June, 79-91.
Prencipe, A. (1997). Technological competencies and product's evolutionary dynamics a case study from the aero-engine industry. Research Policy, 25, 1261-1276.
Prencipe, A., Davies, A. and Hobday, M. (eds.) (2003). The Business of Systems Integration. Oxford Univ. Press.
Reuer, J.J., Arino, A. (2002). Contractual Renegotiations in Strategic Alliances. JoM, 28 (1), 47-68.
Robertson, P.L. and Langlois, R.N. (1995). Innovation, networks, and vertical integration. Res. P., 24 (4), 43-562.
Sanchez, R. (1995). Strategic flexibility in product competition, Strategic Man. J., 16, S. 135-159.
Sanchez, R. and Mahony, J.T. (1996). Modularity, flexibility, and knowledge management in product and organization design. Strategic Management Journal, 17 (Winter), 63-76.
Schilling, M.A. (2000). Toward a general modular systems theory and its application to interfirm product modularity, Academy of Management Review, 25 (2), 312-334.
Simon, H. A. (1962). The Architecture of Complexity. Proc. of the Am. Philos. Soc., 106 (6), 467-82.
Sosa, M.E., Eppinger, S.D. and Rowles, C.M. (2004), 'The Misalignment of Product Architecture and Organizational Structure in Complex Product Development', Management Sci., 50 (12), 1674-1689.
Tadelis, S. (2002). Complexity, Flexibility, and the Make-or-Buy Decision, AEA Papers and Proc., 92 (2), 433-437.
Takeishi, A. (2002), 'Knowledge partitioning in the Interfirm Division of Labor: The Case of Automotive Product Development', Organization Science, 13 (3), 321-338.
Teece, D.J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy, Research Policy, 15, 285-305.
Teece, D.J. (1996). Firm organization, industrial structure, and technological innovation. Journal of Economic Behavior and Organization 31, 193-224.
Thompson, J.D. (1967). Organizations in Action, Social Science Bases of Administrative Theory. McGraw-Hill, NY
Tushman, M.L. and Nadler, D.A. (1978). Information processing as an integrating concept in organizational design. Academy of Management Review, 3, 613-624.
Ulrich, K.T. (1995). The role of product architecture in the manufacturing firm, Res. Pol., 24, 419-440.
Van den Ende, J. and Jaspers, F. (2004), 'Governance Modes for Systemic Innovation. Service Development For Mobile Telecommunications', Proceedings of the 11th International Product Development Management Conference, 20-22 June, Dublin, Ireland, EIASM, 617-632.
Venkatraman, N. and Prescott, J. E. (1990), Environment-Strategy coalignment: An empirical test of its performance implications. Strategic Management Journal, 11(1), 1-23.
Von Hippel, E. (1990). Task Partitioning: An Innovation Process Variable. Research P., 19, 407-418.
Voss, C., Tsikriktsis, N., and Frohlich, M. (2002). Case research in operations management, International Journal of Operations & Production Management, 22 (2), 195-219.
Williamson, O.E. (1985). The Economic Institutions of Capitalism. New York: The Free Press.
Yin, R.K. (1994), Case Study Research; design and Methods, 3rd Edition, Sage, Thousand Oaks, CA.