Universität der Bundeswehr München
Fakultät für Luft- und Raumfahrttechnik
Institut für Industrielle Informationsprozesse

PRODUCT DEVELOPMENT AS DYNAMIC CAPABILITY

Dissertation

von

Markus Blum

Ingolstadt, im Juli 2004

What matters is not predicting the future,

but being prepared for the future.

Perikles, ca. 500–429BC

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Motivation and Objectives

The concept of dynamic capabilities is an influential strategic management framework for understanding how competitive advantage evolves in situations of rapid and unpredictable change and how this advantage sustains over time (Teece et al., 1994, Grant, 1996, Kogut and Zander, 1997, Teece et al., 1997, Eisenhardt and Martin, 2000, Pisano, 2000, Zollo and Winter, 2002). This perspective focuses on the processes and structures by which managers "integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997).

Despite the recognized significance of dynamic capabilities, the perspective has not gone unchallenged. It has been criticized as conceptually vague and tautological and that it lacks empirical grounding (Mosakowski and McKelvey, 1997, Williamson, 1999, Priem and Butler, 2001). Moreover, D'Aveni questioned the existence of sustained competitive advantage in dynamic markets (1994).

The tautology surrounding the concept of dynamic capabilities may be caused by the fact that it is frozen within theoretical firm-level derivations instead of a more operational and empirical grounding. The ambiguity created by this can be seen in the various definitions of dynamic capabilities in literature. (See, for example, Teece (1997), Eisenhardt (2000), or Zollo (2002)). Most of them use highly aggregated definitions like "the learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness" (Zollo and Winter, 2002). These definitions are academically true and valid but still on a high level of abstraction. This tautology and vagueness have made it difficult to derive concrete implications for real management practice.

We have recently witnessed some interesting attempts to break up this tautology. One of these attempts was Eisenhardt and Martin's re-conceptualization of dynamic capabilities (2000). They identified dynamic capabilities as "specific organizational and strategic processes (e.g. product development, strategic decision making, alliancing) by which managers alter their resource base". In their view, dynamic capabilities consist of "identifiable and specific routines that often have been the subject of extensive empirical research in their own right outside the resource-based view of the firm" (Eisenhardt and Martin, 2000).

The results of such attempts are a first step, confirming that the concept of dynamic capabilities can be linked to concrete business operations in a way that is more realistic, empirically valid and non-tautological. A more empirical-based approach to dynamic capabilities seems to be necessary, one that links dynamic aspects of organizations to real business operations, but stays within a broader configuration of business strategies and firm-level contexts.

Using an empirical-based approach to dynamic capabilities requires a fundamentally different understanding of what dynamic capabilities are, away from abstract definitions like 'routines-to-learn-routines' towards specific processes and structures that can be described and observed in real business operations. But within the traditional strategic management context, the idea of using specific processes like product development as level of analysis for the research of dynamic capabilities could hardly find a taker, due to the now acknowledged dominance of the resource-based view of the firm (Priem and Butler, 2001).

However, these persistent research problems on dynamic capabilities suggest that we still do not have a sufficient understanding of the nature and evolution of dynamic capabilities and, as a consequence, we can hardly derive implications for management practice. Therefore, a more empirical-based understanding of dynamic capabilities and of the pattern they exhibit in specific processes (like product development) is desirable. This work aims to achieve such an understanding by investigating a dynamic capability perspective to product development following Eisenhardt and Martin's proposition that dynamic capabilities exhibit common features that are associated with effective processes across firms (Eisenhardt and Martin, 2000).

1.2 Research Question

My claim is to reduce tautology and vagueness from the concept of dynamic capabilities. I contend that we can reduce tautology and vagueness if a dynamic capability perspective to product development provides valuable contributions for product development operation.

Thus, I derive my research question

> *"Does the concept of dynamic capabilities provide valuable contributions for product development operation?"*

1.3 Expected Results

Explaining how and why some firms are more successful than others in developing new products has been a central and enduring quest of researchers in management and other disciplines. This topic was the subject of various case studies in which product development success stories were known to have been used. The case studies investigated how and why this success story had occurred, entertaining several rival explanations such as coherent product-market positioning, superior project organization, or charismatic team leaders, among others.

A dynamic capability perspective to product development presents a different approach. Most research on product development either employs highly aggregated concepts like product-market positioning or focuses on low level tasks and practices. A dynamic capability perspective to product development, by contrast, is an intermediate-level concept that combines product development operation into cohesive wholes, yet offers a fine-grained, differentiated perspective. Such a perspective is inherently dynamic. Because product development capability unfolds over time, this perspective captures linkages among activities that are often lost in static models and cross-sectional analyses.

A dynamic capability perspective to product development encourages thinking in story lines rather than events. For this reason, the approach is unusually helpful in addressing problems of implementation of strategic intentions (Hamel, 1989). Managers can articulate the required steps in product development tasks and projects as well as improvements.

Finally, product development represents the intimate connection between diverse perspectives and the futility of analyzing them in isolation. It is extraordinary difficult to derive management implications based on one single variable without first taking account of the others.

As for research on dynamic capabilities, a dynamic capability perspective to product development provides a disaggregated model of dynamic capabilities, but does so in ways that make the operationalization of dynamic capabilities more tractable and explicit. Put another way, if the concept of dynamic capabilities answer the 'what to do' question, product development operation provides a fine-grained answer of the 'how to do it' question.

1.4 Research Methodology

It is clear from my research that sustained product development success is a function of an organization's overall product development capability. I reviewed the existing literature as a guide of research in order to identify pattern of product development capability. After reviewing the more 'static' pattern, I investigated dynamic aspects of product development capability. In this sense, I apply a dynamic capability perspective to product development according to the conceptualizations of Teece (1997) and Eisenhardt (2000). I identified open and vague links and cause-effect patterns between dynamic aspects (like learning processes and path dependencies) and product development tasks. From this standpoint, where literature is vague and poor in content, I continued with exploratory case study research.

My research strategy follows the procedure proposed by Stuart et al. (2002). The research process comprised five stages that will largely dominate the reminder of this work (Figure 1):

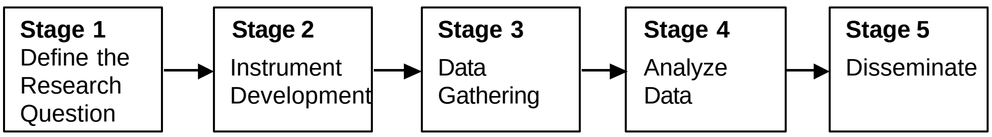


Figure 1 – The Five Stage Research Process (Stuart et al., 2002)

Chapter 1 explains the problem and defines the research question. Chapter 2 starts with theory development of the capability to develop new products successfully or what I have termed 'product development capability'. It develops the theoretical foundation of a dynamic capability perspective to product development that is to be validated and extended in the following data gathering and analysis phase. Conducting stage 3, I report two exploratory case studies in two different settings: the first in automotive industry at the German automobile manufacturer Audi and, the second, in telecommunications industry at the enterprise network (EN) division of Siemens ICN. The Audi cases were studied in the course of my observations of project work at the Audi Product Management Department (1999-2003). The data of the Siemens cases follow my observation of a restructuring initiative at Siemens ICN-EN in order to address the problem of fast changing environments (2000-2002). Stage 4 analyses case study evidence and derives propositions and links out of the cases. The stages 2-4 are described in more detail in Figure 3 and they are compatible to the framework for case study research proposed by Yin (1994).

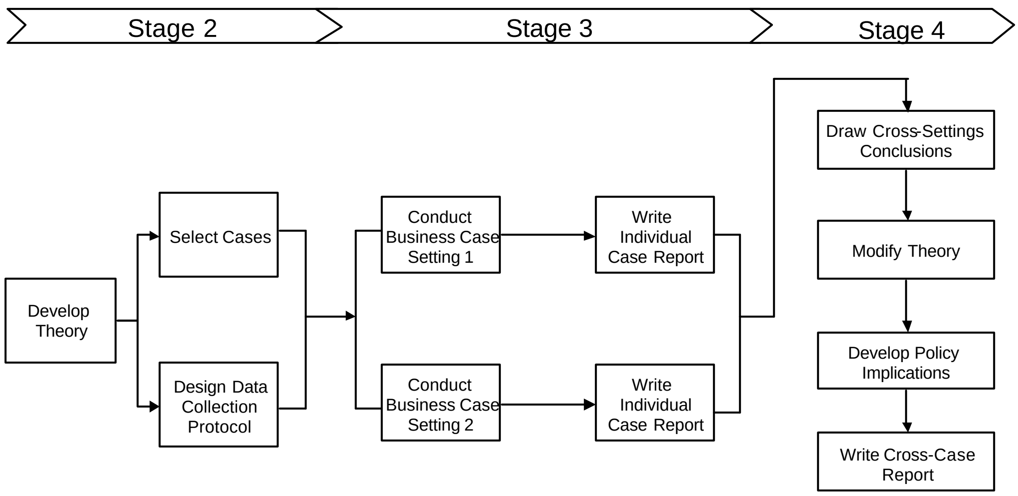


Figure 2 – Applying Case Study Research Methodology (Yin 1994)

The core of empirical work examines the relationship between elements of dynamic capabilities and product development operation. This methodological approach is rooted in the work of many others that studied dynamic capabilities within the product development context; see, for example, Leonard-Barton (1992), Henderson and Cockburn (1994), Iansiti and Clark (1994), Tabrizi and Eisenhardt (1995).

1.5 Contribution to Theory and Practice

To academia, this research intends to make contributions for both dynamic capabilities research and product development research.

Firstly, the work attempts to reduce tautology and vagueness from the concept of dynamic capabilities. Much of dynamic capability literature is locked into highly aggregated concepts with the firm as the level of analysis. The perspective developed here sketch potential elements for operationalization of dynamic capabilities as 'common features' (Eisenhardt and Martin, 2000) of working-level practices. Linking working-level practices with dynamic aspects of product development capability will reduce the tautology and vagueness of the concept.

Secondly, research on dynamic capabilities is criticized because it lacks empirical grounding (Mosakowski and McKelvey, 1997, Williamson, 1999, Priem and Butler, 2001). By reporting several product development case studies of two different firms in different industries, this work contributes to fill this gap.

Thirdly, by exploring a dynamic perspective to product development, I provide some new insights into the question "Why are some firms more 'capable' than others in developing new products?" These issues are central for various research streams in academic management literature.

Fourthly, research on product development profits from this research in the way that such a 'dynamic' perspective calls into question traditional 'market-based' approaches to product development where planning and doing proceed sequentially. In dynamic environments, a more 'learning-based' approach might be more adequate where probing and learning proceeds iteratively.

The use of this work for management practice is twofold. First, it can help managers to see product development projects as elements of a broader firm-level context. Such a view is not focused solely on individual projects but also on market positions and competence bases that themselves are objects for evolution through effective product trajectories.

Second, it provides implications for managers to institutionalize and manage dynamic routines like learning and reconfiguration. These processes have hardly been in the focus of traditional product development literature but, as we will see in the case studies, they can and should be managed in order to create and sustain new product success.

1.6 General Outline

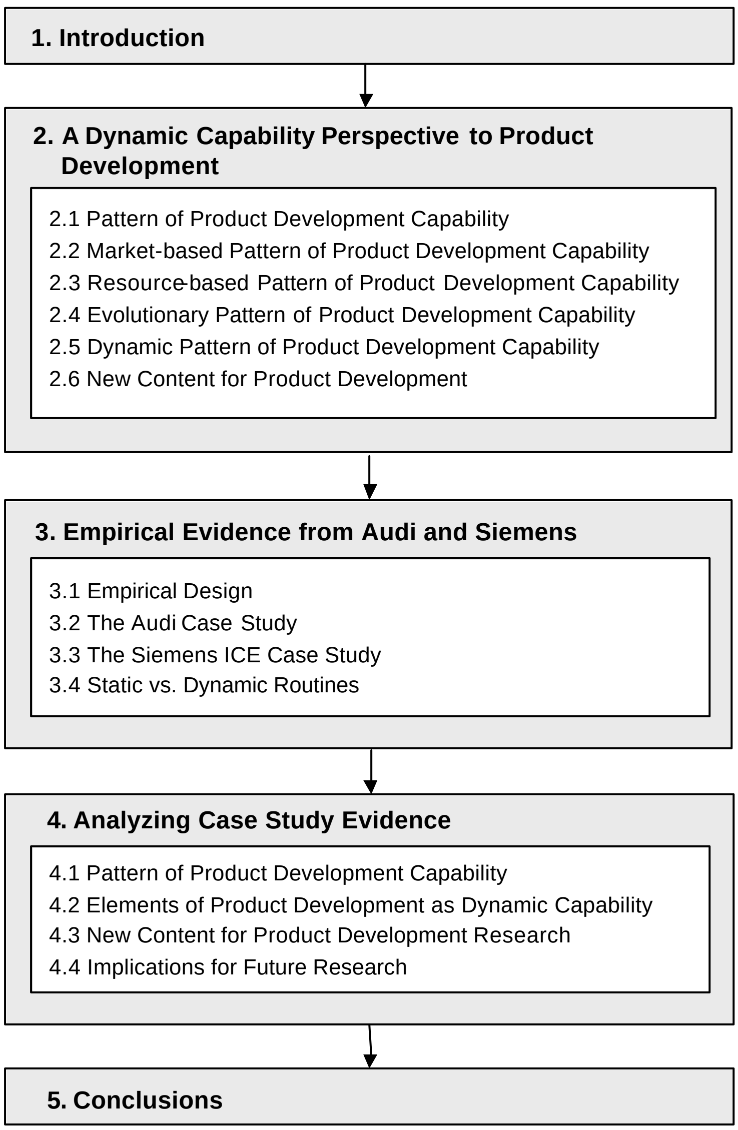


Figure 3 – Structure of Work

The remainder of this study follows the methodology and is structured as depicted in Figure 3. Theoretical work starts in Chapter 2 with a literature review about pattern of product development capability. At least three different patterns of product development capability have been found to be important: market-based, resource-based and evolutionary pattern. The analysis is followed by a dynamic pattern of product development capability based on the concept of dynamic capabilities. In a third step, some basic elements of a dynamic capability perspective to product development are determined that are a basis for the following empirical work.

The transition to empirical work is performed in Chapter 3 and describes two exploratory case studies at Audi and Siemens ICN-EN. Chapter 4 analyzes and discusses the case studies in order to identify pattern of product development capability that are then discussed and compared with theoretical derivations of Chapter 2. Chapter 4 finishes with implications for future research. Chapter 5 concludes the results and insights out of the case studies.

2 A Dynamic Capability Perspective to Product Development

This chapter develops the theoretical foundation of a dynamic capability perspective to product development. It comprises six sections, one introductory in nature, four on the routines and structures that build the pattern of product development capability and one concluding the results. Section 2.1 introduces product development capability as the driver of sustained new product success as it is seen by strategic management and product development literature and probes the relevant aspects of it to clarify the rough areas of interest. Sections 2.2 to 2.5 discuss patterns of product development capability; each from a different perspective (market-based, resource-based, evolutionary, dynamic). Section 2.6 turns attention to product development operation and concludes the results as 'New Content for Product Development'.

2.1 Product Development Capability

Successful new products and services are critical for many organizations, since product development is one important way that firms can implement strategic intentions into real business operations (Brown and Eisenhardt, 1995). There is, accordingly, a large and growing literature on product development at the level of both specific projects (e.g. Cooper, 1996) and the firm as a whole (e.g. Wheelwright and Clark, 1992). Researchers have identified various characteristics that relate to new product success, such as market-orientation (Day, 1990) or innovative product features (van de Veen, 1986) among others.

Some of the earliest work of product development that emphasized the importance of market issues over purely technical ones was written by Myers and Marquis (1969). They studied 567 successful products in over 100 firms and 5 industries. They concluded that market pull, i.e. identifying and understanding customer needs, was substantially more important to new product success than technology push. In addition, they identified cross-functional integration as the key factor for product development success.

Subsequent research sharpened the emergent emphases on product advantages, market attractiveness, and product development organization. Particularly important were several studies of Cooper and Kleinschmidt (1979, 1987). The 1979 study, called NewProd, examined 102 successful and 93 failed products within 103 industrial firms in Canada. The 1987 study investigated 203 products in 125 manufacturing firms, including 123 successes and 80 failures. Cooper and Kleinschmidt observed that the most important determinant of new product success was product advantage. The intrinsic value of the product, including unique customer benefits, high quality, attractive cost, and innovative features, was the critical success factor. Such products were seen as superior to competing products. Project organization was also found to be important. Particularly important was pre-development planning. This included a well-defined target market, product specifications, clear product concept, and extensive preliminary market and technical assessments. Finally, market conditions also affected new product success. Cooper and Kleinschmidt (1987) found that products that entered large and growing markets were more likely to be successful. However, they also noted that market characteristics were less important than were product advantage and internal organizational factors such as pre-development planning and a clear product concept.

More recently, Cooper and Kleinschmidt (1995) conducted another study of product development efforts by 161 business units in the chemical industry. The authors replicated some of their earlier findings. Most notably, this time they highlighted that product development organization was most strongly associated with new product success. They recommended a “high quality product development process” as a major determinant of new product success. Contrary to their earlier studies, the authors found in this study that market competitiveness had no relationship with new product success.

Other studies focused not on sole projects or products but on sequences of products. Arthur D. Little (1991), for example, noted that many organizations still have difficulty with sustained product development success, or managing a number of product development efforts over time. Sustained new product success has been found particularly difficult for organizations with long histories of stable operations.

However, these results suggest that product development literature remains ambiguous in what characteristics and activities make product development successful. Is it either the product-market positioning, the way product development is organized or innovative product features or other things that are the source of new product success? In a way, all of the mentioned topics are important. They altogether build a kind of pattern of product development capability. This pattern needs further investigation. To do so, I first review the existing literature as a guide for research and, based on this review, I explore concrete routines and structures that form the cumulative patterns of product development capability.

2.1.1 Product Development and Competitive Advantage

Product development success can be defined as the achievement of something desired, planned or attempted. Firms that enjoy successful products also enjoy the positive economic consequences. I start with identifying the relevant attributes that determine product development success. To do so, we ask how product development affects the firm's competitive position. From such a standpoint, we can argue that product development is successful when it produces positive strategic consequences or, in other words, when it creates and sustains competitive advantages.

In a popular work of product development, Clark and Wheelwright concluded that product development can create competitive advantage in at least three areas: market position, resource utilization, and organizational renewal (Clark and Wheelwright, 1993). All three areas are studied within traditional product development literature. However, their theoretical foundations are more dedicated to strategic management literature, where one can find constructs and theoretical concepts that explain sources of competitive advantage from different viewpoints. Using strategic parlance, we can argue that product development can create competitive advantage of at least three different types: market-based advantages, resource-based advantages, or evolutionary advantages.

Market-based Advantages

A firm's market position consists of the products or services it provides, the market segments it sells to, and the degree to which it is isolated from direct competition (Porter, 1980). In general, the best positions involve supplying distinctive products to price-insensitive buyers, whereas poor positions involve being one of many firms supplying marginally distinctive products to well-informed, price-sensitive buyers.

Market-based advantages can be gained by foresight, superior product-market positioning, or just by luck (Barney, 1986b). In such a sense, product development is successful when it builds or improves valuable market positions.

Resource-based Advantages

Resources include patents, trademarks, specialized physical assets, and the firm's relationship with suppliers and distribution channels as well as a firm's reputation with its employees, suppliers, and customers. Resources that constitute advantages are specialized to the firm, are built up slowly over time through the accumulated exercise of superior capabilities, or are obtained through being an insightful first mover (Lieberman and Montgomery, 1988), or just by luck. For example, during the 80s, Japanese car manufacturers possessed an advantage that was embodied in superior product quality.

In this sense, product development is successful when it builds or improves valuable resources or capabilities for the firm.

Evolutionary Advantages

A firm's way of learning and reconfiguration can be a source of advantage if capabilities are based on the firm's history of learning-by-doing and if it is rooted in the coordinated behavior of many people. By contrast, capabilities that are based on generally understood scientific principles, on training that can be purchased by competitors, or which can be analyzed and replicated by others are not sources of sustained competitive advantage (Barney, 1991).

Evolutionary advantages are usually organizational, rather than the improvement of individual skills. They involve the adept coordination and collaboration of specialists and are built through the interplay of investments, operation, and learning (Nelson and Winter, 1982). Unlike physical assets, evolutionary advantages enhance capabilities by their use. Capabilities that are not continually used and approved will atrophy (Abell, 1999).

Evolving technologies and customer requirements can make existing capabilities obsolete or sometimes require new ones. Therefore, product development is successful when it contributes to renewal of capabilities over time (Dougherty, 1992).

2.1.2 Capabilities vs. Competences

In the last section, I identified three different types of competitive advantage that product development creates: market-based, resource-based, and evolutionary advantages. I introduced the term "capability" as a construct to describe resource-based and evolutionary advantages created by product development. Before I continue to explore the sustainability of these advantages, the parlance of this work is to be defined.

We argue that new product success that is not built up by luck is rooted in fundamental product development capability (Stalk et al., 1992). The capability under examination is defined at a relatively broad level as the capability to develop new products (Moorman and Slotegraaf, 1999). More specifically, it can be defined as the 'ability' of the management to use and integrate existing organizational competences to create and sustain new product success.

In contrast to my definition here, Prahalad and Hamel (1990) use the term 'competence' or "core competence" with a different understanding. In this work, I differentiate between the terms competences and capabilities. The term 'competence' is used to describe more technological competences and the term 'capability' is used for broader organizational capabilities.

In this logic, various competences build the overall product development capability. These competences can be combined in various ways, for example, through joint ventures or other forms of alliances with partners, licensing agreements, franchising relationships and long-term contracts, the combinations of which result in networks. This can happen in parallel, as when an electronic firm combines its research competences with that of a mechanical product firm to develop electromechanical products together. Or it can happen sequentially, as when the design competence of one firm is combined with the engineering competence of another. However they are combined, altogether these competences build the overall product development capability of a firm (Hagedoorn and Narula, 1996, Duysters and Hagedoorn, 1998, Steensma and Corley, 2000).

2.1.3 Characteristics of Product Development Capability

Most organizations can develop a successful new product occasionally. The critical question is "What sustains this success, keeping competitors from imitating or replicating it?" For example, Peters (1992) described the introduction of a successful new product by a 120-year-old machinery manufacturer but wondered if the organization could replicate that success. Hage (1988) argued that long-stable organizations are especially challenged by changes in technology and global competition.

For a firm's product development capability, in order to provide sustained new product success, and thus, by implication, be a source of superior financial performance, three characteristics must be met. Product development capability must be valuable, rare, and imperfectly imitable (Barney, 1991).

First, product development capability must be valuable; it must enable the firm to develop products in ways that lead to high sales, low costs, high margins, or in other ways add financial value for the firm. Because financial value is an economic concept, product development capability, to generate such value, must have positive economic consequences.

Second, product development capability must be rare; it must have attributes and characteristics that are not common to the product development capability of a large number of other firms.

Finally, product development capability must be imperfectly imitable; firms without such product development capability cannot engage in activities that will change their product development capability to include the required characteristics, and if they try to imitate this product development capability, they will be at some disadvantage (experience, reputation etc.) compared to the firm they try to imitate.

These three requirements result from work on sustained competitive advantage by strategic management researchers (Porter, 1980, Barney, 1991). The first requirement that a firm's product development capability must enable it to develop products in ways that add economic value to the firm, is clearly a prerequisite for generating economic performance. If a firm's product development capability enables it to develop products in ways that are inconsistent with a firm's competitive position, then that capability cannot be a source of sustained competitive advantage.

The requirement that valuable product development capability must be rare to generate sustained competitive advantage reflects Porter's industrial analysis framework (Porter, 1980). If many firms have a similar product development capability that allows them to develop products and compete in approximately the same way, none will possess a capability-based competitive advantage, and above-normal economic performance cannot be expected.

Finally, even if the above conditions are met, it is still necessary for a firm's product development capability to be imperfectly imitable to generate sustained new product success. Perfectly imitable capabilities, even if they are valuable, and even if they are currently rare, are subject to imitation that dissipates any new product success they may provide. The capability-driven new product success of one firm creates an incentive for other firms to modify their product development capability in order to duplicate that success. If the capability is perfectly imitable, it cannot give any one firm a sustained new product success and financial performance. Thus, for example, if 'best practices' are, in fact, easily transferable, as it is suggested by numerous consulting firms, then these 'best practices' cannot be a source of sustained new product success, and their existence cannot be an explanation of such a success.

This leads to an interesting preliminary result: when product development capability creates and sustains new product success, then 'best practices' in a narrow sense cannot be the source of sustained new product success. If 'best practices' are instead part of an unfolding sequence of activities that altogether form the overall product development capability, then they can be the source of sustained competitive advantage.

Product Development Capability and Financial Performance

A firm that has a valuable, rare, and imperfectly imitable product development capability enjoys sustained new product success. Such a firm will enjoy the positive economic consequences of its product development capability. Relatively few other firms will be able to obtain these same benefits, and those firms that currently do not enjoy them cannot engage in activities that will make it possible to achieve them. However, the overall financial performance of a firm with such advantages can decrease if a firm fails to manage other strategically relevant capabilities and resources. While a firm with a valuable, rare, and imperfectly imitable product development capability can obtain superior financial performance, other capabilities and resources of the firm like, for example, marketing capabilities and, not to forget, luck, can also lead to such performance.

That analysis does not imply that most firms currently enjoying capability-based advantages always enjoy these advantages because a valuable capability today, in different economic and competitive contexts, can become a rigidity tomorrow (Leonard-Barton, 1992a). Moreover, because other capabilities and resources can also generate sustained above-normal performance, it is possible that several firms in an industry can all obtain sustained superior financial performance based on different capabilities. Therefore, superior financial performance can only restrictively be an indicator for product development capability.

The preliminary result of this section is that firms' sustained new product success is rooted in product development capability if this success is founded in fundamental product development capability that is valuable, rare, and not easy to imitate. But we are still on a highly aggregated level where one can hardly derive management implications. In order to get a more cogent understanding of what such a pattern of product development capability looks like, I review the existing literature as a guide for research.

2.1.4 Different Perspectives to Product Development Capability

To understand patterns of product development capability, researchers have borrowed many concepts, techniques, and theories from other disciplines, ranging from social theory to evolutionary biology. These concepts include industry-level, firm-level, and business unit-level observations. This variation has created a theoretical pluralism that has uncovered various ways to explain patterns of product development capability.

However, the diversity of theories and concepts borrowed from different disciplines often encourages compartmentalization of perspectives that do not enrich each other and produce isolated lines of research (Gioia and Pitre, 1990). As van de Ven and Poole recognized: “It is the interplay between different perspectives that helps one gain a more comprehensive understanding of organizational life, because any one theoretical perspective invariably offers only a partial account of a complex phenomenon.” (van de Ven and Poole, 1995). Yet when different perspectives are compared with each other, they provide a powerful focus for a more cogent understanding of product development capability.

Three Perspectives to Explore Pattern of Product Development Capability

To identify pattern of product development capability, I describe the different viewpoints to the topic. Some authors started from an industrial viewpoint where they identified product development as an instrument to achieve superior market positions (Ansoff, 1965, Andrews, 1971, Porter, 1980, Porter, 1986, Mintzberg, 1988). The notion of ‘competitive and generative strategy’ resulted from this stream. Others started from the firm level and investigated superior resources and their utilization as sources of competitive advantage (Wernerfelt, 1984, Prahalad and Hamel, 1990, Barney, 1991, Peteraf, 1993). Many concepts and tools, like the notion of core competences, derived from this research stream. A third stream, initiated by economists, concluded that the prime drivers of technological and organizational progress are mechanisms of variation, selection, and retention (Schumpeter, 1934, Nelson and Winter, 1982, Utterback, 1994, Tushman and Anderson, 1997). The emphasis on ‘innovation’ resulted from this research stream. Successful product development, in this sense, helps to develop the firm’s market position and competence base over time.

By inductively examining the substance and argumentation paths of each viewpoint, I found that they could be utilized as three complementary perspectives to explore patterns of product development capability. Each of these three streams has a rich and long-standing intellectual tradition although various research fields use different terminologies. I refer to them as market-based, resource-based and evolutionary pattern of product development capability.

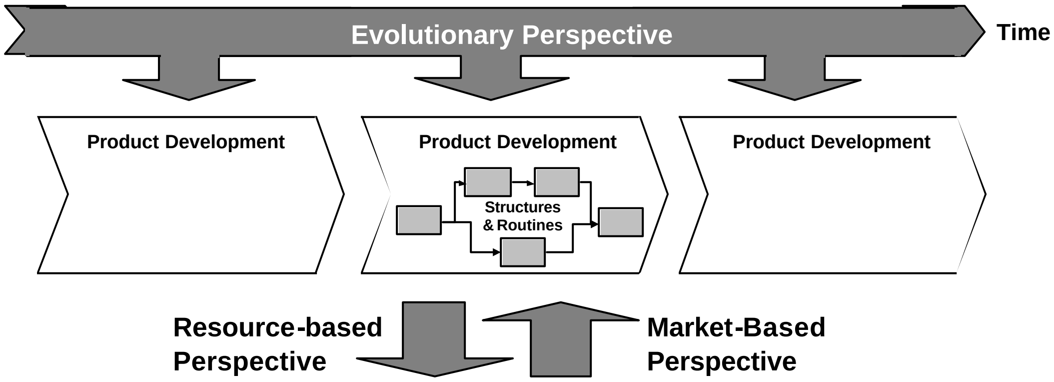


Figure 4 – Three Different Perspectives to Product Development Capability

Figure 4 illustrates that these three perspectives provide fundamentally different accounts to explore patterns of product development capability. From a resource-based perspective, product development capability involves the development process and internal organizational aspects ('inside-out'). A market-based perspective determines product development capability from outside-in. Together, these two perspectives determine how product development is assigned and completed, how products match customer requirements, and how new technologies are introduced.

At any given time, each organization's product development capability has a mix of resource-based and market-based characteristics ('white arrow'). An evolutionary perspective, the succession of the 'white arrows', shows the organization's product development capability as it moves through time. This evolution is affected by prevailing resource and market characteristics and will unfold in different ways depending on generic aspects of resources and market position.

This section describes these three perspectives in their pure ideal-type forms. Various studies of product development combine elements of these ideal types to explain observed pattern of product development capability in specific areas and contexts. Table

1 outlines the three perspectives in terms of key idea, relevant theories, representative studies, and role of product development.

I shaped my review around these perspectives because each involves a pattern of cumulative citations evolving from some representative studies. The market-based perspective builds mainly on studies of Porter and Mintzberg with their notion of "generative and competitive strategies"; the resource-based perspective on studies of Wernerfelt, Prahalad and Hamel, Barney, and Peteraf with their notion of "firm-specific resources and competences"; and the evolutionary perspective on Schumpeter, Nelson, Winter, Utterback, Tushman and Anderson with their emphasis on technological and organizational progress.

	Market-based Perspective	**Resource-based Perspective**	**Evolutionary Perspective**
Key Idea	Competitive advantage through superior product-market positions.	Competitive advantage through superior resources and competences.	Competitive advantage through superior mastering of change.
Theory	Generative and Competitive Strategy Framework	Resource-based View of the Firm	Evolutionary Theory
Representative Studies	Ansoff (1965) Andrews (1971) Porter (1980) Porter (1986) Mintzberg (1988)	Wernerfelt (1984) Prahalad and Hamel (1990) Barney (1991) Peteraf (1993)	Schumpeter (1934) Nelson and Winter (1982) Utterback (1994) Tushman and Anderson (1997)
Role of Product Development	Infuse and shape market position	Applies and utilizes resources and competences	Adapts and reconfigures resource and market positions

Table 1 – Three Fundamental Perspectives to Product Development

Further, although there are overlaps in focus and analysis across these areas, research within each area centers on particular aspects of product development capability. The market-based perspective focuses on the product in its market context, whereas the resource-based perspective focuses on internal firm-specific characteristics, and the evolutionary perspective concerns the emergence of technologies and market contexts.

Moreover, the research within each area is theoretically and methodically complementary. The market-based perspective is primarily a 'static' perspective and helps to broadly define 'outside-in' aspects of product development capability. The resource-based perspective complements these 'outside-in' aspects by accomplishing 'static', 'inside-out' aspects of product development. The evolutionary perspective adds a 'dynamic' consideration of how product development capability is influenced by technological and industrial evolutions over time.

Working out the relationships between such seemingly divergent perspectives provides opportunities to develop new theory that has stronger and broader explanatory power than the initial perspectives. Some integration is thus desirable, but it must preserve the distinctiveness of alternative theories. I contend that such integration is possible if different perspectives are viewed as providing alternative pictures of the same phenomenon without nullifying each other. This can be achieved by identifying the viewpoints from which each dimension applies and the circumstances when these elements are interrelated in the context of product development. This approach preserves the authenticity of distinct theories, and at the same time advances theory building because it highlights circumstances when interplays among theories may provide stronger and broader explanatory power of successful product development.

Overall, based on this review, these three perspectives capture best the cumulative pattern of product development capability. In the subsequent sections, I outline briefly each perspective, including their key concepts, underlying theory, critical findings, methods, strengths and weaknesses. However, as noted, although all areas are coherent bodies of work, they also complement and somewhat overlap one another.

2.2 Market-based Pattern of Product Development Capability

The ambiguous role of product development was one of the most popular issues addressed by management researchers. Given impetus especially by Porter (1980), product advantage and product-market positioning came into the scope of management and management research during the 1980s and is still popular (Markides, 1999). Probably the best known model attempts to display the current product line from a growth rate and market share perspective (see Figure 5). This matrix, proposed by the Boston Consulting Group (BCG), categorizes products into one of four quadrants. The matrix indicates new products not yet developed and introduced.

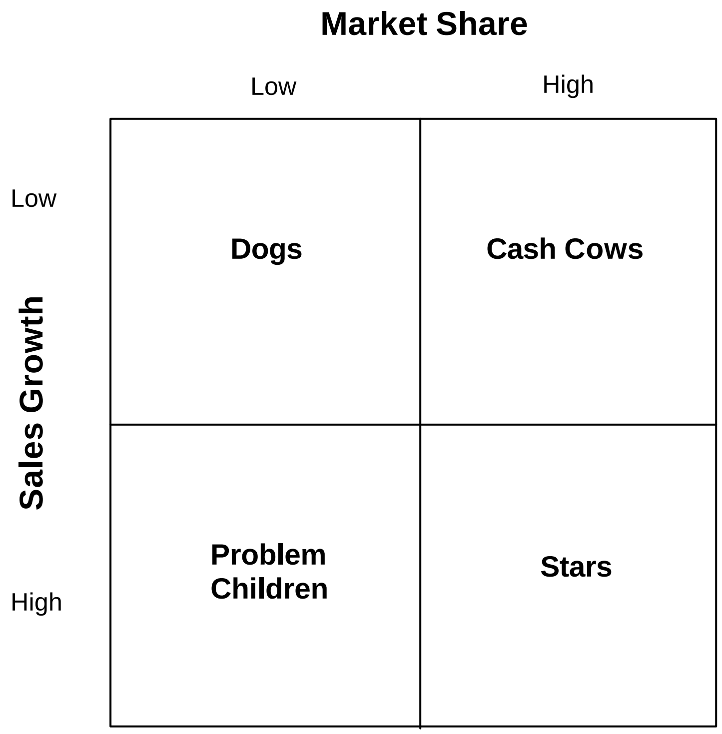


Figure 5 – Product-Portfolio Matrix – Boston Consulting Group (BCG)

While the BCG matrix looks at product development only from a financial viewpoint (cash-flow and investment), the reasons why, for example, a product is a 'star' are not displayed.

The reasons why products become, for example, a 'star' has two aspects: the product must both match its basic mission and it must at the same time compete with other products (Porter, 1986). This dual character of the relationship between the product and its environment has its analog in two different aspects of product development success.

Analysis of the first is normally done by looking at changing market conditions over time. Analysis of the second, by contrast, typically focuses on the differences across products at a given time. In literature, this dualism is usually termed the generative and competitive aspect of strategy (Porter, 1986).

The key to evaluating both aspects is an understanding of why the product in its market, as it currently stands, exists at all and how it assumed its current pattern. Once the analyst obtains a good grasp of the basic economic foundation that supports and defines the product in its market, it is possible to study the consequences of environmental changes.

The problem was posed most clearly by Porter (1986), with his generative model of strategy. Porter posted that there are two basic types of product advantage a product can provide in the marketplace: low costs or differentiation (Porter, 1986). These combine with the 'scope' of a firm's operation (the range of market segments targeted) to produce three generic strategies for achieving above-average product success in the market place: (1) cost leadership, (2) differentiation and (3) focus, as shown in Figure 6.

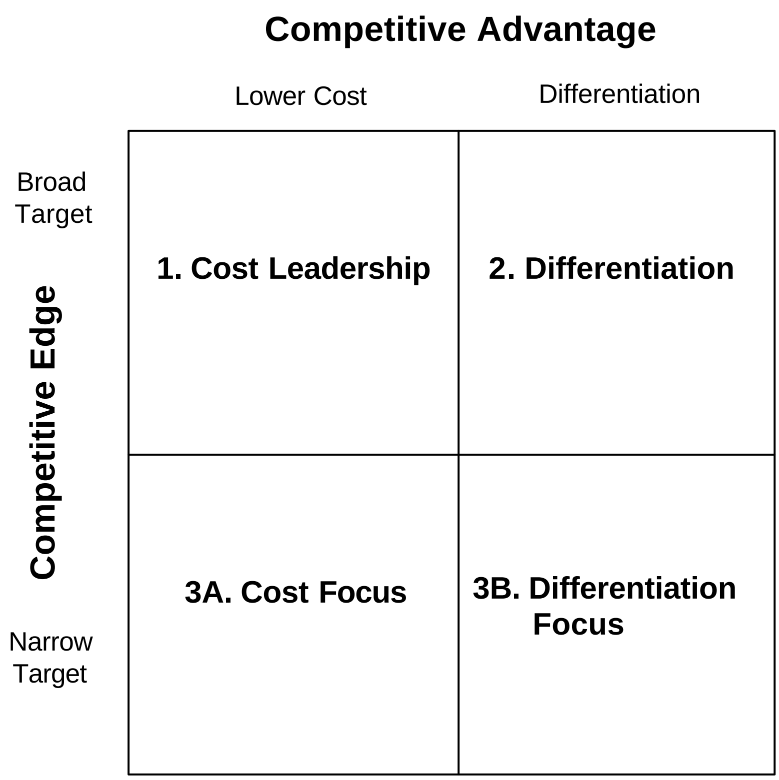


Figure 6 – Porter's Generic Strategies (Porter, 1986)

Mintzberg (1988) extended the conceptualization by Porter and argued that an organization can differentiate its products in six basic ways: along price, image, support, quality, design, and no differentiation. These 6 basic ways are briefly described in Table 2.

Product Differentiation	**Description**
Price Differentiation	The most basic way to differentiate a product (or service) is to charge a lower price for it. Price differentiation may be used with a product undifferentiated in any other way – in effect, a standard design. The organization absorbs lost margin, or makes it up through higher volumes of sales.
Image Differentiation	Organizations are sometimes used to create differentiation where it does not otherwise exist – an image is created for the product (or the company). Image has an emotional dimension independent from the physical attributes of the product.
Support Differentiation	More substantial, yet still having no effect on the product itself, is to differentiate on the basis of something that goes alongside the product, some basis of support. An example is 24h-delivery service.
Quality Differentiation	Quality differentiation has to do with product features that make it better. Examples are greater reliability, greater long-term durability, and/or superior performance.
Design Differentiation	Design differentiation means offering something truly different that breaks away from the 'dominant design' to provide unique features.
No Differentiation	No differentiation is a strategy. Copying successful products can be a strategy if there is enough room in the market.

Table 2 – Strategies of Differentiation (Mintzberg, 1988)

According to Mintzberg, the second dimension to distinguish product-market positions is by the scope of the product and services offered, in effect the extent of the markets in which they are sold. Mintzberg proposed four market strategies: unsegmentation, segmentation, niche, and customizing that are described in Table 3.

Along with these models, there now exist clear guidelines as to how product development decisions can be better reflected within corporate decisions.

Market Strategy	Description
Unsegmentation Strategy	"One size fits all". Examples are Ford T model, salt, sugar etc.
Segmentation Strategy	The possibilities for segmentation are limitless, as are the possible degrees. A distinction can be made between simple segmentation (cars: sedan or station wagon) to fine segmentation strategy (individual colors etc.). Also some organizations seek to be comprehensive in their product line, to serve all segments, others to be selective, targeting only certain segments.
Niche Strategy	Niche strategies focus on a single segment. Porsche's niche is sports cars. In a sense, all strategies are in some sense niche, characterized as much by what they exclude as by what they include.
Customizing Strategy	Customization is the limiting case of segmentation. Each customer constitutes a unique segment. Architecturally designed houses and buildings are examples.

Table 3 – Strategies of Scope (Mintzberg, 1988)

2.2.1 Market-Based Routines in Product Development Operation

The market-based perspective had its impact in product development operations. It emphasized that products should be planned and designed thoroughly before they are implemented physically.

Separating the 'Planning' from the 'Doing'

This philosophy leads to a separation of 'planning' and 'execution' or 'concept development' and 'product implementation'. Figure 7 shows this simple product development principle.

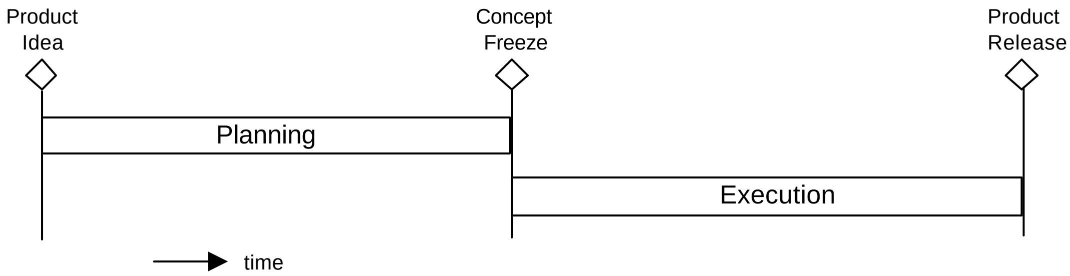


Figure 7 –Separation of 'Planning' and 'Execution' in Product Development Operation

Product development starts with a product idea and ends with the product release. The process consists of two phases: concept development (planning) and product implementation (execution) separated by a 'concept freeze' milestone.

Product development works as follows: concept development, aimed at the creation of a distinctive product concept, is optimized for the investigation of market opportunities, competitive moves, technical options, and production requirements. Once the product attributes are agreed, a product team defines the product concept that is then 'frozen' and transferred to the product implementation phase. While in the concept development phase effectiveness dominates the tasks ('developing the right product'), product implementation activities are optimized to realize a product efficiently ('developing the product right').

In such an approach the 'frozen' product concept is the pivotal topic in the development process. It is the link pin between management policy and product development operation. As such, the product concept critically determines product development success.

The term product concept has been so widely used for different purposes that it has several defined meanings. For the purposes of this work, a product concept is a set of goals and objectives that, taken together, define the scope of the product development effort and its approach to create a successful product.

A product concept addresses four important questions (Clark and Wheelwright, 1993):

1. What products will be offered (i.e. breadth and the depth of the product line)?
2. Who will be the targeted customers (i.e. market segments)?
3. How will the product reach those customers (distribution channel)?
4. Why will customers prefer our product to those of competitors (distinctive attributes and value)?

Devising adequate answers to these questions is neither simple nor straightforward. It requires a reasonable store of situation-based knowledge and more than the usual degree of insight. In particular, each product concept is unique. For example, one cellular phone manufacturer might rely on new and innovative features as primary development goal while another might place primary low costs as highest objective. Neither strategy is ‘wrong’ or ‘right’ in any absolute sense; both may be right or wrong for the firms in question. Concept development must, then, rest on a type of situational logic that does not focus on ‘one best way’ but which can be tailored to the market situation as it is faced.

Concluding Market-based Pattern

Together, the market-based perspective recognizes the importance of pre-development planning and product-market positioning before the product is realized and it considers the effects of competition. This perspective evolved mainly from strategic management studies and developed strategies for effective product-market positioning that is generative and competitive in diverse market contexts. In this case, product development capability is seen as having the right product and market strategy. This perspective also highlights the role of the competitive context for effective product development.

The market-based perspective emphasizes that product development needs an attractive product for an attractive market (Dougherty, 1990). Simply put, if a product is well planned and designed, the product development effort will create a superior product-market position and, thus, will be a success.

However, the stream suffers from several shortcomings. This stream may help to think about products and market positions, but it totally neglects internal organizational characteristics that allow for, for example, a ‘cost differentiation’ strategy. It does not answer the question if the organization is ‘capable’ to realize such a strategy. These inside-out aspects of product development capability are the scope of the following resource-based perspective.

2.3 Resource-based Pattern of Product Development Capability

The resource-based perspective focuses on intra-organizational characteristics that lead to new product success (Verona, 1999, Bharadwaj, 2000). The most influential theory of this perspective is the resource-based view of the firm, which describes how competitive advantage within firms is achieved and how this advantage might be sustained over time (Penrose 1959; Wernerfelt 1984; Barney 1991; Peteraf 1993). The resource-based view focuses on internal organization of firms, and so complements the market-based view within the structure as determinants of competitive advantage (Henderson and Cockburn, 1994, Porter, 1996, Eisenhardt and Martin, 2000).

In particular, the resource-based view of the firm assumes that firms can be conceptualized as bundles of resources, that those resources are heterogeneously distributed across firms, and that resource differences persist over time (Wernerfelt 1984; Amit and Schoemaker 1993). Based on this assumption, the different approaches of the resource-based view of the firm explain the development of competitive advantage that leads in the long term to 'above-normal rents'. The basic argument of the resource-based view is that competitive advantage is the result of unique resources (Wernerfelt, 1984, Barney, 1991, Peteraf, 1993) and distinctive capabilities (Selznick, 1957) of the firm.

Resources in this context include "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve efficiency and effectiveness" (Barney 1991).

According to Barney (1991), competitive advantage only evolves if resources are valuable (contribute to firm's effectiveness or efficiency) and rare (not widely held). When these resources are simultaneously imperfectly imitable (they cannot easily be replicated by competitors) and not substitutable (other resources cannot fulfill the same function) – the so-called VRIN attributes – those resources fulfill the necessary attributes for sustained competitive advantage.

If these resources are applied in the 'right' combination and 'adequate' coordination then competitive advantage evolves (Kogut and Zander, 1997). This is where the conceptualization of 'capabilities' develops the argument further. Amit and Shoemaker define capabilities as "a firm's capacity to deploy resources" (Amit and Schoemaker, 1993). Grant provides a more concrete conceptualization: "capabilities involve complex patterns of coordination between people and people and other resources. Perfecting such coordination requires learning through repetition" (Grant, 1991).

Experience-based learning through frequent repetition of similar activities builds the basis for the evolution of organizational routines, where the organizational knowledge to solve context-specific problems is inherently codified. In other words, all standardized procedures or patterns of decision-making and problem-solving are based on routines and thus these routines are basic components of any organizational capability and therefore they can be interpreted as the essence of competitive advantage (Montgomery, 1995).

Figure 8 presents the different levels of aggregation and analysis of the resource-based view of the firm.

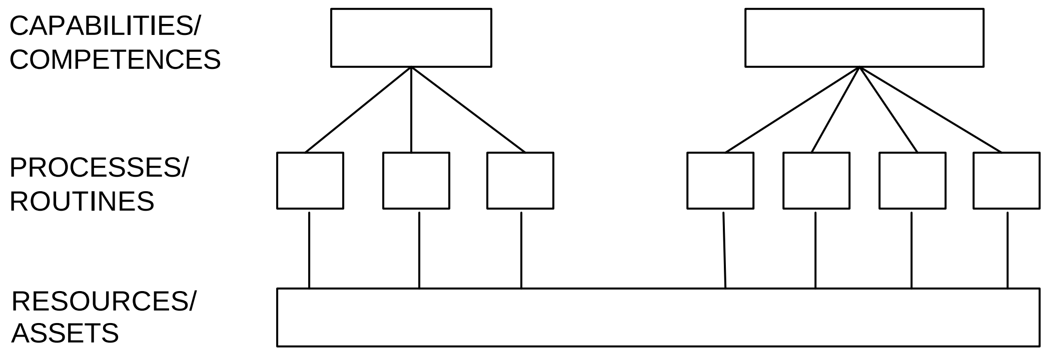


Figure 8 – Resource-Based View of the Firm - Levels of Aggregation

Resource-based view recognizes the importance of resources and their utilization in explaining product development capability. But it also considers the value of collaboration and alliances. Embedded in the resource-based view of the firm is the assumption, that product development capability is inherently a function of resources and competences (Dougherty and Hardy, 1996, Moorman and Slotegraf, 1999).

But still the constructs of resources and capabilities are very vague referred to their application in product development operation. If we focus on product development, it becomes clearer what types of resources or competences are required for product development.

2.3.1 Product Development and Competences

Products reflect the competences captured by organizations that create them (Prahalad and Hamel, 1990). This comprises competences of the underlying technical foundations, specific engineering fields, managerial processes, users, distribution channels, markets etc. If one compares automobiles of different manufacturers, one can see different competences in design, ergonomics, manufacturing etc. As such, product development capability is linked to the underlying competences (Prahalad and Hamel, 1990). Because these competences comprise many different elements, for product development there is a need to distinguish between competences of at least two different types: function-specific competences or what can be termed "component competences" and context-specific competences or what can be termed "architectural competences" (Henderson and Cockburn, 1994).

Part of the competences required for conceptualizing a new product is captured in product components or sub-systems. These are self-contained, functional disciplines independent of the product architecture, such as brake system or radio receiver in automobiles. Developing a product means drawing upon many components. For example, competences needed for a complex product, like a cellular phone, range from integrated circuit design to antenna design and testing technologies. Creating these competences is a critical challenge for organizations. Successful product development is built on functional excellence, and no company can compete without strong foundations in functional competences. Strength at the component level is not enough, however. The diverse functional competences must be integrated with each other and with their product architecture to produce a product that functions consistently in diverse application contexts (Clark, 1985, Clark and Fujimoto, 1991). In a cellular phone, for example, the integrated circuits must work with circuit boards, and the whole must function reliably even in situations of movement or in humid environment. This is where architectural competence comes in.

In distinctive products, diverse component competences combine to a coherent whole, consistent to its product strategy (Clark and Fujimoto, 1991). The competence needed to perform these integrative tasks is not usually captured by component competences. Part of the competences needed to perform product development is made up of integrative or architectural competences, which describes the interactions between components and their application context (Henderson and Cockburn, 1994).

Therefore, product development capability from a resource-based perspective requires at least two different types of competences: function-specific competences and architectural competences.

To assess the existence of these competences it is useful to ask two questions. Firstly, has the organization demonstrated that it possesses the function-specific competences and problem-solving abilities required by the product concept? A product concept, as such, does not and cannot specify in detail each action that must be carried out. Its purpose is to provide structure to the general issue of the business' goals and approaches to coping with its environment. It is up to members and departments of the organization to carry out the tasks defined by product concept. A concept that requires tasks to be accomplished which fall outside the available competence base might probably fail.

And secondly, has the organization demonstrated the degree of integrative and architectural competence necessary to carry out the product concept? The key tasks required of a product concept not only require specialized function-specific competences, but often make considerable demands on the organization's ability to integrate disparate activities (Lorenzoni and Lipparini, 1999). A manufacturer of standard cars may find, for example, that its primary difficulty in entering the luxury segment is a lack of system attributes like smoothness and gentleness of drive although they used only top quality components. Firms that want to expand their product portfolio to new markets with new products may find that the integrative competence, rather than function-specific competences, becomes the weak link in the concept posture.

We can derive that, from a resource-based perspective, effective product development is only possible if the right resources or competences are available. Developing new products often requires the integration of complementary resources. These resources can be distinguished between as internal and external to the firm.

It is not unusual for a company to lack some of the complementary resources required to transform the product concept into a commercial product. The company can develop such resources internally, at the expense of lead time. Alternatively, the company might gain access to important complementary resources by entering into strategic alliances or other forms of collaboration. These collaborations are especially valuable when the resources gained through such an alliance are difficult to replicate or to substitute by competitors.

2.3.2 Resource-Based Routines in Product Development Operation

During the eighties and nineties, some organizations 'overlapped' concept development and product implementation (Schilling and Hill, 1998). Overlapping phases means that these organizations started product implementation before the final concept specification was agreed (see Figure 9). The key idea is that product implementation can start with a rough product concept that can be further detailed. Such organizations shortened development lead time dramatically compared to competitors that used the traditional separation of 'planning' and 'doing'.

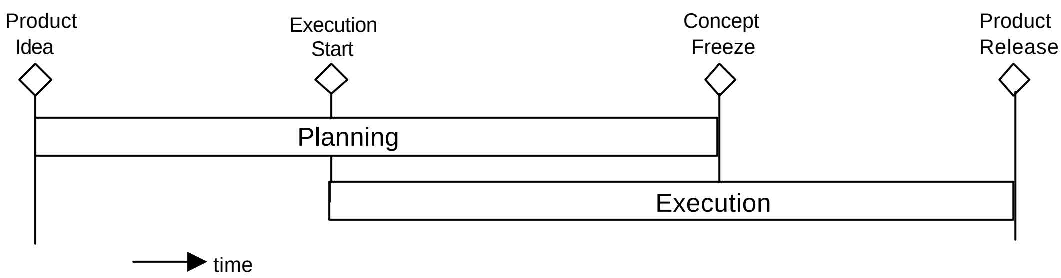


Figure 9 – Overlapping 'Planning' and 'Execution'

Moreover, this efficiency leap allowed firms to expand their product portfolios within the same available resources. For example, in 1985, Audi offered only two product lines, Audi 80 and Audi 100 with two derivatives Audi Coupe and Audi 200. Today, they offer 5 product lines A2, A3, A4, A6, A8 with various derivatives.

Starting implementation during concept development made the management of product development more challenging. While a clear separation of concept development and implementation made it easier to focus either on effectiveness or efficiency, an overlapping of phases made it necessary to manage both at the same time. Concept development, therefore, was not the ‘playing in the sand’ anymore; late concept changes had a significant impact on development cost and project lead time. With ‘overlapping’, firms gained some advantages over their competitors. They could increase the number and frequency of products launched into the marketplace and were faster in the market than their competitors (Lieberman and Montgomery, 1998).

In the resource-based perspective to product development, sustained new product success or ‘sustainable competitive advantage gained via the product’ are taken for granted as an outcome of effective and efficient product development organization. This view of product development is rooted in the traditional economic view of organizations as operating systems (e.g. Wild, 1995). Using simple system terminology, product development may be seen to comprise inputs, processes, and outputs. This simple system structure represents product development with product ideas as input and product releases as output. In the words of Clark and Wheelwright: “The aim of any product or process development project is to take an idea from concept to reality by converging to a specific product that can meet a market need in an economical, manufacturable form.” (Clark and Wheelwright, 1993).

The Product Development Funnel

This view of product development was conceptualised by Wheelwright and Clark using the “funnel” metaphor (1992). Product development starts with a broad range of ideas as input and gradually refines to a product concept and selects from among them, creating some formal development projects that can be pushed to rapid product implementation and market introduction. This notion of a converging funnel is illustrated in Figure 10 and helps to explain the product development process. The funnel metaphor structures the generation and screening of alternative product development options, combining a subset of these into product concepts, which are then implemented into commercial products. A variety of different product and process ideas enter the funnel for investigation, but only few of them will become a real commercial product or service. In the words of Clark and

Wheelwright "The funnel creates the architecture for the set of development activities that must occur as part of a successful development project" (1993).

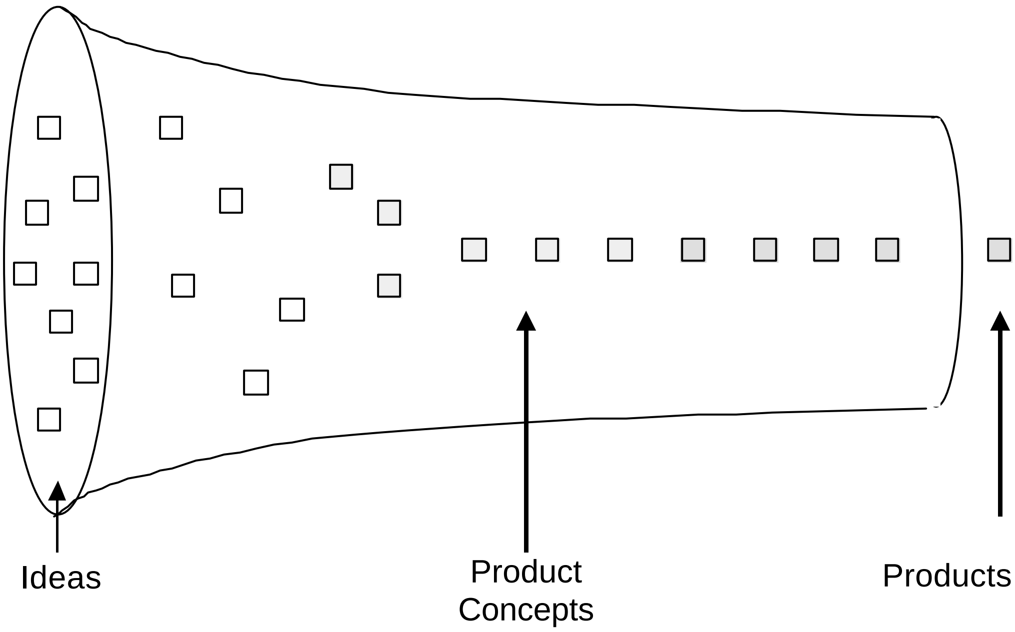


Figure 10 – The Development Funnel (Clark and Wheelwright, 1993)

Managing the development funnel entails some challenges. The first is to build variation of product ideas since organizations must expand their knowledge base and access to information to increase product ideas. The second is the selection of product ideas; that means to screen and focus resources on the most attractive opportunities. The third challenge is to balance variation and selection of product ideas. It seems best to combine various idea-generating mechanisms with a monitoring and control process.

A framework to manage product development was proposed by Cooper (Cooper, 1990) with the concept of 'stage-gate systems' that gained a lot of attention in management practice.

Stage-Gate Systems

The concept of stage-gate systems aims to monitor and control the firm's product and project progress (Cooper, 1990). A stage-gate system is a systematic process for moving a development project through the various stages from idea to launch. Cooper proposed the following structure with five stages and five gates, exhibited in Figure 11. Stage 1-2 builds the concept development phase and stage 3-5 the product implementation.

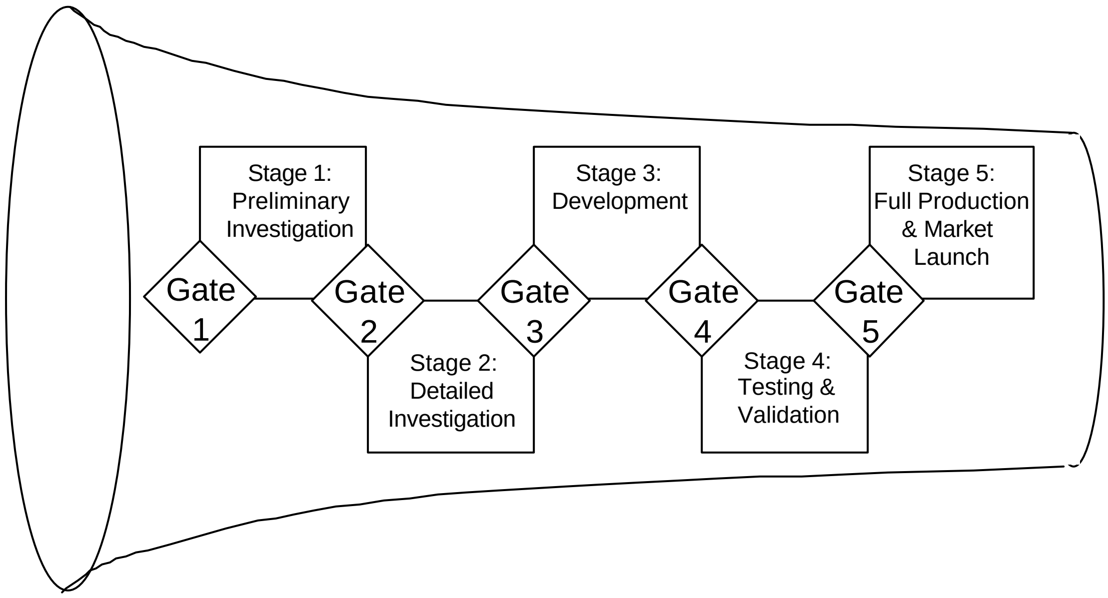


Figure 11 – A Funneling Approach, with 5 Overlapping Stages and Gates (Cooper, 1994)

Cooper and Kleinschmidt supported their stage-gate concept by a benchmarking study examining new product efforts of 161 business units (Cooper and Kleinschmidt, 1995). The authors identified three critical success factors to be the drivers of new product success: A high quality process, a clear and well-communicated new product strategy, and adequate resource allocation for the development effort. The three success factors in detail were

1. A high quality process: This process includes those steps and activities in a product development project from idea to launch. Particularly important was the concept development phase. This included developing a well-defined target market, product specifications, clear product concept, and extensive preliminary market and technical assessments. Other process factors were also important, including cross-functional skills and their synergies with existing competences.

2. A clear and well-communicated new product strategy. Cooper and Kleinschmidt found that products with clear goals and objectives were more likely to be successful.

3. Adequate resource allocation for new products. Senior management support was found to be especially important for devoting the necessary resources to achieve the project's goals.

A high quality product development process was found to be the strongest common denominator among successful products – more powerful than having a new product strategy or even having the right resources in place – although the three critical success factors were intimately connected, and the symbiotic effect of all three acting together yielded the most positive results.

Concluding Resource-Based Pattern

For product development, the resource-based perspective has several implications. New product success depends on the consistency between the intended product concept and the firm's available resources and competences. Therefore, developing a product means not only to think about products and markets. It also requires thinking about available resources and competences that determine feasibility of the intended product concept.

In addition, this perspective emphasizes that product development capability is reflected in product development organization, i.e. structure and process. Simply put, if product development is professionally organized and carried out, product development is successful.

The resource-based perspective recognizes the importance of resources and their utilization and coordination in explaining new product success. However, a resource-based perspective suffers from some shortcomings. This view may help to think about internal characteristics of product development capability, but it loses sight of product and market and cannot adequately explain how and why certain firms enjoy competitive advantages in situations of rapid and unpredictable change (Eisenhardt and Martin, 2000).

In contrast to the market-based perspective, this perspective has more depth and is more specific about product development process and organization.

However, both market-based and resource-based perspectives scarcely consider the dynamic aspects of changing markets and technologies. This is the topic of the following evolutionary perspective to product development capability.

2.4 Evolutionary Pattern of Product Development Capability

A fast growing number of management researchers suggest the need for developing conceptual frameworks that would allow an explanation of the dynamic aspects of firm behavior over time. Evolutionary theory may be useful for this purpose. This perspective is emerging in economics (Nelson and Winter, 1982), organization theory (Hannan and Freeman, 1984) and strategic management literature (Burgelman and Rosenbloom, 1997).

Evolutionary theory recognizes the importance of history, irreversibility, invariance, and inertia in explaining organizational behavior as a sociological system. Clark (1985) found that the study of product development contains many elements that seem compatible with the variation-selection-retention structure of evolutionary theory.

In evolutionary theory, a general term used to explain the behavioral pattern of firms is 'routine'. Routines can be interpreted as the basic elements of processes and play the role that genes play in biological evolutionary theory. They are a persistent feature of the organism and determine its possible behavior (Nelson and Winter, 1982).

An evolutionary perspective focuses on mechanisms of variation, selection, and retention for explaining dynamic behavior over time. This is reflected in the three different types of routines proposed by Nelson and Winter (1982): search routines, investment routines, and operating routines in order to explain dynamic firm behavior. Teece et al. (1994) proposed a distinction between static and dynamic routines.

Two characteristics of routines are important to note. Firstly, the distinction in different types is subtle and continuous and not clear and sharp and secondly, different types of routines exhibit simultaneous, interacting aspects of the evolutionary process (Nelson and Winter, 1982).

Embedded in the evolutionary perspective is a view of product development as a social learning process. In this view, effective product development is inherently a function of building and reconfiguring of competences (Teece et al., 1997). Such reconfigurations are the source of opportunities, which are discovered, selected, and retained through product development. Performing product development is expected to have feedback effects on the overall product development capability (Burgelman and Rosenbloom, 1997).

Two key ideas for product development capability underlying the evolutionary perspective are useful to note. First, successful firms develop distinctive product development capability in the course of their product development efforts and the direction of development cannot be determined at the outset (Nelson and Winter, 1982). The second idea is that "unlearning" is an important aspect of product development capability (Nonaka and Takeuchi, 1995).

2.4.1 Technology as Driver of Evolutionary Processes

In the following, I focus on technology as a driver of evolutionary processes. In a narrow sense, this scope is incomplete because market shifts and changes of customer preferences can also drive evolutionary processes. But for the purposes of this work, and not to lose the main focus of product development, I concentrate on technology as the driver of evolutionary processes.

When technology, in its broadest sense, is embodied in technological competences, technical progress puts the organization in a state of incessant reconfiguration. Its structure and processes must continuously adapt to innovations in products, technologies, modes of organization, and to evolving competitiveness of markets (Brown and Eisenhardt, 1997, Eisenhardt and Brown, 1999). Competences that embody new technologies must continually be created, while outdated competences must be released.

Effective product development can, therefore, be interpreted as a Schumpeterian process of "creative destruction" (Schumpeter, 1942, Neff and Shanklin, 1997) that results in an ongoing renewal of competences and often entails distressing competence losses, even of core competences (Leonard-Barton, 1992a, Lynskey, 1999).

Product development should define an effective response to threats and opportunities in markets and technologies by matching the approach of the project and product to the firm's evolving environmental context (Teece, 1998). These threats and opportunities in markets and technologies are opportunities for innovation and, therefore, innovation should be seen as an integral part of product development (Tyre and Orlikowski, 1993, Tyre and Orlikowski, 1994, Bower and Christensen, 1995).

Product development in such a sense is not an isolated event where managers can conceptualize the product along their available resources and market positions. Product development happens in an environmental context, which influences all levels of managerial and organizational routines embedded in product development activities (D'Aveni, 1999, Teece, 2000). Therefore, new product success is strongly driven by the requirements of the environmental context.

Categorization of Environments

In literature, characteristics and categorization of environmental contexts can be found in different research streams. In strategic management literature, environments are categorized according to their dynamism; environments are described as “high-velocity” (Eisenhardt and Bourgeois, 1988) or “hyper-competitive” (D'Aveni, 1994) and according to new developments in complexity theory as “rugged fitness landscapes” (Beinhocker, 1999).

However, not all environments with above-the-average change rate can be termed dynamic. Environments that change often but in a predictable way and environments with a limited number of strategically relevant variables (e.g. government regulated markets) can hardly be classified as dynamic environments. In literature, two characteristics are often used to describe dynamic environments: frequency and intensity of technological change.

Frequency of technological change is one characteristic of dynamic environments. The more technological innovations occur in one industry, the more dynamic are environments. Some studies use R&D expenditures, e.g. (Medcaf, 1999), or patent citations, e.g. (Deng et al., 1999), as metrics that indicate the frequency of innovation.

Intensity of technological change is another characteristic of dynamic environments. The more radical innovations occur in one industry, the more dynamic are environments. Some studies use cyclical models of technology (Anderson and Tushman, 1990), and/or trajectory models of technology (Christensen, 1997) that explain intensity of technological change.

Such dynamics have accentuated the importance of speed and variety in product development especially in turbulent industries like telecommunications. But changes in competition, customer demand, and technology also have dramatic effects on older, more mature industries in which product innovation has always been an important part of competition. In the automobile industry, for example, life cycles have shortened and product variety has increased. In addition, competition has placed increased pressure on new innovative product features as well as reliability and cost (Tyre and Orlikowski, 1993).

2.4.2 Incremental vs. Breakthrough Projects

Concurrent to the intensity of technological change, organizations can develop products in different ways. Their projects can follow a breakthrough path, resulting in products that satisfy customer needs by embodying a fundamentally different technological base (Stringer, 2000). Such was the case in the development of the Sony transistor radio, which offered the customer a large increase in functionality at a much lower price. Projects can also follow an incremental path (Johnson, 1988). This approach leverages existing technologies and resources, increasing their match with market requirements. This was the case when Sony introduced the Walkman in the early 1980s. The product achieved a much smaller size than usual cassette players without changing its technology base. Not only can both breakthrough and incremental paths tackle technological challenges but both types may coexist even within the same context (Henderson and Clark, 1990, Utterback, 1994, Sharma, 1999). Such is the case in some platform projects that are incremental by definition but can possess some breakthrough characteristics. The same firm might even choose different approaches for different aspects of a single new product. Day and Schoemaker (2000) found that many manufacturers often decide to introduce new technologies in some subsystems, and focus on more incremental change.

These different degrees of change have different implications for product development (Rice et al., 1998, Kaplan, 1999). Radical technological change can be associated with breakthrough projects and incremental technological change with incremental projects (see Figure 12). The higher the level of technological change, the greater the organizational impact.

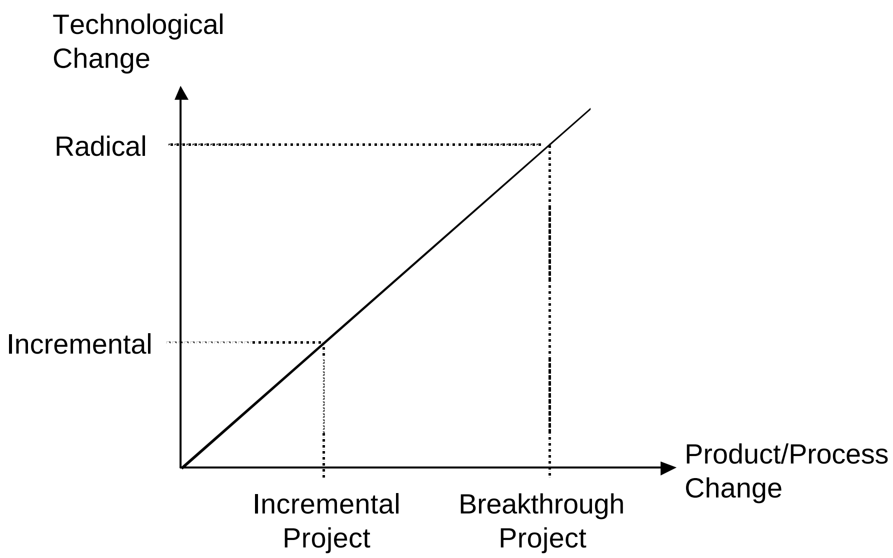


Figure 12 –Types of Projects

Framed in the way of Figure 12, incremental and breakthrough projects are extreme points along both dimensions. Breakthrough projects might establish a new dominant design, which means new product/process components linked together in a new product/process architecture. Incremental projects extend the established design, which is exhibited in improvements of individual product and process components, but the product and process architecture remain the same.

In this logic, one can characterize the context of development projects along their degree of change. A breakthrough project renders obsolete the competences required to master the technology that it replaces. For example, the skills of mechanical type writers were rendered irrelevant by the development of electronic type writers and integrated circuits, respectively.

An incremental project builds on competences embodied in the technology that it replaces. For example, the Audi Cabriolet built on the technology platform of the Audi

A4. Incremental projects introduce new technical competences, with enhanced product performance while building on an existing technical order rather than making it obsolete.

2.4.3 Evolutionary Routines in Product Development Operation

Work by Abernathy and Utterback (1978) showed that radical technological change does not emerge fully developed at the outset of product development. Technological evolution is usually characterized by periods of uncertainty followed by the acceptance of a dominant design that opens the period of incremental change.

This pervasive phenomenon that occurs across industries and that is critical to understanding when and why breakthrough or incremental projects occur is the dynamic of product, service, and process innovation, dominant designs, and substitution events which together make up technology cycles (Utterback, 1994, Tushman and Anderson, 1997).

In any industry, there is a pattern of competition that describes the development of products over time (Tushman and Anderson, 1997). Technology cycles begin with a proliferation of innovation in products or services as the new product or service gains acceptance. At some point, a design emerged that became the standard preferred by customers. Once this occurred, the basis of competition shifted to price and features, not basic product or service design. The emergence of this dominant design transforms competition in the market (Utterback, 1994). Once it is clear that a dominant design has emerged, the basis of competition shifts to process innovation, driving down costs, and adding features. Instead of competing through product or service innovation, successful strategies now emphasize compatibility with the standard and productivity improvement. This competition continues until there is a major new product, service, or process substitution and the technology cycle kicks off again. As firms change their strategies, they must also realign their product development efforts to accomplish the new strategic objectives. This often requires breakthrough projects.

The Interaction between Technology and Product Development

The concept of technology cycles and dominant design provides the answer of when and how incremental and breakthrough projects occur. Over a period of time, successful firms learn what works well and incorporate this into their operations. This is what organizational learning is about; using feedback from the market to continually refine products to get better and better at accomplishing its product trajectories. Such an attempt requires a kind of concurrency between product development projects and technology cycles. Further, since this concurrency is never perfect, achieving concurrency is an ongoing process requiring first a breakthrough project in order to create product/service innovation, and then to harvest the trajectory by incremental projects through continuous improvement (Orlikowski, 1992, Tushman et al., 1992, Tushman, 1996, Romanelli and Tushman, 1994). Figure 13 exemplifies the principle.

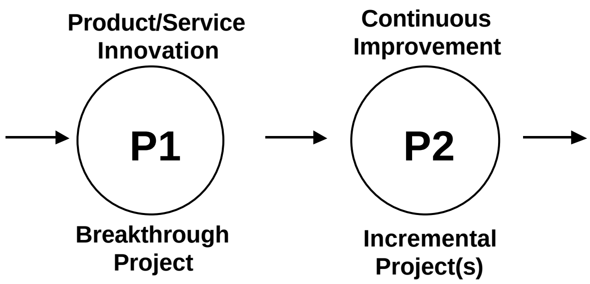


Figure 13 – Concurrency between Project Trajectories and Technology Cycles

Concluding Evolutionary Pattern

Overall, the evolutionary perspective envisions that product development capability creates product trajectories that evolve concurrent to technological evolutions. Firms learn through breakthrough project and utilize their competences through one or more incremental projects. In other words, from an evolutionary perspective, effective product development creates effective product trajectories concurrent to environmental evolutions.

The evolutionary perspective recognizes the importance of technological opportunities in explaining effective product development (Lieberman and Montgomery, 1988). Product development shouldn't be approached as a sole event; it is more a series of projects that mutually adapts technology and organization in order to stay ahead of competition. Simply put, if firms are able to find and follow fruitful technology trajectories they enjoy long-term new product success.

Firms engaging in innovation may find a path dead ahead. New technological opportunities may be attractive to create new product trajectories. If this opportunity is extremely attractive, firms can shift the allocation of resources away from traditional pursuits.

In contrast to the market-based and resource-based perspective, this stream is more specific about technology cycles and their organizational impact. Product development in this sense is not an isolated event; it is part of an unfolding sequence of technological solutions that altogether create streams of product development projects.

However, this stream suffers from some shortcomings. This perspective may help to think about the importance of technological progress but its scope are industry-level aspects. So it has more breadth but less depth than product-market aspects and resource utilization aspects of new product success. In addition, some of the constructs are very theoretical and therefore challenging for management practice. For example, how does management detect technological opportunities or how can organizations be responsive to technological change? Although this lack of clarity may reflect the complexity of the subject, it also impairs the usefulness of this perspective.

2.5 Dynamic Pattern of Product Development Capability

All three presented perspectives (market-based, resource-based, evolutionary) provide different accounts to product development capability. The market-based perspective emphasizes the significance of product-market positioning while the resource-based perspective outlines the importance of product development process and organization. The evolutionary perspective puts the focus on technological opportunities in order to create technological progress and related product trajectories.

However, no one perspective can capture all different facets of product development capability. Some authors criticized each of these perspectives. For example, Barney (1991) criticized market-based perspective as "only half the story of understanding sources of competitive advantage". Priem and Butler (2001) criticized a resource-based view in four broad categories: (1) that a resource-based view is tautological, (2) that the argument fails to acknowledge that many different resource configurations could generate the same value for firms and, therefore, would not be sources of competitive advantage, (3) that the role of product markets is underdeveloped in the argument, and (4) that the theory developed has limited prescriptive implications (Barney, 2001). Miller and Shamsie (1995) found that it is meaningless to attempt to define resources independent of the tasks they are to serve and the environment within which they must function.

Eisenhardt noted that a resource-based view cannot adequately explain how and why certain firms are more effective in situations of rapid and unpredictable change than others (Eisenhardt and Martin, 2000). D'Aveni found that sustained competitive advantage is unlikely in dynamic markets (D'Aveni, 1994). Gould criticized evolutionary theory and more general the application of concepts from biological evolutions to processes of social and cultural evolutions and termed it the "fallacy of unwarranted analogy" (Gould, 1987).

Taking into account these admonitions, an integration of concepts and theories that utilizes each perspective's strengths and avoids weaknesses would be a possibility to overcome this criticism. Especially complementing (the more 'static') market-based and resource-based perspective with evolutionary reasoning promises new insights for product development research. Evolutionary reasoning in identifying and explaining technological and organizational evolutions can provide further insights and understanding especially of dynamic phenomena.

Integrating perspectives may be useful for integrating extant literature on management and technology (Burgelman and Rosenbloom, 1997) or as Winter pointed out "It is addressing the dynamics of resource exploitation that one finds the strongest complementarities between the resource-based view and evolutionary economics…" (Winter, 1995).

In 1997, such an 'integrated' theory was presented by Teece, Pisano and Shuen with the concept of 'Dynamic Capabilities' (Teece et al., 1997). The concept of dynamic capabilities can be interpreted as a 'hybrid' of a resource-based view and evolutionary theory.

2.5.1 The Concept of Dynamic Capabilities

The concept of dynamic capabilities has its roots in the notion of core competences (Prahalad and Hamel, 1990) and related learning mechanisms. As an 'integrated' strategic management concept, it was first presented in 1997 by Teece, Pisano and Shuen (1997) and later reconceptualized by Eisenhardt and Martin (2000). Both conceptualizations are briefly presented within this section.

The concept of dynamic capabilities is an influential framework in strategic management literature for understanding how competitive advantage is achieved and how that advantage might be sustained over time (Teece et al. 1997; Eisenhardt and Martin 2000). This perspective integrates the internal organization of firms and the dynamic interaction between firms and their environmental context (Henderson and Cockburn 1994; Teece et al. 1997).

In 1997, Teece, Pisano and Shuen proposed a dynamic capabilities framework, which "analyzes the sources and methods of wealth creation and capture by private enterprise firms operating in environments of rapid technological change" (Teece et al., 1997). According to Teece et al. (1997), dynamic capabilities can be defined as a "subset of competences, which allow the firm to create new products and processes, and respond to changing market circumstances". This definition makes clear that product development capability can be interpreted as a dynamic capability in the sense of the concept of dynamic capabilities.

Following Teece and colleagues, the evaluation of dynamic capabilities is only possible through a differentiated analysis of (i) the firm-specific resource position, (ii) the historical path, and (iii) the processes of a firm (see Figure 14).

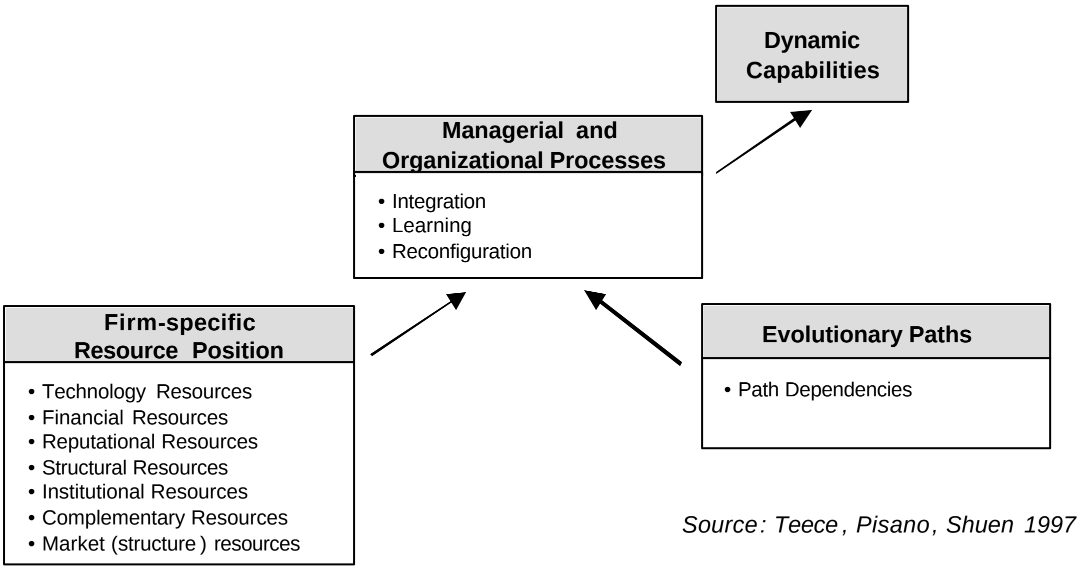


Figure 14 – The Concept of Dynamic Capabilities according to Teece, Pisano and Shuen 1997

According to 'positions', Teece et al. (1997) noticed "The strategic posture of the firm is determined not only by its learning processes and by the coherence of its internal and external processes and incentives, but also by its specific assets. (…). These include its difficult-to-trade knowledge assets and assets complementary to them, as well as its reputational and relational assets." For the assessment of the firm-specific resource position, a definition by Barney (Barney, 1991) or a framework proposed by Wernerfelt (Wernerfelt, 1984) can help to evaluate existent resource positions.

According to the evolutionary path and firm history, Teece et al. (1997) noticed, "the notion of path dependencies recognizes that "history matters". Bygones are rarely bygones, despite the predictions of rational actor theory. Thus a firm's previous investments and its repertoire of routines (its "history") constrain its future behavior". Consequently, apart from other factors, the evolutionary path of the firm constrains product development capability and, therefore, new product success.

The managerial and organizational processes[1] represent the organization's knowledge and its competences (Teece et al., 1997). This goes largely with Nelson and Winter's

[1] For a complete conceptualization of managerial and organizational processes see Garvin (1998)

evolutionary view on organizations (Nelson and Winter, 1982). Both approaches focus on the evolution and renewal of organizational capabilities over time. They evolved from different motivations and from different levels of perspective, but lead to similar results and insights. This can explicitly be seen in a process definition of Teece (1997): “By managerial and organizational processes, we refer to the way things are done in the firm, or what might be referred to as its routines”. Teece and colleagues characterized processes with the term “routines”, which builds the focus of interest of Nelson and Winter’s evolutionary level of analysis (Nelson and Winter, 1982).

These three classes of factors ‘positions’, ‘processes’, and ‘paths’ help determine a firm’s dynamic capabilities. Therefore, dynamic capabilities are embedded in organizational processes and are shaped by the assets the firm possesses (internal and market) and by the evolutionary path it has adopted (Teece et al., 1997). I will follow and apply the approach of Teece and colleagues in the case studies in Chapter 4.

In 2000, Eisenhardt and Martin re-conceptualized dynamic capabilities from “tautological routines to learn routines that have been criticized as being tautological, endlessly recursive, and non-operational” towards “identifiable and specific routines that have been the subject of extensive empirical research in their own right outside the resource-based view of the firm” (2000). Moreover, they observed that dynamic capabilities “exhibit common features that are associated with effective processes across firms. (..) In popular parlance, there is best practice” (Eisenhardt and Martin, 2000). Table 4 presents the contrasting concepts of dynamic capabilities of Teece et al. and Eisenhardt et al.

Overall, Eisenhardt and Martin claimed that dynamic capabilities are specific processes like product development. Moreover, these capabilities are supposed to exhibit common features that are associated with effective processes across firms, which is commonly termed as “best practice”. They provided examples like cross-functional teams or customer feedback for such commonalities. However, the re-conceptualization of dynamic capabilities of Eisenhardt and Martin comes close to our aim to study the pattern of product development capability on an operation-level instead of firm-level. To do so, we need to study the routines and structures of product development from a dynamic capability perspective.

	Traditional view of dynamic capabilities	**Reconceptualization of dynamic capabilities**
Definition	Routines to learn routines	Specific organizational and strategic processes (e.g. product development)
Pattern	Detailed analytic routines	Depending on market dynamism, ranging from detailed, analytic routines to simple, experiential ones
Competitive Advantage	Sustained competitive advantage from VRIN attributes	Competitive advantage from valuable, somewhat rare, equifinal, substitutable, and fungible dynamic capabilities

Table 4 – Contrasting Conception of Dynamic Capabilities (Eisenhardt and Martin, 2000)

2.5.2 Organizational and Managerial Processes

Following the dynamic capabilities perspective of Teece (1997) and Eisenhardt (2000) the processes that create product development capability can be distinguished into three different types: routines of integration (e.g. Helfat and Raubitschek, 2000), learning (e.g. Henderson and Cockburn, 1994), and reconfiguration (e.g. Katzy et al., 2003).

Routines of integration continuously integrate all executed activities in organizations. Recently, these processes were very much in the scope of various initiatives, e.g. process reengineering (Hammer, 1990, Hammer and Champy, 1994, Hammer and Stanton, 1999) or cross-functional teams (Clark and Fujimoto, 1991, Wheelwright and Clark, 1992, Clark and Wheelwright, 1992, Lutz, 1994) among others. Identification and adoption of new knowledge is commonly dedicated to learning routines. Changes in organizational structure and processes are usually referred to as reconfiguration routines. Both static and dynamic routines show interacting aspects, their separation is not clear and sharp (Nelson and Winter, 1982, Ghemawat and Costa, 1993). Because of increasing turbulences in technology and markets in the last years, the routines of learning and reconfiguration especially have recently been in the scope of literature in strategic management and change, e.g. (Cohen and Levinthal, 1990, Henderson and Clark, 1990, Tushman, 1996, Burgelman and Rosenbloom, 1997, Eisenhardt and Brown, 1999, Eisenhardt and Martin, 2000, Teece et al., 1997).

The idea that routines might lead to dynamic capabilities seems to contradict well-known theories that routines cause organizational inertia (Hannan and Freeman, 1984). However, this ambiguity requires a distinction between routines of different ‘orders’ (Nelson and Winter, 1982). Lewin (1951) argued that any operation at any point in time is order zero, change of that operation is order 1, change of change is level 2 etc. To distinguish these types of routines, I term order ‘0’ routines ‘static routines’ and order ‘1 or more’ routines ‘dynamic routines’. With such nomenclature, we can note that routines of integration are static routines (order zero) and routines of learning and reconfiguration are dynamic routines (order 1+).

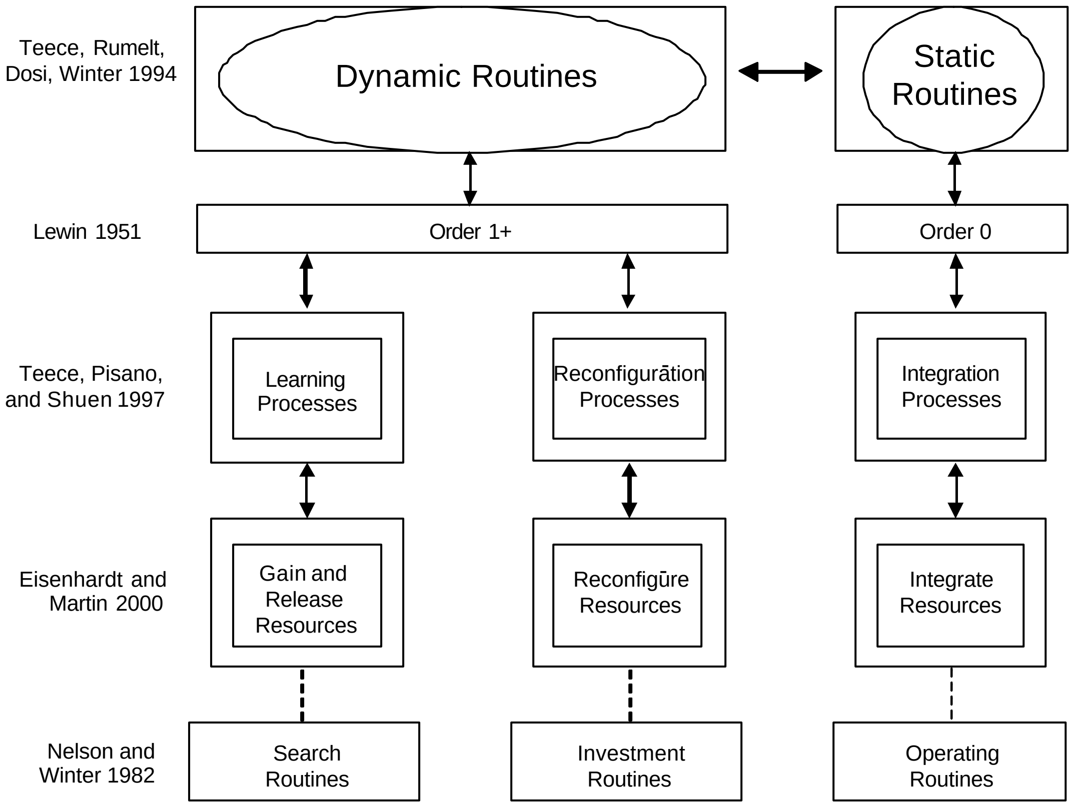


Figure 15 – Pattern of Product Development Capability from a Dynamic Capability Perspective

This complementary classification of routines allows conceptualizing product development capability in accordance with the concept of dynamic capabilities. Figure 15 shows the pattern of product development capability from a dynamic capability perspective. Pattern of product development capability can be conceptualized by distinguishing between static and dynamic routines. While static routines are the sequences of activities that build the overall product development process (operating routines), dynamic routines are mechanisms of learning and reconfiguration (search and investment routines).

The knowledge generated by product development may be thought of as organizational routines and standard operating procedures (Nelson and Winter, 1982). These are patterns of interactions which represent successful solutions to particular problems and which are resident in group behaviour, through certain sub-routines may be individual behaviour (Teece et al., 1994).

Routines can be of several kinds. In this process model of product development capability, product development is presented as a set of static and dynamic routines. Static routines embody the capacity to replicate certain previously performed tasks. Such routines are never entirely static, because with repetition routines can be continuously improved. The presence of learning curves often indicates the operation of static routines (Teece et al., 1994, King and Tucci, 2002).

Product Development Capability and Routines of Integration

Integration embraces the effective and efficient coordination and integration of activities (Lawrence and Lorsch, 1967, Aoki, 1990, Iansiti and Clark, 1994). Work by Clark and Fujimoto on product development in the automobile industry illustrates such 'static routines' and the role of coordination, communication, and integration in developing new products (Clark and Fujimoto, 1991). Their study reveals a significant level of variation in how different firms perform the various activities required to develop a product from concept to market. These differences in product development capability seem to have a significant impact on such performance variables as development cost and time, and quality and seemed to have persisted for a long time.

The fact that the dominant structure in most organizations is functional and that most tasks needed in a development project are defined and conducted in functions, adds the challenge of cross-functional integration. From engineering one needs design, tests, and prototypes; from marketing, product positioning, customer analysis, and launch plans; from manufacturing, processes, cost estimates, pilot production and ramp-up. Integration and coordination within and between these functions were very much in the scope of recent product development literature, e.g. Takeuchi (1986), Clark and Fujimoto (1991) or Wheelwright and Clark (1992).

In the 1990s most organizations adopted cross-functional team structures. However, as organizations experimented with such teams, they discovered that success with cross-functional teams required more than simply putting together a team. The problem lied in making such teams work effectively.

In automobiles, Clark and Fujimoto's findings suggest that the best firms in the auto industry have cut traditional new car development cycle times significantly. In the process, they have delivered better products and, in many cases, more than doubled the productivity of critical engineering resources. These firms seem to have developed a much more effective way to organize and lead cross-functional teams than their rivals (Clark and Fujimoto, 1991).

The reasons lie in structures and dedicated project leadership. Four levels of teams are commonly described in product development literature: functional teams, where work is completed in the function and coordinated by functional managers; lightweight teams, where a coordinator works through liaison representatives but has little influence over the work; heavyweight teams, where a strong leader exerts direct, integrating influence across all functions; and autonomous teams, where a heavyweight team is removed from the function, dedicated to a single project, and co-located.

Because of the wide range of situations in which firms operate, it is not surprising that different organizations employ different project and team structures and there is not one best way for project organization.

While integration is important, learning and reconfiguration are at least as important as integration but often neglected in product development literature. From a dynamic capability perspective, these dynamic routines are a crucial part of product development capability and, therefore, they have to be studied more thoroughly.

Product Development Capability and Routines of Learning

Learning starts with the identification of 'productive opportunities'. These opportunities can be new technologies with potential for product innovation as well as new market potentials for existing products. The recognition of new opportunities depends heavily on the applied search routines of the firm, which can be interpreted as in operational processes codified search behavior (Mc Grath et al., 1995, Winter, 2000). This search behavior catalyses the generation of new internal and external competences, and can be termed as "absorptive capacity" (Cohen and Levinthal, 1990, Zahra, 1999).

The constructs 'search routines' and 'learning' can be more accurately described in terms of learning mechanisms that have been identified principally in various streams of management and social literature (Leonard-Barton, 1992b, Eisenhardt and Martin, 2000). For example, repeated practice builds experience as an important learning mechanism. The codification of that experience into technology and formal procedures makes that experience easier to apply and accelerate the building of routines (Zander and Kogut, 1995, Eisenhardt and Martin, 2000).

Experimentation also plays a critical role as a learning mechanism. Experimentation involves the systematic searching for and testing of new competences and there are obvious parallels to systematic problem solving. But unlike problem solving, experimentation is usually motivated by opportunity and expanding knowledge, not by current difficulties. Experimentation takes two main forms: ongoing programs and one-of-a-kind demonstration projects (Garwin, 1994).

Ongoing programs usually involve a continuing series of small experiments, designed to produce incremental gains of knowledge. They are the mainstay of most continuous improvement programs and are especially founded in the quality movement (Juran and Gyrna, 1988). Audi, for example, experiments continuously with diverse raw materials and new technologies to increase quality and provide better product functionality. In production, Audi regularly examines new techniques and improved technologies to raise productivity and reduce costs.

Demonstration projects are usually larger and more complex than ongoing experiments. They involve holistic, system-wide changes, introduced at a single site, and are often undertaken with the goal of developing new organizational competences. Because these projects represent a sharp break from the past, they are usually designed from scratch. For example, in 1991, the Audi 'Avus' , the first aluminum-bodied prototype of Audi, was a pioneering demonstration project initiated to introduce the idea of reducing weight and increase performance of high-performance cars by using aluminum instead of steel as the body material.

In sum, from a dynamic capability perspective, learning is a basic mechanism of product development capability and especially critical in turbulent markets where technology bases and customer preferences are shifting. However, learning is affected by the historical path a firm evolved through the past.

Product Development Capability and Path Dependencies

The firm's current ability to 'learn' is restricted by the existing products and competences. An example for such 'path dependencies' can be observed at the Italian sports car manufacturer Lamborghini, which was bought by Audi in 1998. Because Audi has an in-depth expert knowledge with aluminum car bodies, Audi replicated its aluminum competence for Lamborghini by sending Audi people to the manufacturing plant of Lamborghini and by training Lamborghini people at the Aluminum Competence Center in Neckarsulm. Lamborghini combined its existing competence in building high performance sports cars with the aluminum competence of Audi and applied this new competence base to the design of a brand new aluminum-bodied sports car, called 'Gallardo' which was launched in 2003 and which is remarkably light-weighted.

This example shows that the development of a lightweight Lamborghini sports car was only possible because of the combination of Audi's aluminum competence and Lamborghini's sports car competence. In many cases, some of the management recognized opportunities couldn't be exploited because the necessary competences are not available internally and externally. In that case, new competences have to be built or existing competences have to be enhanced through internal learning by research efforts, reorganization initiatives etc. or external learning through acquisitions, strategic alliances, joint ventures or new people etc. (Kogut and Zander, 1997).

Therefore, ‘learning’ depends on the historical path of the firm (Nelson and Winter, 1982, Teece et al., 1997). Exemplarily, I describe an important phenomenon of this evolutionary problem in building new competences from a resource-based perspective:

“Coherence (…) is a measure of relatedness” (Teece et al., 1994). This phenomenon can be analyzed on the level of organizations and product trajectories. Following the theory of coherence, which is an integration of an evolutionary and resource-based view, an organization has only a very restricted “learning domain” for successful innovations and for the building of new competences. This “learning domain” is determined by the deployed technologies and well-known markets. Figure 16 reflects this argument graphically.

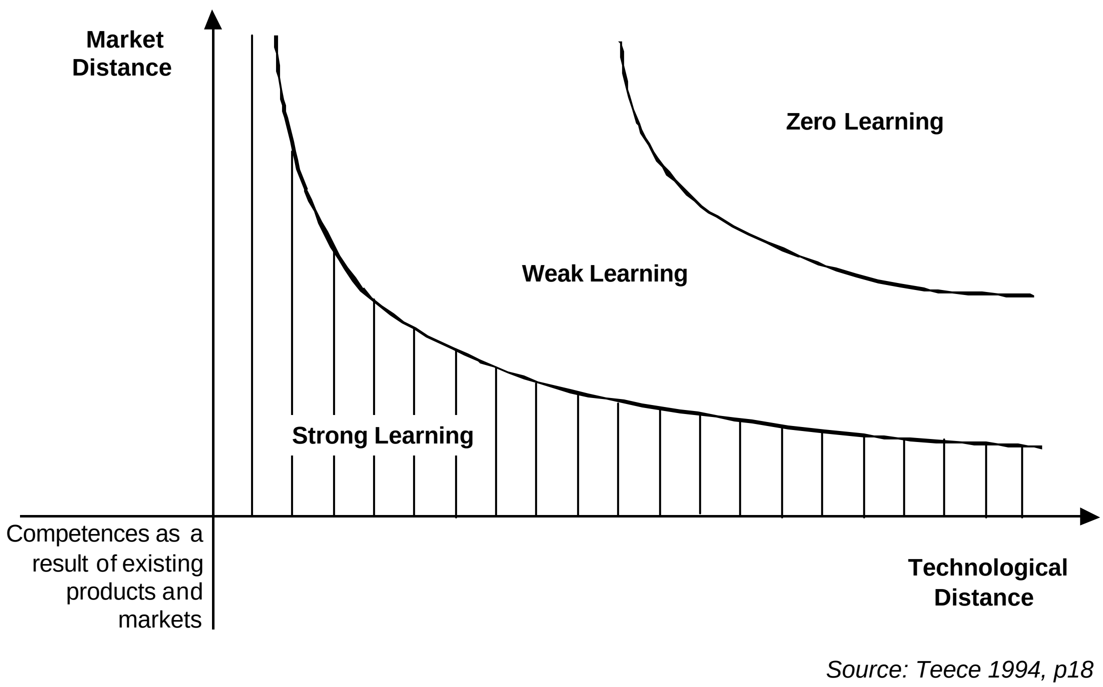


Figure 16 – “Learning Domain” - Dependence on Existing Competences

Teece and colleagues described this phenomenon with the following words: “The local nature of enterprise learning significantly restricts what firms can do. Their future activities are highly dependant on what they have done in the past (…). Opportunities for successful new product development will be ‘close in’ to previous activities and will thus be transaction and product specific (…). If many aspects of a firm’s learning environment change simultaneously, the ability to ascertain cause-effect relationships is confounded because cognitive structures will not be formed and rates of learning diminish as a result.” (Teece et al., 1994).

In other words, the ability to build new competences is restricted by the existing competence base and market position or, referred to this work, product development capability is influenced by the current existing competence base and market position. Core competences in this sense can become easily core-rigidities and impede learning (Leonard-Barton, 1992a).

Figure 17 shows graphically the argumentation that project P_3 is only possible with market position M_2 and competence base C_2 and both were developed by project P_2 etc. Therefore, a firm is restricted in what product concept it can develop or not.

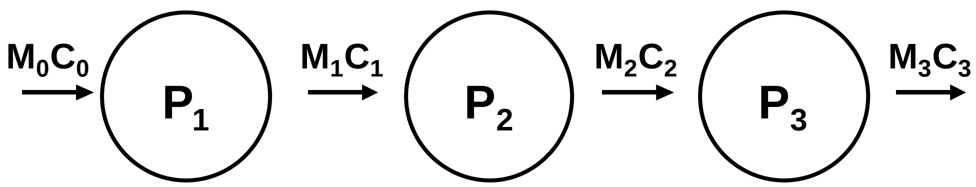


Figure 17 – Product Development and Path Dependency

Product Development Capability and Routines of Reconfiguration

Teece (1996) found that firm boundaries (the level of integration) and formal and informal organizational structure must be recognized as major determinants of the rate and direction of innovation. Today’s textbooks describe organizational structures as either organic and thus appropriately structured for innovation and change (Burns and Stalker, 1966, Lawrence and Lorsch, 1967, Rindova and Kotha, 2001), or machine-like, and thus appropriately structured for environmental stability (Mintzberg, 1979, Mintzberg and McHugh, 1985).

In such a sense, product development organization should be either 'adaptive and flexible' or 'productive and efficient'. Simply said, product development should be structured either for flexibility or efficiency. However, what if the conditions require both flexibility and efficiency? Neither of these simplistic views for organizing comes close to adequately describing the subtleties required to develop a product successfully.

Brown and Eisenhardt's (1997) study of multiple product development processes is an illustration. The authors found that firms with highly structured processes such as extensive gating procedures developed new products quickly, but that those products often were not well adapted to market conditions. But firms without some simple rules were equally ineffective. Developers at these firms had difficulty developing products on time to hit market windows and consistently reinvented technological solutions.

From this standpoint, I agree with Schoonhoven and Jelinek's (1990) argumentation that modern firms need both flexibility and efficiency. This imposes a dynamic balance on product development to be simultaneously clearly structured for efficiency while adapting to organizational modifications required by changes in their technological and market conditions. For product development, this has to be done time after time, product after product, depending on the environmental context. The old formula of flexibility vs. efficiency does not work because product development must simultaneously be both flexible and efficient to be successful, and thus organizations must be organized simultaneously for both flexibility and efficiency.

This argumentation shows that one way through which organizations reconfigure themselves to adapt to technological and environmental change is by reorganizing their formal structures, rather than by so-called organic structures (Burns and Stalker, 1966, Lawrence and Lorsch, 1967), in which responsibilities are continuously ambiguous.

For product development, companies should adapt their structure to the type of project (incremental vs. breakthrough) they are faced with (Schoonhoven and Jelinek, 1990). They shift from one existing clear structure designed for a specific kind of project to another clear structure. Again, Figure 17 shows these reconfigurations on a project-by-project basis.

This reconfiguration on a project-by-project basis is neither simple nor easy to manage. It requires a reasonable store of architectural knowledge of the product that is going to be developed and more than the usual degree of insight (Galunic and Eisenhardt, 1996, Galunic and Eisenhardt, 2001). For example, Henderson and Clark (1990) studied the problems of established firms in the photolithographic industry with reconfiguring for architectural innovations. These are innovations where new product architectures are required but the technological foundation remains the same.

Neither organizational structure is ‘wrong’ or ‘right’ in any absolute sense; each may be right or wrong for the firms in question (Brown and Eisenhardt, 1997, Madhok and Osegowitsch, 2000). Reconfiguration must, then, rest on a type of situational logic that does not focus on ‘one best way’ but which can be tailored to the project context as it is faced.

As these derivations show, dynamic routines, i.e. learning and reconfiguration, are at least as important as static routines (integration) as basic components of product development capability. They are path dependant and restricted by the current resource and market position. Within the following section, I want to identify the nature of such routines in product development operation.

2.5.3 Processes of Product Development Operation

In contrast to the previous perspectives, the dynamic capability perspective highlighted the importance of different type of processes to explore the pattern of product development capability. We know how firms learn on a project-by-project basis but it still remains fuzzy as to how static and dynamic routines are exhibited and interrelated in product development operation. I therefore change towards a project-level perspective to study product development activities and their interaction with dynamic routines mentioned above. I ask how organizations learn and reconfigure within product development projects because this question is important to structure observations of the following case studies.

Research on product development has contributed a much deeper understanding of processes, structures, and tools underlying product development success. Practitioners and academics have written about the product development imperatives of speed, productivity, and quality. This research has also investigated the approaches needed to meet these challenges, such as integrated problem-solving and concurrent engineering, the impact of project teams, and the role of project leadership (Maidique and Zirger, 1985, Roberts, 1988, Ancona and Caldwell, 1990, .

Traditionally, companies adopt a kind of linear approach to product development that assumes the required information on market needs and technical options is available at the outset of a project, and thereafter remains stable throughout its duration, (e.g. Cooper, 1990). Product development is therefore characterized by several activities separated by milestones as depicted in Figure 18.

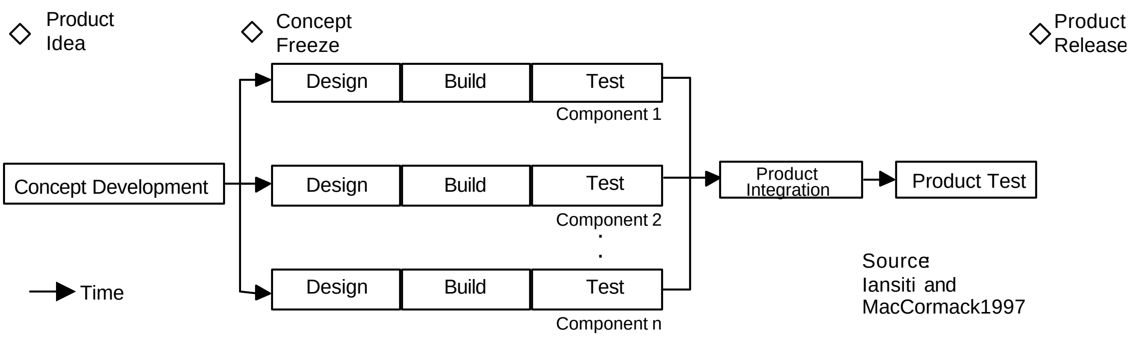


Figure 18 – Linear Approach to Product Development

The initial stage establishes the concept design; implementation begins with design-build-test cycles for each product component, and ends with testing the performance of the overall product design against the requirements determined during the concept development phase. Several models have been proposed in the literature describing the optimal sequence of activities in the process. In addition, many studies have investigated mechanisms which allow projects to avoid making late design changes, through anticipating critical decisions and gathering additional knowledge during the early stages, e.g. see Houser and Clausing (1988), Bacon, Beckman et al. (1994), Cooper and Kleinschmidt (1994) or Cooper and Kleinschmidt (1995).

Such an approach correlates with a market-based pattern of product development capability where planning (concept development) is clearly separated from doing (product implementation). Learning is not necessary because the targeted product is well-known and the environment is supposed to be stable. When the environment is more turbulent and the outcome is more uncertain, a more iterative approach to product development is necessary that enables probing and learning, e.g. see Tabrizi and Eisenhardt (1995), Iansiti and Clark (1994), Iansiti and MacCormack (1997) or von Hippel and Tyre (1995).

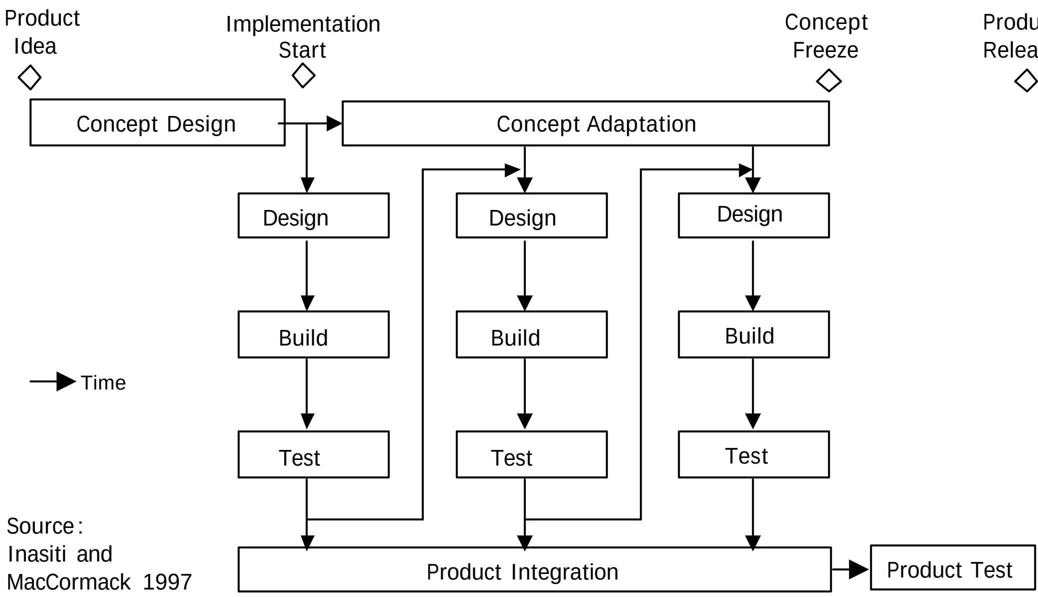


Figure 19 – Iterative Approach to Product Development

In this context, new knowledge about market needs and technical opportunities often arises during product development. Referring to Figure 19, a more iterative approach allows firms to exploit this information and adjust the concept design to environmental changes until the later stages of the project. This ability to adapt appears to be generated by a different model of product development, one in which development activities proceed in parallel rather than as a sequence of different stages separated by milestones (Iansiti and MacCormack, 1997).

Such an approach correlates with resource-based pattern of product development capability where planning (concept development) and execution (product implementation) is highly overlapped. Learning and reconfiguration happens by several design-build-test iterations. These kinds of projects are characterized by design-build-test iterations between the activities of intended concept design and implemented product design, the feedback obtained in one iteration being used to evolve design decisions in the next (Tabrizi and Eisenhardt, 1995). These iterations build the basis for learning and reconfiguration of product and competences.

The Design-Build-Test Cycle

Learning and reconfiguration within product development is enabled through iterative design-build-test cycles. The design-build-test cycle is a problem-solving cycle (Clark and Fujimoto, 1991, Wheelwright and Clark, 1994). A ‘problem’ occurs when developers encounter a gap between intended and realized product attributes. To close such a gap, organizations apply a problem-solving or design-build-test cycle.

Solving problems in product development is both a learning and reconfiguration process. No matter how much an individual may know about a given problem, there are always aspects of a new product that must be understood and adapted before an effective design can be developed. Except for trivial problems, developers are unlikely to come up with a complete design in a single iteration. Instead, developers go through several iterations, learning a little more about the problem and alternative solutions each time before committing to a final design and detailed specifications. Each iteration or ‘learning cycle’ consists of the three phases illustrated in Figure 20.

In the design phase, a developer frames the problem and establishes goals for the problem-solving process and generates alternative solutions. Based on the developer’s understanding of the interdependencies between design parameters and customer requirements, several designs for the prototype may be appropriate. The purpose of alternative designs may be to explore the relationship between design parameters and specific customer requirements.

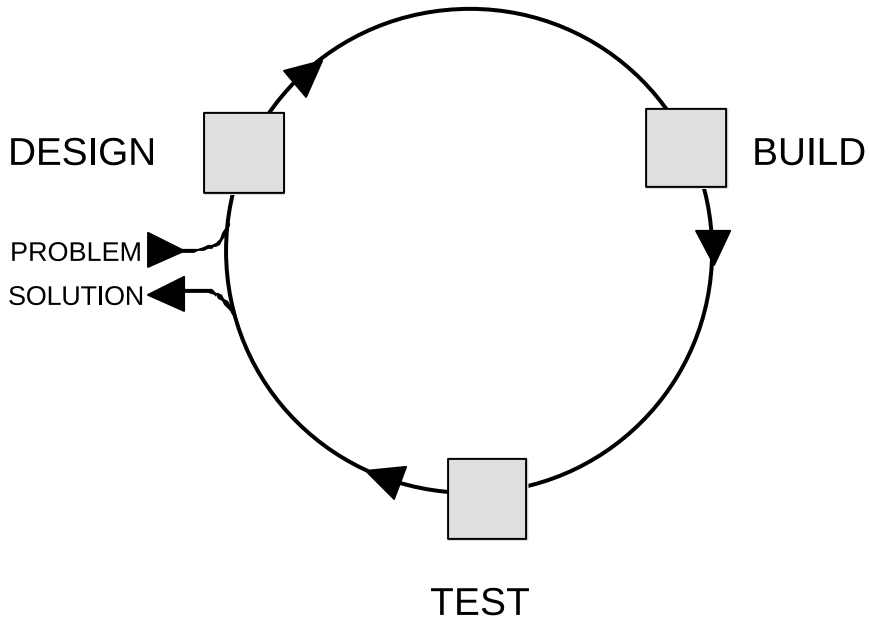


Figure 20 – The Design-Build-Test Cycle (Clark and Fujimoto, 1991)

In the second, or build phase of the problem-solving cycle, working system models or prototypes are built that allow for testing. Depending on what the developer is trying to learn, the working models may take several forms. At an early stage, for example, a developer may implement alternatives electronically in a computer-aided design (CAD) workstation. At later stages, physical prototypes are built using materials and production processes close to those used in a commercial process.

In the third or test phase, working models or prototypes are tested. Depending on the purposes of the cycle, the tests may focus on a particular component or may involve the whole product system.

A single design-build-test cycle generates insight and information about the interdependencies between specific design attributes and customer requirements. That information becomes the basis for a new design-build-test cycle and the process continues until developers arrive at a solution: a design whose attributes meet customer requirements.

As an answer to our question of how organizations learn in the course of product development we can note that they learn through design-build-test cycles. But learning in such a sense depends not only on the speed and productivity of each individual step in the cycle, but also on the number and quality of cycles required to achieve a solution. The number of cycles depends directly on the extent to which activities at each phase are linked and integrated. The challenge in product development, therefore, is both to execute individual phases of the cycle rapidly and well, and link individual cycles so that products are coherent.

Customers as 'Test' Institution

Such a dynamic focus drives customer involvement during product development. Many products fail to produce an economic return because they fail to meet customer requirements (Schilling and Hill, 1998). Integrating customers and other stakeholders into the design-build-test cycles can help to avoid such mismatches. But such customer involvement only makes sense if it serves as a vehicle for learning about the product, and whether and how it can be scaled up, about the market, and which applications and market segments are most receptive to the various product features, and about the influence of exogenous factors, such as changes in customer perceptions.

Customers become an integrated part of the design-build-test cycle. Firms show early versions of the product to customers, learn from the reaction, modify the product based on what they have learned and then try again. Product development becomes a process of successive approximation, each time striving to take a step closer in the product's match with market requirements.

2.6 New Content for Product Development

In this chapter, I described three basic perspectives (market-based, resource-based, evolutionary) in the light of their potential to explore the pattern of product development capability. Each perspective evolved from different sources and focused on different aspects of product development capability. The market-based perspective emphasized that product development capability is a function of superior planning and design, the resource-based perspective showed that it is also a function of product development organization, and the evolutionary perspective requires technological opportunities as critical variables for product development success.

Then, I changed to a dynamic capability perspective as a kind of hybrid of perspectives. With the concept of dynamic capabilities, our attention moved from static considerations to dynamic aspects of product development. The former explains product development as perfectly adjustable systems focused to successfully follow the rules dictated by competitors, and the latter claims to change the rule of competition. This shift started with evidence that new product success is often driven by dynamic aspects like learning and reconfiguration and not by the intended market position or project organization.

The ambiguous role of routines – static and dynamic - within product development operation was among some recent research efforts. Iansiti and Clark (1994) studied dynamic capabilities in product development and introduced the measure of 'dynamic performance'. Leonard-Barton (1992a) called it a paradox, the role of learning and unlearning through product development. Henderson and Clark (1990) observed that firms have their problems in developing new products when they cope with architectural innovation. Such innovation requires reconfiguration of existing structures and processes.

Unfortunately, the application of these theoretical concepts in product development operation may have been insufficient. It is still challenging today to implement and balance static and dynamic routines in product development operation. One reason is the difficulty to 'operationalize' the content of dynamic theories. Such an attempt requires fundamental changes in managing product development: product development is not a fixed sequence of activities anymore, it is an employment of routines to ascertain where to learn, how to learn and how much to learn.

The difficulties with the new content of product development may be caused by the fact that it is frozen within a static market-based instead of a dynamic view of product development. The contradictions created by this can be seen in the various process models of product development in product development literature (see, for example, Cooper (1996)). Most of them clearly separate the 'planning' from the 'doing' and emphasize pre-development planning as the key success factor (Bacon et al., 1994). But implementing learning and reconfiguration into product development operation requires a fundamentally different perspective of that for the role of product development, from mere “follower” of strategic planning to active “leader” of strategy. But within a market-based context, the idea of using learning and reconfiguration as a competitive weapon is difficult to implement due to the dominance of product planning and design (Mintzberg, 1994).

This is why a dynamic view may be necessary, one where the primary goal of product development is to learn and build fruitful paths in concurrence with an evolving environmental context to create long-term new product success. The innovative content for product development would be supported directly by existent market position and competence base.

As we shall see, the current view of product development will have to be updated in order to take account of a dynamic view of product development. At the heart of this paradigm change, this view on product development may include dynamic issues such as learning and path dependencies, which had been considered up to now as cultural aspects (O'Reilly III and Tushman, 1997). We will see how these issues do not simply have to be aligned with product development operation, but must be managed integrally, in order to be both supportive and generative of sustained product development success. This may change completely the theoretical focus of product development, creating new links with more “qualitative” theories of organizational dynamics and strategic renewal.

The key to develop this conceptualization are two observations. First, that existing product development literature is largely caught in a market-based perspective to product development. And second, that effective product trajectories rather than sole projects are important drivers of sustained new product success.

In contrast to the traditional view of product development, a dynamic view has more breadth in theories and more depth in scope. The conceptualization is based on an evolutionary perspective where resources and market position evolve from project to project and focuses not on static market analyses but on the ability to learn on project-level with firm-level impact.

Also a key to develop this paradigm change of product development is the observation that the concept of dynamic capabilities and traditional product development research have complementary approaches. Product development research is largely non-theoretical, consisting of collections of observations. In contrast, dynamic capabilities research has a cognitive theoretical orientation, which links ideas about organization to effective management practice.

These overlapping and complementary scopes of research as well as the theoretical complementarities suggest that the streams can be synthesized to a dynamic capability perspective to product development. Table 5 compares key dimensions of traditional product development research and a dynamic view of product development.

	Traditional Conceptualization of Product Development	**Product Development as Dynamic Capability**
Aim	The aim of product development is to take an idea from concept to reality by converging to a specific product that can meet a market need in an economical, manufacturable form.	The aim of product development is to build successful product trajectories by building and leveraging product development capability.
Scope	Process and Structure	Positions Paths Processes
Pattern	Plan and Execute	Probe and Learn
Level of Analysis	Individual Project	Individual Projects Sequence of Inter-related Projects
Theories	Market-based Theories Resource-based Theory	Resource-based Theory Evolutionary Theory. Concept of Dynamic Capabilities
Outcome	New Product Success	Sustained New Product Success

Table 5 – Contrasting Traditional and Dynamic View to Product Development

The diverse perspectives to approach the pattern of product development capability have much in common. Each views product development as an instrument to create and sustain new product success and each takes a holistic approach, grouping activities and decisions in coherent, logical ways. The latter quality is especially important because it suggests that the dynamic view to product development provides managers with a powerful integrating device, a way of meshing specialized, segmented activities with larger organizational needs.

Despite these similarities, the diverse perspectives capture different organizational phenomena and are best viewed as complementary pieces of a larger puzzle. They can, in fact, be combined into a single model of product development capability that includes both cross-sectional and dynamic elements.

In accordance with Teece et al. (1997), the following three key dimensions of a dynamic capability perspective to product development can be recapped.

- *Positions.* Product development capability is shaped by the firm's current product market position M_i and the available positional options. And it is shaped by its current function-specific and architectural competences C_i that are relevant for the feasibility of the intended product concept.
- *Paths.* Product development capability is path dependant. It embraces the identification of technological opportunities for product development that can be new breakthroughs but also opportunities for incremental improvements. The firms' product trajectories restrict potential product development options. They are limited by the current competence base C_i and market position M_i .
- *Processes.* Product development capability is correlated with superior static routines that build the capacity to replicate certain previously performed product development tasks. But it also embraces dynamic routines, i.e. the collective learning and reconfiguration through product development, or in other words, the level of knowledge the firm has to acquire within projects and across projects through successive product generations. Both are highly interrelated.

The dynamic capability perspective to product development offers several advantages.

First, it provides a convenient, intermediate level of analysis. We know that firms exhibit dynamic capabilities (Teece et al., 1997) but still we lack confidence in how we can build and improve them. The dynamic capability perspective to product development opens up the black box of the firm without exposing analysts to the 'part-whole' problems that have plagued earlier dynamic capability research. Past studies have tended to focus on either the forest (the firm as a whole) or the trees (the practices); they have not combined the two. The dynamic capability perspective to product development gives the needed integration, ensuring that the realities of product development are explicitly linked to the firm's overall functioning.

Second, such a focus provides new insights for product development operation. Most studies of product development have been straightforward descriptions of best practices, roles, and activity streams, with few attempts to dynamic routines like learning and path dependencies. In fact, most past research has highlighted the restrictive role of culture when firms couldn't translate best practices into successful product development efforts (Barney, 1986a). A dynamic approach, by contrast, emphasizes the links among learning and routinization, showing that seemingly unrelated tasks – a technological decision, a prototype modification, or a system test – are often part of a single, unfolding sequence that form the overall capability to develop new products. From this vantage point, managing product development becomes far more rational and effective.

However, we are still far from describing an effective pattern of product development capability. How do organizations learn within and across product development projects? How do they reconfigure themselves within projects and on a project-by-project basis? How are they restricted by their competence base and historical path? To answer these questions, we have to continue our analysis on an empirical level in order to see how organizations learn and reconfigure within and across product development efforts. The following case studies of Audi and Siemens might help to answer this task.

3 Empirical Evidence from Audi and Siemens

Empirical and explicit understanding is essential for understanding product development as dynamic capability. This chapter represents the empirical part of this work by exploring ‘positions’, ‘paths’, and ‘processes’ on an empirical level in the broader context of business strategy and the firm’s overall functioning. It comprises four sections, one introductory in nature, two on the cases and characteristics by which Audi and Siemens exhibit dynamic capabilities and one section for the demarcation and interrelation of static and dynamic routines.

3.1 Empirical Design

Exploring a dynamic capability perspective to product development entails difficult challenges. How can one ensure that the observations provide accurate and robust implications for management research? How can one ensure that the sample of organizations includes enough variation in approach to be interesting and representative? How can one define a methodology that is structured enough to provide reliable qualitative and quantitative analysis while being rich and flexible enough to capture the details of the phenomenon one is trying to study? The telecommunications environment especially, where technology evolves unpredictably and where the environmental context is uncertain, makes these questions difficult to tackle.

I approached these challenges by founding the research on a cross-sectional comparison of product development projects in automobiles and telecommunications, each limited to a very narrowly defined environmental context. Each project was chosen to make sure that it had well-defined, stable, and reliable performance measures and that it included breakthrough or incremental innovations. I also used multiple approaches to observe performance dimensions and organizational characteristics, combining extensive qualitative case studies (Yin, 1994) with structured empirical comparisons (Glaser and Strauss, 1967) creating qualitative and quantitative evidence (Jick, 1979, Eisenhardt, 1991, Wacker, 1998). This structure created a robust and rich analysis, examining two distinctive empirical environments through multiple empirical methodologies. The goal was to achieve consistency across levels of analysis and contexts.

3.1.1 Empirical Work Design

The structure of empirical work follows the framework of Figure 21. I start by conducting two single case settings at Audi in automobiles and at Siemens in telecommunications. I finish the empirical work by conducting a cross-case setting analysis.

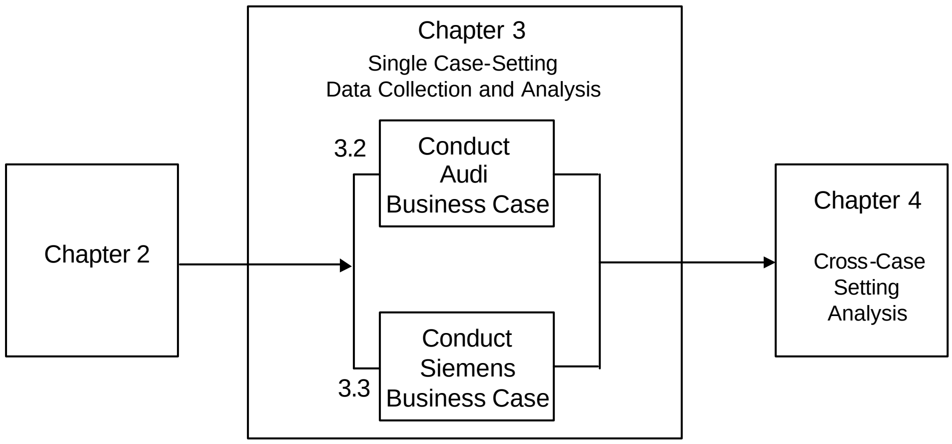


Figure 21 – Empirical Work Design

The aim of identifying a specific pattern of product development capability challenged this methodology in several ways. First, given the different dynamics of technology of the environments studied and comparing 'better' or 'worse' learning in different projects in a precise way was a subtle undertaking. Comparing the development of cars to the development of enterprise networks, could not be done by simply adjusting for the number of parts or price, since each product is different in nature and comes from a fundamentally different technological base. While the development of an enterprise network hinges upon new information technologies, the development of cars makes predominant use of existing technologies. Since the goal was to study the relationship between dynamic aspects of product development capability and product development operation, it was necessary that basic differences in the environment of a given project do not drive any observed difference in product development.

To solve this problem, I decided to perform the fieldwork in very narrowly defined product segments. This ensures that each project comparison was truly made at a comparative level. For example, the study of product development in automobiles focused only on aluminum-bodied cars: the Audi A8 and Audi A2. I compared the development of different product generations: the most recent Audi A8 model (internal code: D3) and predecessor (internal code: D2). All project studies faced different technology dynamics and market uncertainty. What's more, because of the similarity of the projects, each project's characteristics could be compared precisely along well-defined criteria. A similar approach was used in the studies of product development in telecommunications - it focused only on Voice-over-Internet-Protocol (VoIP) technology - so that each time a comparison was made, observed project differences could confidently be linked to differences in the pattern of product development capability – not to basic differences in the environmental context surrounding each project.

Next, I needed to find ways to assess differences in the product development projects of Audi and Siemens ICN. In a two-year European project, I investigated the enterprise network division of Siemens ICN in detail. During my PhD studies, I followed a major restructuring program at Siemens ICN where I could follow and analyze the Siemens ICN structure and major product development efforts in enterprise networks. These investigations were used to develop the basic empirical conceptualization for this study, including the definition of dynamic aspects of product development capability.

During my PhD studies, I also collected observations on the major projects recently performed by Audi. There were two projects analyzed in detail. More than 50 structured and unstructured interviews were held with scientists, developers, and managers at different levels in the organization involved with the most critical aspects of each project. A questionnaire was used to guide the interviews and to gather additional data to add to and check the information drawn from interviews. Histories were recorded for each development effort, tracking the completion of each major prototype iteration as well as the resources used, and observations were gathered on the basic characteristics of the organization, the processes employed, and the behavioral patterns of managers and engineers. These observations were used to create overall project evaluations and a project-specific pattern of product development capability.

In total, detailed field observations were gathered for more than six projects in two different environmental settings. As anticipated, the results show a clear relation between the dynamic aspects of product development capability and new product success.

3.1.2 Empirical Settings

Identifying the pattern of product development capability is conducted in two different empirical settings. The empirical work focuses primarily on the automobile and telecommunication environments. Each is characterized by simultaneous challenges of technology dynamics and market uncertainty. Both firms, Audi and Siemens, faced rapidly changing and ambiguous innovative opportunities as well as a diverse and complicated context in which new products needed to be developed.

The nature of technology and market dynamics in each of the environments varied considerably. At the time of the study, the automobile industry's technology base was moderately dynamic. Dynamics and uncertainty in electronic components such as, for example, navigation systems or brake systems, could be observed, but the overall product architecture remained relatively stable. Its automobile market environment exhibited uncertain and rapidly changing customer preferences, a fact that confirms Clark and Fujimoto's observation (Clark and Fujimoto, 1991). Instead, a more predictable customer base characterized the enterprise network industry; preferences were held stable by technology compatibility standards. The technical base, on the other hand, evolved in rapid and discontinuous fashion, and companies in the industry were constantly prompted to acquire new technological competences, for example in wireless technologies like UMTS or Bluetooth.

In the automobile industry, product development includes thousands of components and sub-systems and development costing billions of dollars including manufacturing equipment. In enterprise networks, because of the decreasing margins of telecommunication equipment, a trend has established from mere hardware orientation towards integrated hard- and software applications and services.

It must be emphasized, therefore, that the differences among empirical settings are very substantial. As such, comparisons between the development of automobiles and telecommunication equipment and services are useful tests of the generalisability of the results obtained.

In sum, this study presents a base of empirical evidence and discusses observations made by a variety of independent methodologies assessing firm-level and project-level aspects of product development. The evidence covers settings as different as a multi-billion-dollar car project and a call center software application project carried out by a few software specialists and managers over a few months. The findings present a consistent outlook across industrial environments, methodologies and levels of analysis. The outlook suggests that product development should not be approached in a scattered and single-project fashion. Rather, creating streams of new product success is a central challenge in a dynamic and uncertain environment, and the ability to develop new products successfully is associated with dramatic differences in competitiveness in the short and long term.

3.2 The Audi Case Study

The first evidence comes from the automobile industry. The research, conducted between 1999 and 2003, focused on the development of the last major generations of Audi automobiles. This section investigates how Audi in the automobile industry exhibits a pattern of product development capability. For Audi, product development is a strategic process based on reacting to the needs of its technological and market environment. After looking at the current market position and competence base, I turn to path dependencies and look how Audi has built fruitful product trajectories for sustained new product success. Finally, I turn to product development processes in order to analyze the role of static and dynamic routines in product development operation.

3.2.1 Positions

At the time of the study, the automobile market in Germany represented 3.24 million vehicle sales in 2003; -0.5% compared to 2002. Figure 22 shows the vehicle sales in Germany during the last 13 years. The German automobile market has been decreasing for four years and is intensely competitive.

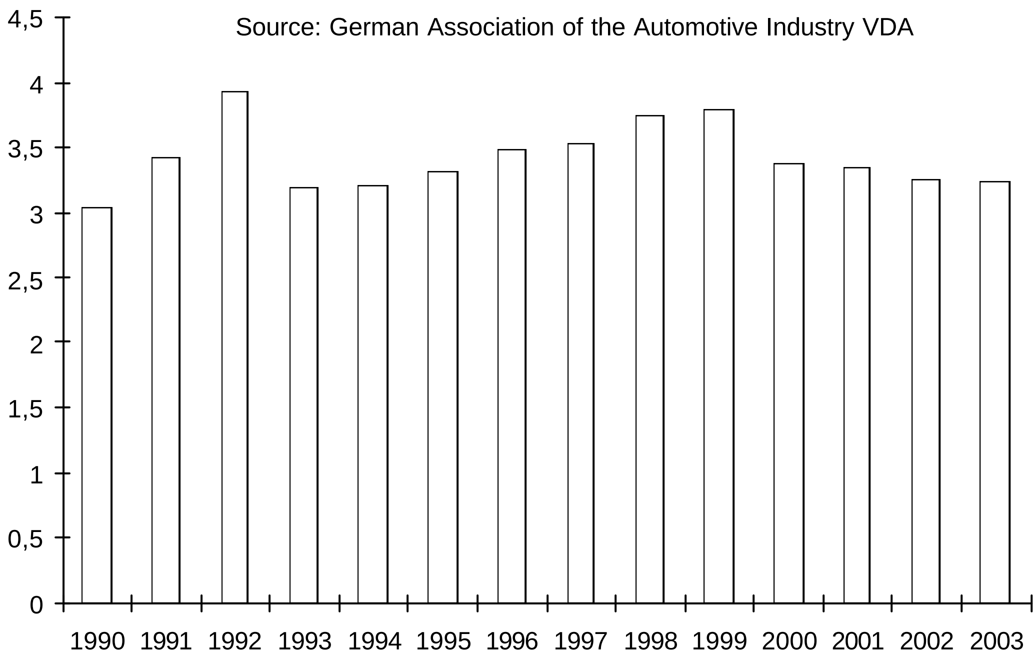


Figure 22 – Vehicle Sales Germany in Millions per Year

In 2003, Audi was particularly successful in Germany, conquering its position as No. 4 on the league table of manufacturers from Ford behind VW, Mercedes, and Opel.

Not only did Audi set yet another record for vehicle sales in 2003, it also succeeded in increasing its vehicle sales for the tenth year in succession. Despite the fact that the overall economic situation remained difficult, Audi vehicle sales worldwide increased by 3.7 percent to 769,893 cars. Audi's export quota was around 69 percent (2002: 67 percent).

The company's market share in Western Europe stayed at the previous year's level of 3.8 percent. A total of 547,666 Audi models were handed over to their new owners in this market (down 0.4 percent). 237,786 Audi models were sold in Germany (down 2.4 percent). The company consequently succeeded in maintaining its market share at the same high level of 2002, at 7.4 percent (see Figure 23). 37,467 vehicles were sold in France (down 8.2 percent). Audi increased its sales volume in Great Britain by 6.9

percent to 70,107 units, in Italy by 2.5 percent to 51,341 units and in Spain by 0.2 percent to 41,124 units.

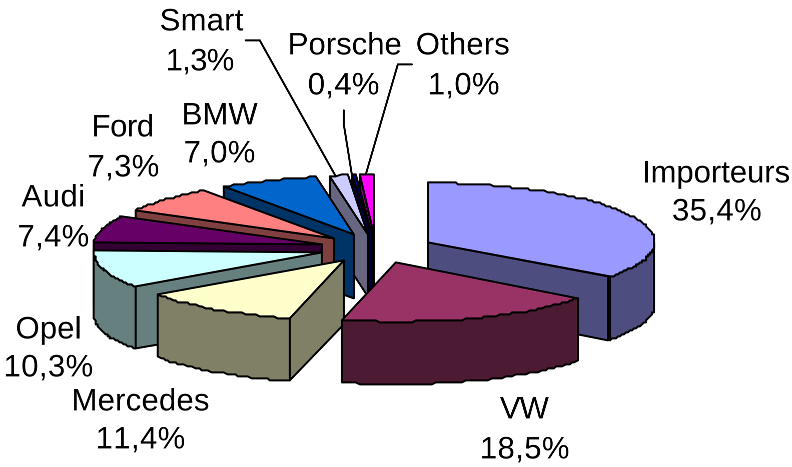


Figure 23 – German Car Market 2003 – 4th Position in Sales for Audi (Source: VDA)

A total of 86,421 Audi models were handed over to customers in the USA, Audi's biggest export market. This is equivalent to an increase of 0.8 percent, making it the fourth record sales year in succession. Moreover, Audi was particularly successful in China (including Hong Kong) where it sold a total of 63,531 cars (up 71.5 percent). Sales figures in Japan rose by 12.8 percent to 13,137 vehicles.

Audi set new records for vehicle sales in 20 markets including the USA, Great Britain, China, Italy, Austria, the Netherlands, Canada, Denmark, Greece and Australia. These records had their source in the historical path of Audi that is to be described in the following.

Historical Path

With the beginning of the 1980s, Audi's corporate strategy changed from a mid-range towards a premium car manufacturer with the claim of technology leadership. The Audi quattro coupe was launched to a stunned reception at the 1980 Geneva Motor Show. Until then, the all-wheel-drive principle had been restricted to relatively clumsy off-road vehicles, but the Audi quattro was a genuine high performance car designed to have superior handling on wet or dry roads, and it immediately began to show its potential on the international rallying scene. Permanent all-wheel drive was offered on the Audi 80 in 1982, and by 1984 every Audi model in the range was available with all-wheel drive. 'Vorsprung durch Technik' was the credo for Audi.

With the amazing success of the Audi quattro in international rallying in the early 1990s, the reputation of Audi changed completely. The brand that had been evolved from the Auto Union and DKW was no longer a brand looking for identity – the position now claimed and occupied by Audi was one of technology leadership, power, and excitement.

In 1982 the Audi quattro swept all before it to take the manufacturers' world title, with Michele Mouton runner-up in the drivers' championship. The following year, Hannu Mikkola won the driver's championship in his quattro, and Audi were runners-up in the manufacturers' category. The crowning year was 1984, with new Audi driver Stig Blomqvist winning the driver's title and Audi taking the manufacturers' championship. This was the year in which Walter Röhrl led an Audi in the Monte Carlo Rally and Audi's pioneering work on the quattro driveline was acknowledged with the 'Motor Sport Car of the Year' trophy. Quattro was associated with Audi, Audi was associated with quattro, and a new era had begun that has endured until today.

The final integration of brand and company into a single concept came in 1985, when AUDI NSU AUTO UNION AG was transformed into AUDI AG, and the head office moved from Neckarsulm to Ingolstadt. With competition on world markets intensifying, an additional 943 million DM were allocated to new investment, earmarked mainly for production technology and the all-new fully-galvanized Audi 80, launched in the fall of 1986.

During the second half of the eighties, major investments were made in a new quality assurance department as well as extra staff-training facilities. Public evidence of the company's commitment to customer service came in October 1988 when the introduction of the first Audi V8 brought with it the service for customers to personally collect their new car from the delivery center at the Neckarsulm factory. This service was later extended to the Ingolstadt factory, and the majority of customers now combine the delivery of their car with a tour of the production plant or a visit to the historical vehicle collections at each location.

In 1991, a process started which would give Audi independence from Volkswagen in marketing, sales and dealer relations, and in 1994 the oval Audi logo gave way to the 'four rings'.

At the same time, closer business links within Europe and with the rest of the world meant that Audi was increasingly becoming a global company. Worldwide sourcing of components and services, design centers in Spain and California and the opening of an engine plant in Hungary were just a few of the projects undertaken to ensure Audi's long-term competitiveness. Another major step was the manufacture of the Audi 100 in China. New markets were opened up in Asia-Pacific, Eastern Europe and South America.

1991 was a watershed year for Audi. Not only was it a record year for both production (with 451,265 cars built) and turnover (14.8 billion DM) but almost the entire product range had been replaced with new models during the year. The following year saw an even greater output – 492,085 cars, but a slump in sales in 1993 on the back of an international recession led to major structural and procedural changes in the company, including more flexible working hours and a new understanding with the workforce. This would take Audi into the future with the continuing evolvement of a product program that had started in the mid-eighties.

From this time ecological matters had been a major driving force in Audi design, and a fully galvanized bodywork became another Audi trademark. The third-generation Audi 80, and its five-cylinder sister the Audi 90, impressed with their aerodynamic bodies and low-pollution engines, but Audi's entry into the premium segment came with the 1988 V8, with a four-valve alloy 3.6 liter engine and permanent quattro four-wheel drive.

However, Audi's engineers were not totally preoccupied with high power outputs. Simultaneously, huge developments were being made in perfecting direct-injection diesel technology (TDI technology), and records were soon being set for frugal fuel consumption with an engine design that only Audi had succeeded in refining sufficiently for passenger car use.

Increasing recognition of the needs of the environment inspired the major task of developing a construction method that would enable a mass-produced car to be fabricated entirely from aluminum. That car, the A8, celebrated its world premiere at the 1994 Geneva Motor Show, replacing the Audi V8. Apart from being the world's first mainstream aluminum car, the A8 started the renaming process for Audi's products, whereby the letter 'A' would stand for Audi, and the numeral would designate the body-size category.

The second car to receive the new nomenclature was the November 1994 A4, replacing the Audi 80. Introducing five valves per cylinder technology, the A4 became Audi's most successful model ever.

With an expansive model lineup featuring four- and six-cylinder engines, together with turbo charging and quattro all-wheel drive, the A4 was the first Audi to challenge the sales volumes of the established premium competitors.

Audi re-entered the compact premium class in 1996 with the A3, but a new direction was still emerging. With increasingly severe market competition, Audi's existing brand values, whilst strong and compelling, would no longer be enough. The new dimension would be emotion – the building of an image outside the normal rational influences, an image based on a unique combination of style integrity, design progression, technological innovation, and superb quality. The result was the stunningly styled 1997 A6 and the opinion-leading 1998 TT, both of which took the perception of Audi into a new and broader direction.

In 2001, the new Audi A4 product line with sedan, estate, and cabriolet featuring the new multitronic transmission received a lot of attention and continues the success of the previous A4 generation.

Today Audi's success of the latest evolution is reflected in its "figures" as shown in Table 6. In the six years between 1998 and 2003, sales increased by ~70%, net income by ~80%, and employment by ~30%.

		2003	2002	2001	2000	1999	1998
Sales	(€ Mill)	23,406	22,603	22,032	19,952	15,146	13,918
Net Income	(€ Mill)	816	774	769	859	634	463
Employees		52,689	51,432	50,942	49,396	46,558	41,011

Table 6 – Six-Year Figures Audi AG (Annual Report 2003)

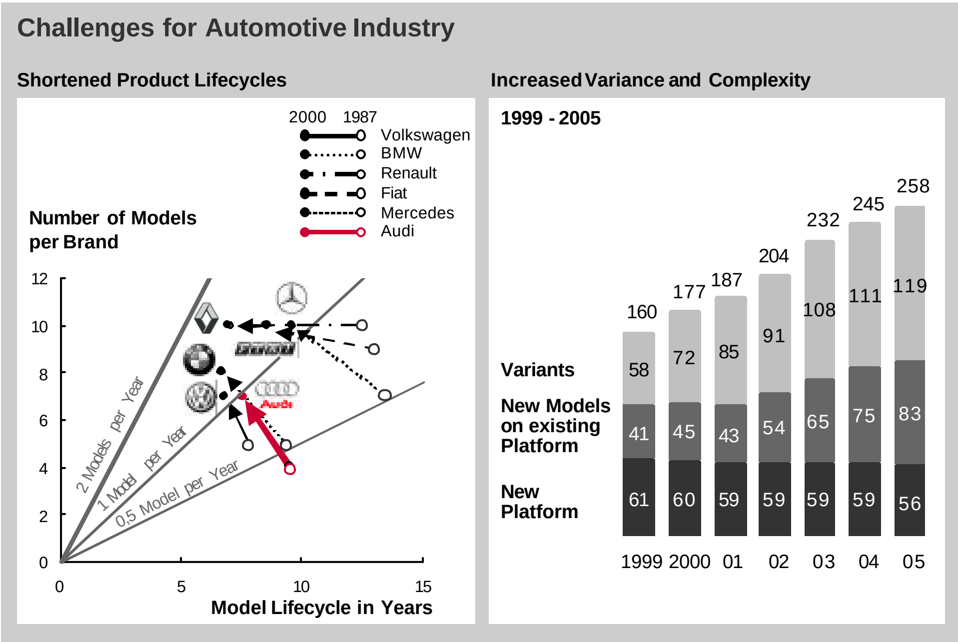
Technology Dynamics

New technology still drives competition. To a significant degree, automobiles are still bought based on performance criteria and comfort features, and both are primarily based on new technologies. Premium cars are premium because they possess attributes that beat those of standard cars. Developing such cars requires high levels of refinement and product integration (Clark and Fujimoto, 1990). Such refinement takes time; it takes relationships with partners from other industries, long-term commitments, and substantial expenditure. How can one achieve such refinements when customer preferences and technologies are continually evolving? New ideas like lane-departure-warning (LDW) or adaptive light (AL) arise almost monthly, resulting from the recognition of new possibilities arising from a still immature technology base. The complexity of the existing car architecture and customer user profile is already considerable, with cars already having more than sixty electronic control units linked to three central bus systems (Audi A8).

At the end of the 90s, most automobile industry competitors were betting that the world of electronics would revolutionize automobile architecture. The former CEO of Audi Dr. Ferdinand Piech, for example, expected in 1997 that 80% of all future innovation in automobiles would be created in electronics and electromechanical engineering. At that time, Audi had significant know-how in mechanical engineering but was hardly competent in the electronic and electro-mechanical business. In a strategic shift, Audi radically changed its functional strategic scope towards electronic and electro-mechanical engineering. Between 1998 and 2003, the number of electronics engineers at Audi rose from 220 to 600. To get some understanding of the speed of change, consider that it takes nearly 5 years to develop an automobile from idea to market.

Market Dynamics

Figure 24 depicts current market trends in automobiles: the product lifecycles are shortening and product variants are increasing.



Source: EIU, Press article „Automobilrevue", Standard & Poor's DRI World Car Forecast, McKinsey

Figure 24 – Challenges for the Automotive Industry in the Coming Years

Both challenges significantly affect product development organization. The increasing number of models per brand and per platform requires a project organization not on a project-by-project basis but for several product development projects to proceed simultaneously. Project teams gain responsibility not only for one model (e.g. sedan) but for a model line (sedan, estate, convertible, coupe etc.). For employees, their work becomes much more complex: they have to participate in several projects at the same time in different phases.

In 2003, Audi restructured its product development process towards the so called "Modellreihenstruktur", where teams were built with life-cycle responsibility. Life-cycle responsibility means that these teams are responsible not only for a whole model line that is in development but also for the previous and successive generations, which are in production or sometimes still in the product planning phase. This new structure allows Audi to cope with market requirements such as increased product variance and product complexity.

3.2.2 Paths

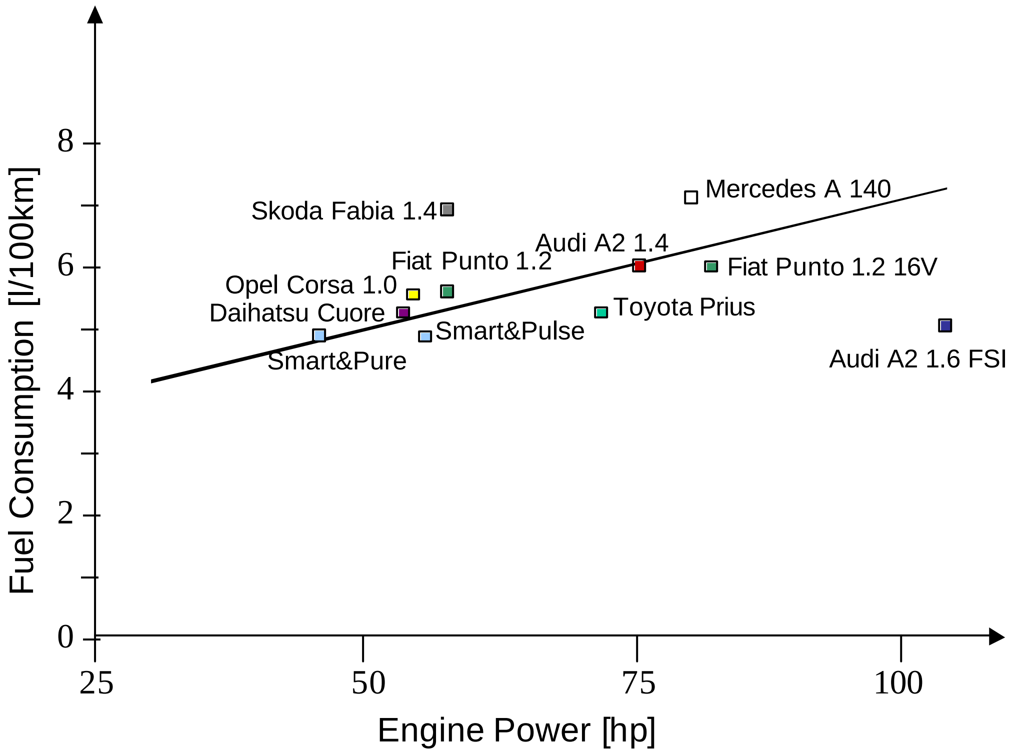


Figure 25 – Fuel Consumption and Engine Power (Spark-Ignition Engines)

Figure 25 shows one possibility for classifying the nature of projects in automobiles. Data is taken from Audi market research and draws on data on most smaller cars on the German market in 2002. Fuel consumption is used as the performance indicator. A close distance to the average line indicates an incremental technology. A large distance to the average line (to the top) indicates old technology and a large distance to the bottom indicates a breakthrough technology. Figure 25 shows that different firms in the same environment tend to achieve different product performance of their products.

Audi scores high with its A2 1.6 FSI, indicating that the product is a breakthrough compared to the industry norm. An internal look at Audi's competences is consistent with this analysis. The revolutionary technical approach is linked to Audi's research activities. The product superiority of the A2 1.6 FSI is caused by a lightweight aluminum body, termed Audi Space Frame (ASF).

ASF is a high-strength aluminum frame structure into which the panels are integrated so that they also perform a load-bearing function. In conjunction with high-strength aluminum sheet, the aluminum body is characterized by exceptional stiffness and above-average crash protection, yet at the same time by substantially lower weight. Comparison: an Audi A2 weighs ~950 kilograms (in average across the model range), about 150 kg less than a comparable car with a conventional steel body. Advantages for the driver are greater safety, increased performance, improved handling, lower fuel consumption, ease of repair and lower insurance premiums.

This section takes a look at how Audi builds fruitful product trajectories that start with breakthrough projects to implement new technologies and result in incremental projects to profit from the competences built by the previous projects. In literature, product development in breakthrough projects is associated with high levels of learning while product development of incremental projects is associated more with high levels of planning leveraging existing competences.

My observations at Audi are largely consistent with these propositions. In breakthrough projects, many design-build-test iterations in all areas of the firm indicate high levels of learning. In incremental projects, managers rely more on people's experience. Experimentation is targeted when extension of existing experience is necessary. My observations indicate that most projects are something in between, the optimal balance between planning and learning is critical for product development. But how is this optimal balance carried out?

The following reveals these differences in some detail. It illustrates how Audi first built a technological foundation in aluminum technology through a breakthrough project, then expanded its innovation to larger markets, and finally consolidated it through following incremental projects.

Audi's history of automobile development is an interesting example of building successful product trajectories. In 1993, Audi replaced its Audi V8 in the premium car segment by introducing the full-aluminum-bodied A8, whose design and performance gained a lot of attention in the motor press. The A8 (internal code: D2) was a breakthrough project, introducing a number of new technologies. While not the leader in its field, the A8 established an outstanding technological foundation for the future. In 2000, Audi expanded the aluminum technology of the first A8 project (D2) by delivering the first cars of the A2, the first four-door car that achieved a fuel consumption below 3 liters per 100 kilometers because of its light weight. The real pay-off came with the next product generation of the Audi A8 .In 2002, Audi revealed the Audi A8 (D3) that substituted its predecessor Audi A8 (D2). The Audi A8 (D3) overtook the BMW 7 Series for sales in Germany 2003 and was recognized for the sportiest premium sedan in the luxury car segment. Audi thus went fr om no market participation in aluminum technology to technological leadership in one of the world's most sophisticated industries in less than 10 years.

The A8 (D3) is an example of a typical incremental project. It built on the functional competences created by the A8 (D2) project and the manufacturing competence of the A2. The Audi A8 (D3) increased the product performance in its class by a substantial margin only by improving and refining the technology base of its predecessors A2 and A8 (D2). The A8 (D3) was in all ways a technological extension of the A2 and A8 (D2). Its superior performance was not due to any fundamental breakthroughs, but rather to attention to detail in optimizing the match between technology and the application context (see Figure 26 for a time line).

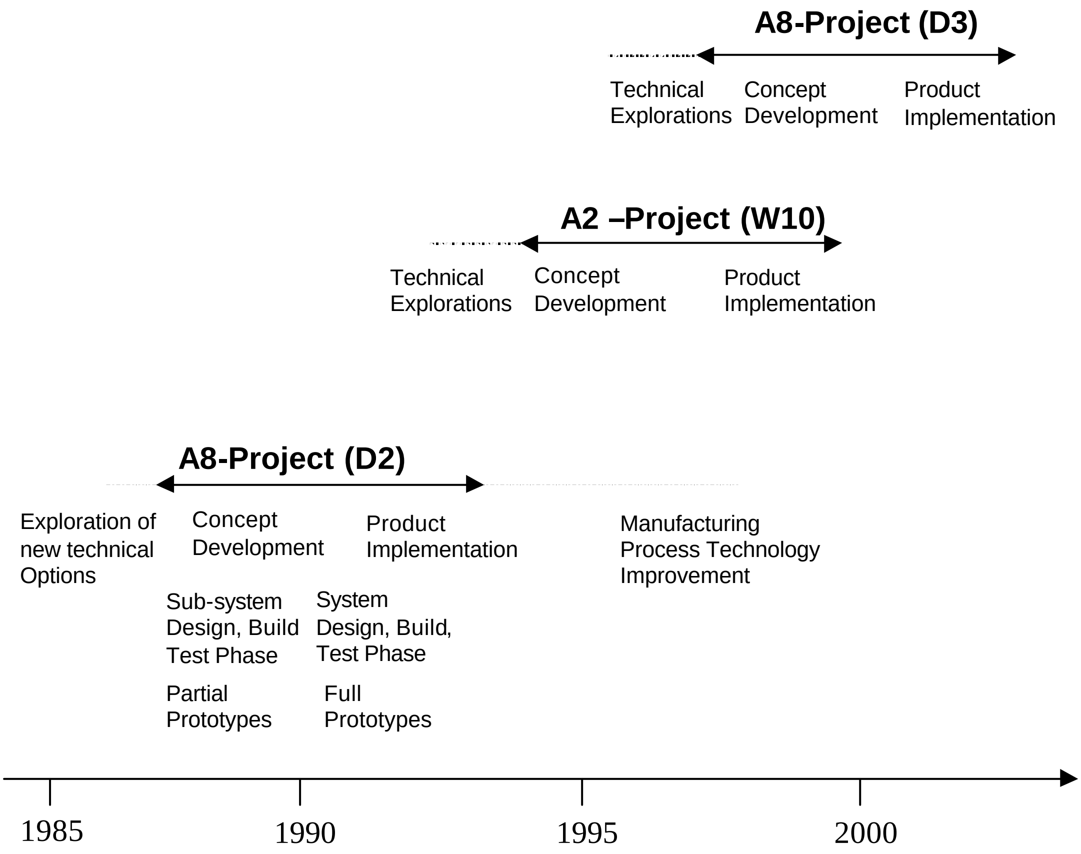


Figure 26 – Aluminum Projects at Audi (internal development codes in brackets)

Breakthrough Project - The Audi A8 (D2)

The Audi A8 (D2) is the first car with an aluminum body built according to the Audi Space Frame (ASF) principle. Advances in aluminum material technology can be traced to research efforts in the mid 1980s. In the late 1980s, conscious of the pressure on conventional steel materials that future performance requirements would bring, Audi researchers, in joint ventures with the aluminum supplier Alcoa, began exploring the technical possibilities of aluminum materials for automobile body design and manufacturing. The new materials had very attractive intrinsic properties that allowed for substantially lower weight and higher stiffness of the car.

Two groups within Audi were particularly critical to the A8 project: the central R&D aluminum group and the manufacturing implementation group, both situated in

Neckarsulm. Members of the R&D group had been active in materials research for many years. The group comprised researchers with expertise in material science and several years R&D experience at Audi. Most of their work was aimed at developing fundamental new techniques and approaches for aluminum utilization with application in new automobiles. For its part, the implementation group focused on creating a working, manufacturable product. While the role of the R&D group was to offer a large breadth of technical options, the implementation group would drive the investigations, select the most promising alternatives, and integrate them into a manufacturable subsystem.

A8 (D2) concept discussions started in 1989. The targeted shipping was 1993, leaving approx. 4 years for the entire effort. During 1988, managers and engineers of the R&D and implementation group met repeatedly to discuss technical options for the car architecture and production process. Members of the implementation group took the lead in setting the direction of the project and began to perform feasibility studies for new production concepts. They initiated discussions with members of the R&D group and with material suppliers, test engineers, and car body designers. Many possibilities were discussed and modeled; the most promising were tested in partial prototypes. Implementation group and research specialists thus decided that three different concepts should be pursued in parallel. The first two were quite new for Audi (these concepts included aluminum material), while the third approach was an extension of the existing steel concept of the predecessor Audi V8 (D1).

Members of the implementation group quickly began to perform feasibility studies for the different approaches. They initiated discussions with members of the central research laboratory in Ingolstadt, material suppliers, test engineers, and car body designers. They also investigated possibilities through experiments, quickly making physical models of the module assemblies to investigate the characteristics of the new materials.

At the end of 1990, the new concept design was complete, and the other two approaches were finally dropped. It employed aluminum materials, whose incompatibilities with the rest of the car architecture had been resolved. This involved the development of a number of specific technical refinements, including new and improved connection techniques and many modifications of the production process.

During 1992, many prototypes of the new architecture were built to assess manufacturability; the emphasis was on completing partial prototypes and a number of models for each of several fundamentally different concepts. The connectivity techniques, for example, were investigated at each stage of the fabrication process. In this way, before the pilot production process began, there was already sufficient data (on connectivity, types of defects, causes of defects, and so forth) to provide confidence in the manufacturing process. Reliability testing began in 1992 leading to some changes in design and production process. The first complete, fully representative pre-production automobiles were built in 1993.

A batch of pre-production cars would be fabricated and tested until a major defect was encountered. Knowledge gained from analyzing the causes of the defect would then be used in construction of the second batch of pre-production cars, while the first batch would be used to conduct additional tests. The implementation group went through many of such iterations. The pre-production cars were tested investigating a wide variety of functionalities and the design was gradually refined.

By 1993, the Audi A8 (D2) concept was complete: The production process had been designed in detail, production workers had been trained, and the product was presented in motor shows and press releases.

As one manager stated

> *The Audi Space Frame (ASF) is no mere duplication in aluminum of what some craft in steel. More than 15 years in the making with Alcoa, the ASF demanded new space-age alloys, more than 40 patents, even new construction techniques in order to see the job through. Was it worth it? Emphatically yes. Not only did we improve performance and safety, we've learned ways to improve our other cars.*

From Breakthrough to Expansion to Penetration – The Audi A2 and Next Generation A8

In 1995, while the A8 project was completed, engineers began working on adapting the new technical approach to mass production of smaller cars, the Audi A2, to be launched in 2000. Soon thereafter, the next generation of the A8 project (D3) was also begun on an informal basis, with discussions about how the A2 production concept could be extended to provide lower production costs for the next generation Audi A8. Project engineers were often allocated to two projects (A2 and A8), facilitating the transfer of knowledge from project to project.

The Audi A2 was introduced on time in 2000, exhibiting the most fuel-economic automobile in its market segment. Its design was based on the Audi A8 (D2), although the number of body parts was reduced by ~40% to reduce production costs. The focus of the engineering team was primarily on cost reduction. The Audi A2 was fully driven by engineers from the implementation group responsible for the A8 (D2). This was still going at full speed at the time, with yield refinement and process improvement activities. Implementation engineers working on the Audi A2 project retained some responsibilities for the Audi A8 (D2).

The official project start of the Audi A8 (D3) was marked in 1997. It was characterized by an approach similar to the A8 (D2) and A2 project and was staffed by many engineers with A8 and A2 project experience. By this time, several members of R&D and implementation group had participated in two project generations (see timeline of Figure 26), with responsibilities ranging from concept development to product introduction. The group's small size and project managers' attention together provided members the chance to obtain broad expertise in a wide range of tasks. Their approach involved project members' continuous participation in the development project from project start to product launch. As a result, members of the implementation group had built up an intimate knowledge of the aluminum's manufacturing context, represented by existing production processes and system-level design considerations. This put them in an ideal position to analyze the interaction between the new approaches and the organization's existing competence base and infrastructure.

Such level of expertise in the implementation group was reflected in many of its decisions. These ranged from relatively major changes such as redesign of the cooling system to account for higher performance specifications to more subtle choices such as the decision to define the production steps.

For both the A8 (D3) and the A2 projects, experimental iterations were much more limited in comparison to the A8 (D2) project. The idea was to validate the designs based on the experience of the R&D and implementation group members, not to explore fundamentally new possibilities. Experimentation efforts were more aligned to confirm expectations, however, since they were carried out in the same facilities and by the same technicians responsible for building the A8 (D2).

The results were impressive: While the A8 (D3) retained essentially the same basic technologies developed in the A8 (D2), the new architecture saved production costs of about 30% compared to the predecessor. The Audi A8 (D3) was introduced in 2002, surpassing existing cars of its class by performance parameters like handling, fuel consumption, acceleration speed, etc. The experience of members of the implementation group, their intimate knowledge of the production system, and the high skills of the technicians all contributed to a design that met aggressive performance specifications. The A8 (D2) project set up a strong technological platform for Audi. For the A2 and A8 (D3) projects, this technology was extended through incremental refinements that enhanced the performance of the systems and established Audi as a leader in aluminum technology in the automobile industry.

Audi's new product success around aluminum technology is based on a specific pattern of product development capability. This pattern should be studied in more detail. In the following section, therefore, we look at how Audi develops new products and how they learn and reconfigure themselves within and across product development projects.

3.2.3 Processes

In 1984, Ferdinand Piech, convinced that without an Audi in the premium car segment a key opportunity was being squandered, urged the development of a new revolutionary sedan that exhibits innovative features that would make Audi the technological leader in the premium car market. He made some experienced people responsible for the project, code-named D1. Piech directed the team to "develop the best premium sedan ever" and finish the project as soon as possible. The end of 1987 was the scheduled completion day.

The D1 team quickly created a rough product concept. Way ahead of its time, the idea was to integrate a V8-engine, automatic transmission and all-wheel drive, a combination rarely found in the market. Some American off-road cars of that time had automatic transmission with non-permanent all-wheel drive and no central differential. No comparison to Audi's high-tech solution with multi-disc center differential and Torsen rear differential.

These objectives overstretched the team's capabilities, and a year passed; several developers were brought in to build a concept car but their work stalled. By the beginning of 1985, the scheduled ship date was still more than two years away, and Piech began to pressure the team to produce results. After a concept review, Piech decided to change the concept and introduced a product manager to guide and lead the project. Several Audi veterans were bought in: along with the addition of a product manager, the Audi V8 development lead took over the same role for the D1, while a well-regarded developer assumed the technical role. A team member described the scene:

> *We all thought that the project was much farther along. We ended up throwing everything that had been done out and started from the product architecture used in the Audi 100 (C3). We were a year behind schedule from the first day we started.*

The project organization was restructured, and a new team of developers was formed. In the second half of 1985, it was dedicated to develop a new specification for the product while pressure mounted, once again, for results. The schedule continued to slip into 1987, and the pressure increased.

Over the next several months all the required components were designed, and in the middle of 1987, the team declared that the 'Design Freeze' milestone had been reached. 'Design Freeze' meant that all that remained to be done was to build prototypes and optimize the car for performance. At Audi, this phase is called confirmation phase, and once the product had stabilized (all known failures were solved and performance was adequate), the product could be built in pre-production series. For scheduling, Audi used a rule of thumb that the confirmation phase typically lasted 12 months.

It soon became clear that the D1 project was not likely to follow the twelve-month rule. Although developers solved problems quickly, the testers seemed to find new ones just as fast. By the end of 1987, the number of problems remained relatively constant, but, during spring 1988, an initiative emphasizing the effects of changes rather than the number of changes was instituted. For the first time, testing people were invited to product reviews, and ownership of the components was stressed. By summer, the project had stabilized and the Audi V8 was released in October 1988. Naturally, the product when it shipped was nothing like the original specification put together by the original D1-team. Its architecture, functionality, and performance had been scaled down considerably to make the project feasible. Still, the Audi V8 was viewed quite favorably by both critics and customers and built into a satisfying business.

Product Development Problems

As is evident from the preceding description, the development of the Audi V8 was fraught with problems. The product shipped one year after its original target date, causing Audi's 100 series (shipped in 1982) to be on the market for 6 years without an adequate premium version (in previous model series: the Audi 200). Moreover the development process was unpredictable; the launch date was in serious question even 6 months before market introduction. Finally, the D1 project completely drained its members, forcing several to take leaves of absence.

Many of these problems can be traced to the product development process. When the first team put together its original, impossible specification, it set incredibly high expectations for all subsequent efforts. Full of new elements, these objectives were defined without any substantial effort at experimentation and prototyping; clearly the team members' guess about the product's feasibility was very wrong. As the description shows, these efforts often failed and even in later project phases, developers felt under pressure to improve functionality at a high rate at the expense of testing and reliability.

The Audi V8 thus failed to incorporate many of the criteria of successful product development. Although it had revolutionary goals, the project resources and competences did not match the requirements to develop a robust and coherent product concept. The project suffered from the inexperience of critical decision makers and responsibility for important tasks like technology and package was uncertain. The role of the product manager was confused with that of many other leads in the project. As such, the Audi V8 suffered problems because of a mismatch of resources and competences with the project requirements.

New Approach to Product Development

Partly in response to the problems with the Audi V8, in 1990 several discussions had been initiated to improve Audi's development organization. These were aimed at improving the reliability and quality of product development while retaining its flexibility and responsiveness. Two different possibilities were discussed.

The first possibility was trying to do what the D1 failed to accomplish – hold development to the original product concept. Some people argued that if enough time were spent in product planning, and enough discipline existed in the team to respect that concept throughout the project, the process could be made to work quite efficiently. The second possibility was to let the concept change during the course of the project – the uncertainties in technologies and market were just too great to be able to predict everything up front. This was the approach with which Audi usually developed products but the difference was to do so in a controlled fashion, driven by regular reviews and milestones. This was the big change in the Audi product development organization. The new process worked as follows: After conducting considerable market analysis and several focus groups, marketing managers described the unfilled needs that the new product should address. A product planning team then translated these general market needs into broad project objectives contained in a product strategy statement and outlined the product concept. Developers worked from the outline specification to bring objectives to life. As developers strove to develop the desired functionality and to optimize product performance, they typically discovered problems and possible improvements. A new process called "ÄKO process" was installed to manage product changes in a controlled manner even in later project phases. The process was under the responsibility of the product management function. As part of the process, problems and improvements were discussed with the project team and, if necessary, the product concept was changed. This cycle was repeated frequently until the project was finished. Another process called "clinic process" was installed. This process allowed for a more institutionalized customer feedback. Each major prototype release would be tested with customers (or quality assurance as customer function), thereby obtaining market feedback as the project evolved. The installation of these two processes therefore allowed the project to remain responsive to market changes by adding or removing functionality in a controlled fashion even in later project stages.

To reduce product complexity, the features of the outline product concept were divided into bundles, each to be developed, tested, and launched sequentially. The product would thus progress from a simple architecture to a complete configuration in a controlled and testable fashion that project management could closely follow. The ideal was to add desired features and product improvements in order of their priority. Developers worked on the highest prioritized features first and gradually expanded the product's feature set until the shipment of the product.

Organizational changes complemented the new development process. A concurrent engineering organization was implemented where product managers became the primary drivers in a typical development project and strongly influenced the company's future. One product manager described the role:

> *The ideal product manager probably would have a development background. The key component, however, is to have the knowledge and ability to talk to developers in their own language. They need to be respected by R&D. A product manager needs good people management skills.*

Another product manager elaborated:

> *A good product manager must be comfortable with the technical aspects of the specification and know how to change it. The product concept gradually evolves until the development is complete. It is important that trade-offs are clearly presented to all functions and levels of management during evolution.*

Product managers at Audi had thus become the integrators in the project; they had responsibility over the entire specification and were charged with making critical decisions. They had to keep a holistic perspective and make sure that the components developed by the developers fulfilled the customer requirements and were in line with the financial targets.

With the new product management function, Audi institutionalized a changing product concept even during product implementation. By working intensively on methodologies for experimentation and testing (e.g. Virtual Prototypes, Rapid Prototyping) and on the role and experience of its product managers, the new development process allowed a good degree of control and predictability while retaining the flexibility to respond to market and technology changes.

With the development process, Audi began to tackle a problem fundamental to all competitors. The current automotive industry environment is characterized by dynamics in peripherical technologies especially in electronics and electro mechanics (approx. 3-year lifecycle), creating a virtually unprecedented need for flexibility and responsiveness. The challenge is to allow the appropriate level of flexibility while keeping the development process and costs under control.

Dynamic Routines at Audi

Audi was late to enter the premium class in automobiles; it was not until the end of the 1980s that Audi really began to focus on developing premium cars, such as a luxury sedan that would rival the Mercedes-Benz S-class and BMW 7 Series. When Audi entered the premium car market, Mercedes and BMW already had a dominant position and were way ahead in technology and design.

Thus, in 1988, Audi with the Audi V8, started its strategic shift towards the premium car segment with remarkable speed. In 1994, Audi shipped the Audi A8, offering a product that several experts claimed was comparable to or better than the Mercedes-Benz S-class or BMW 7 Series. By 2003, Audi was No. 2 in the German luxury car market behind Daimler-Benz and in front of BMW, and the product line A3 in the premium segment was gaining momentum. A senior manager of the Audi Product Management Group characterized Audi's strategic shift to premium cars in this way:

Think of how far we were ten years ago. Within 5 years we put out the RS 2[2] *and the A8 that established ourselves in a sustained way in the premium car segment.*

Audi's development process in the early 1980s was informal with little emphasis on schedule or process. Projects were driven by a few brilliant engineers as technical leads, who had almost total control of a product's design. Not surprisingly, given such approaches and attitudes, what the product would look like and when it would be released frequently remained mysterious. Ferdinand Piech, director of R&D at Audi at that time, was one of the few controls in the process, influencing developers primarily during the intense prototype review meetings he attended. Meanwhile, the company's image was that of a firm producing technically excellent but relatively boring and not inspiring products. At the same time, automobiles became significantly more complex, challenging the project teams even further. One of the company's first product managers recalled this pattern:

Development of outstanding automobiles was starting to require much greater attention to detail than to sheer functionality. What mattered most was attention to how the individual parts fit together into a well-designed, coherent car that was attractive, reliable, and fun to use.

Increases in the automobile's complexity led to corresponding modifications in product development. No longer could one technical lead manage the entire undertaking, and the product management function was created to share the responsibility for financial and time targets. The first product manager was assigned to work on the design of the Audi A4 in the early 1990s. As he noted,

I became a sort of service organization for the R&D department. I helped document the specifications, do the product reviews, and decide what failures were important and what could be postponed to a later release.

By the early 1990s, several people shared the leadership for the development of a new automobile. The product manager was responsible for overseeing the product

[2] The Audi RS2 was a sporty estate car based on the Audi 80 Avant, powered by a 315 hp, 5-cylinder turbocharged engine, developed in collaboration with Porsche.

development effort, including task assignment, scheduling, and coordinating all organizational functions (manufacturing, purchasing etc.). The technical lead had final say in all technical decisions, product reviews, and design standards. The production lead oversaw implementing the product for mass production. The marketing manager handled all the marketing issues such as competitive analysis, positioning, packaging, and advertising. The product manager's job was to integrate and coordinate the efforts of everyone involved in the project. Product managers were also directly responsible for product concept and specification.

Design-Build-Test Cycles

Product development at Audi aims to integrate latest technology and customer preferences. This requires a high degree of customer involvement from concept development to product implementation. Customer involvement is achieved with the following approach: concept development is initially outlined in a rough manner, and then progressively detailed as the project continues. Rather than concept development and product implementation being independent, sequential stages become tightly linked overlapping stages. Implementation begins before there is a precise definition of the product's design. As the project proceeds, it iterates between the activities of concept development and product implementation, each iteration involving a sequence of design, build and test activities, followed by integration into the evolving car design. This model is driven by rapid learning, a significant proportion of which is focused on the feedback of customers on the evolving product design. It differs substantially from the 'traditional' product development process, where product integration (and hence customer feedback) tends to occur late in the project.

The success of such an 'iterative' model has two foundations: First, feedback on the performance of the evolving product design begins early in the process. This feedback is driven by early prototype experiments with customers. Early prototypes, for example, are used to gain an understanding of the trade-offs involved in a car's attributes (e.g. weight or costs). In addition, early integration of the product's components into a working prototype allows testing of problematic interactions between components and then releasing of early prototypes to the user function (parts of quality assurance department) to generate feedback on how the initial design meets customers' expectations.

Second, these experiments proceed intensively during a project's subsequent stages. Frequent iterations are geared to providing new knowledge about car and car components. These iterations are punctuated by regularly updated prototypes, which provide continual feedback on how the additional functions and features being added to the product concept perform in the end-user environment.

While continual iterations provide a way to learn to match customer requirements, this new knowledge must still be consolidated within the organization and applied to car and car components. The goal is to keep the possibility to realize car concept and component adjustments for as long as possible in order to consider the latest shifts in technology and market.

The Audi case shows that product development can be successful when it is approached in a more evolutionary fashion than simply focusing on sole projects. At Audi, the A8 (D2) was a breakthrough for Audi to develop full-aluminum automobiles with reduced weight and increased performance. The Audi A2 project transferred the aluminum technology to higher volume markets that require a more automated production process. Both projects together allowed the development of the Audi A8 (D3) that overtook the BMW 7 Series in sales in the German market in 2003.

The Audi case also shows that dynamic routines play an important role in product development capability. Within projects, design-build-test cycles are the central activities where competences are built, reconfigured, and refined. Across projects, resulting from product development problems, Audi installed specific processes like the 'ÄKO' process or the 'clinic' process in their product development activities that helped to cope with shifting product specifications required by new market dynamics.

These developed capabilities have entrenched Audi as a technology leader in the automobile industry.

3.3 The Siemens Case Study

Siemens is an international electrical engineering and multinational electronics company with $77.8 billion sales, 426,000 employees, and presence in 193 countries (2002). Their product range includes 50,000 product families and approximately one million products. Siemens invests more than 1.2 billion euros in research and development each year and holds more than 17,000 patents and has over 49,000 employees engaged in research and development worldwide. The revenues stem from 6 business segments: energy, industry, healthcare, transportation, lightning and information & communications.

Innovation has always been a part of Siemens' tradition. But new social pressures and rapidly changing technologies throughout the world brought new challenges to Siemens as it faced the 21st century. To deal with this new business market, Siemens used its tradition of intelligence, competences, and systematic application to remain a strong international force. As von Pierer stated in Siemens' 1994 annual report:

> *"Helping set the course of change has been a vital part of our business for nearly 150 years… Fifteen years ago, barely half of our worldwide sales came from products that were less than five years old. This figure has now risen to more than two-thirds--solid proof that we are not just meeting increased demands for change, but are setting the pace for innovation."*

In this case study, I focus on Siemens Enterprise Networks, USA, a division of Siemens Information and Communication Networks (ICN), and study Siemens' product development capability in this market segment. I start with an analysis of the market and resource position and continue with a closer look at product trajectories around VoIP technology. I close the Siemens case study looking at dynamic routines at Siemens.

3.3.1 Positions

In 2003, Siemens Enterprise Networks (ICN-EN) had its headquarters in San José, California, and employed 700 people. In 2000, Siemens was third in the U.S. enterprise networks market and their market share was about 15%.

The presence of Siemens in the U.S. started in 1973, when Siemens opened its first factory producing telephone equipment in New Jersey. In 1988, Siemens acquired

Stromberg Carlson, a manufacturer of switching technology equipment. In 1990, Siemens entered into a joint-venture with ROLM, a manufacturer of communications systems. In 1992, ROLM was fully acquired by Siemens.

The market in which Siemens operates is the enterprise network market. The customers are enterprises for which tailor made information and communication solutions are provided in 5 major areas: Voice Networks, Data Networks, Application (Hardware and Software) Services, and recently Converged Networks (Voice-over Data Networks). Figure 27 depicts an overview of this market and some product examples.

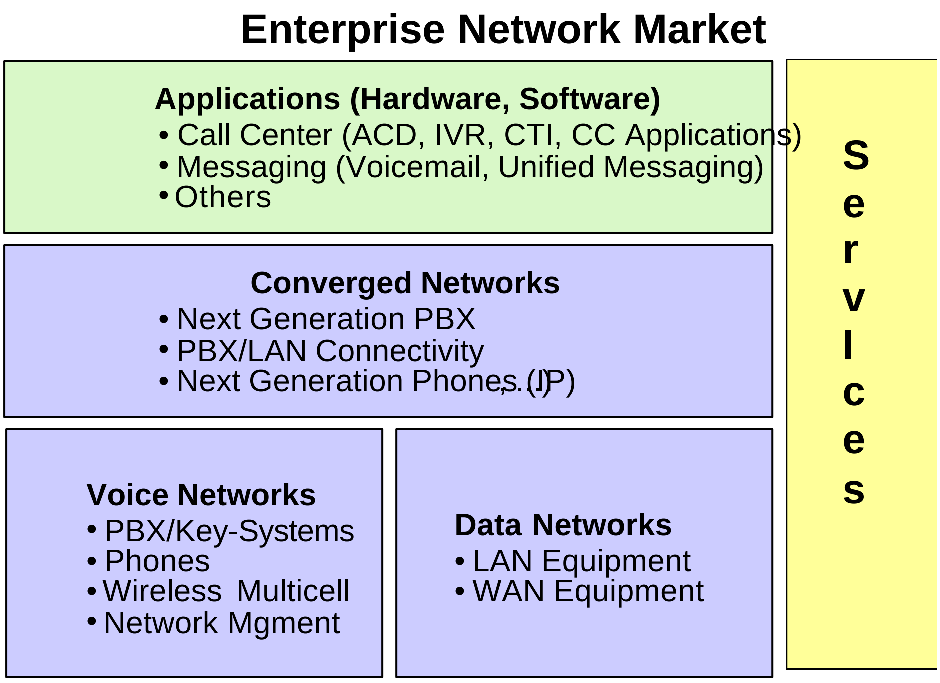
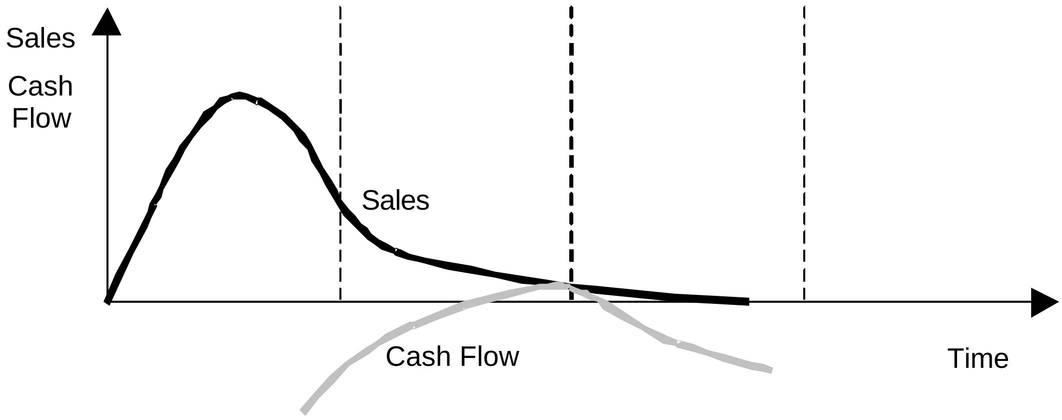


Figure 27 – Enterprise Network Market (Source: Siemens 1999)

Based on the 1995 figures, a product was vivid on the market for 3 years, with investments of approx. 10 million euro per product. At the beginning of the 21st century, Siemens experienced profound changes in its product life cycles. In the telecommunications industry, a range of factors were reported as causing drastic changes in the life cycle of new products. Compared with the traditional 3-year lifecycle, the new product lifecycle was shortened to 9 months, and the required pre-investments more than doubled. An example of the new life cycle is depicted in Figure 28 and shows a study of a wireless device made by Siemens.



Source : Department of Marketing and Finance of Siemens Switzerland, Swisscom

Figure 28 – The Present Product Life Cycle on the Telecommunications Market

One initial conclusion can be drawn from this insight: not sole products but successful product trajectories become a requirement, because pre-investments and new technologies have to be continuously turned into viable returns (see Figure 29).

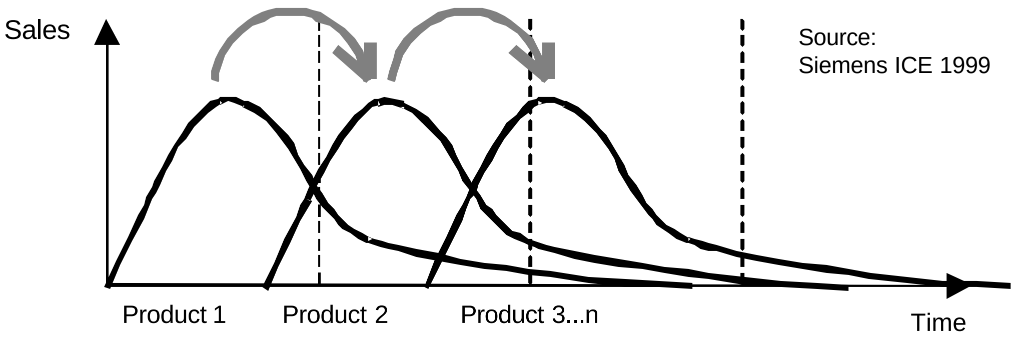


Figure 29 – Product Trajectories to Achieve Viable Returns

Product trajectories have to be established that involve the development of more breakthrough innovations based on entirely new technology platforms (such as change from GPRS to UMTS) that are followed by more incremental ones (such as modifying an existing user interface to yield product characteristics).

3.3.2 Paths

The product trajectory of Siemens around VoIP technology provides an interesting example for how companies can build fruitful paths of long-term new product success.

Voice over IP had its foundation in Israel. At the beginning of 1995, the company 'Vocaltec' was the first to use the Internet medium to transfer voice over data networks via internet protocol (VoIP). Figure 30 shows the technological trajectory of how the VoIP technology evolved. It started with software applications in 1995 and resulted in call-center applications that supported operators with call-related data and telephony features in 1999. The first VoIP-PBX came in 2000 and represents the 1st generation VoIP.

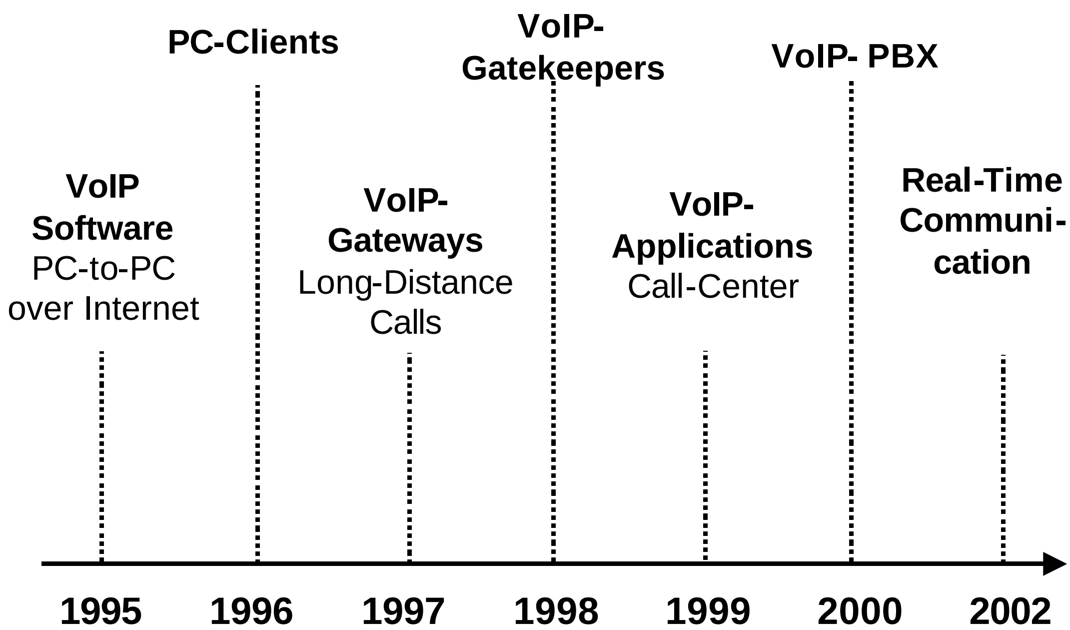


Figure 30 – Development of Voice-over IP Technology and Applications

Major pay-offs of the 1st generation VoIP included cost and design flexibility. The scalability of the Voice-over-IP architecture for enterprise networks removed one of the highest cost items from design – the PBX itself. If one uses the computers that exist nearly at each working place, the modules of the new architecture are relatively inexpensive and it might be possible to create an architecture for a system that would serve a wide variety of customer segments, from small-sized network customers to large-sized server application customers. Moreover, the 1st generation VoIP provided a potential for lower service costs because errors could be located in modules. Lower service costs would be extremely attractive to commercial customers.

Siemens participated in the technological trajectory of VoIP with several projects in order to stay at the front of VoIP technology. The main product trajectory is shown in Figure 31.

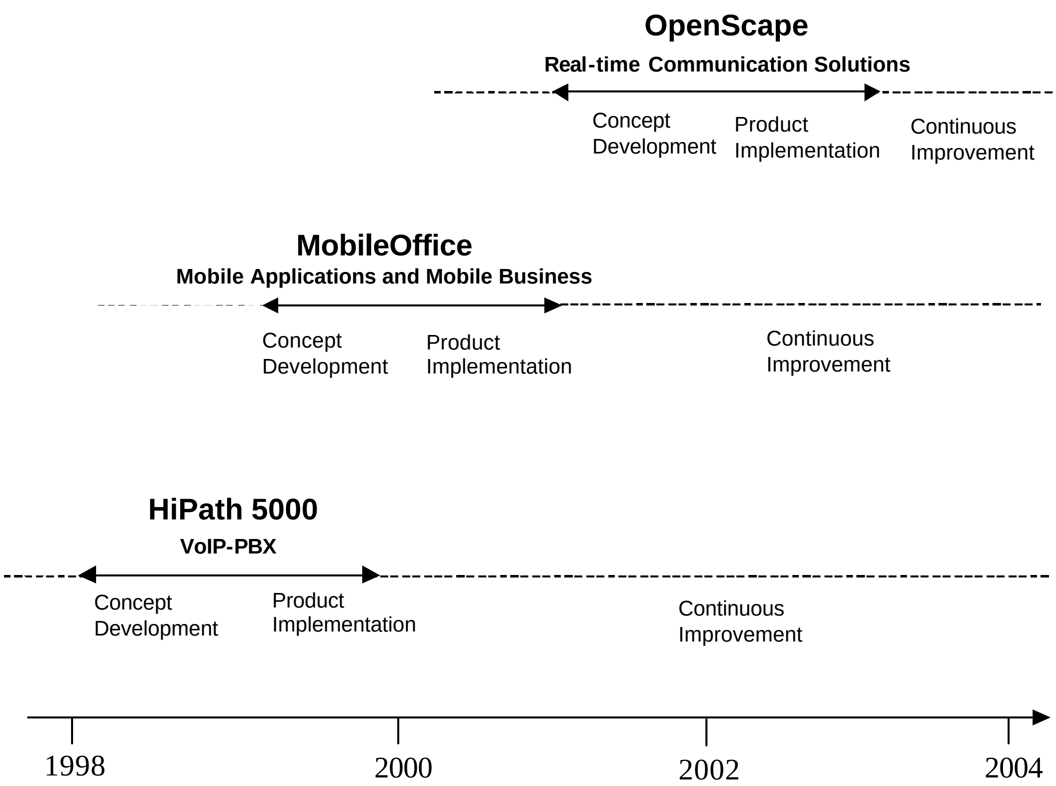


Figure 31 – VoIP Product Trajectory at Siemens

It started with HiPath 5000 which is a native VoIP-PBX that works in packet-switched and circuit-switched environments, and continued with MobileOffice, a comprehensive set of applications to connect mobile devices with enterprise networks. With the competences gained by these two projects, Siemens was able to initiate OpenScape, an "open, presence-aware, real-time communications software suite designed to quickly and easily synchronize people and information to facilitate action or decision-making" and "allows the full potential of IP communications to be realized for the first time" (Siemens Press Texts).

While the search for increased performance was natural for Siemens projects, the focus on VoIP technology enabled a significant strategic shift. Traditionally, Siemens emphasized sales of telecommunication equipment (hardware). VoIP might enable Siemens to expand considerably its presence into other commercial segments, such as software applications and communication services. Several senior managers got involved in the early stages of VoIP development to influence the direction. Other senior managers were more skeptical of the viability of the new technology, but encouraged the investigations as long as a clear focus on low cost and reliability was kept. After introducing HiPath 5000 into the market, Siemens realized that the replacement strategy of traditional PBX through VoIP-PBX was wrong because savings of 5-15% didn't justify the necessary investments in a new VoIP enterprise network.

By the end of 1999, the insight grew that only a more service and application oriented strategy could build new customer value. By the beginning of 2000, new IP-centric applications like ProCenter for electronic Customer Relationship Management (eCRM) or MobileOffice were initiated that finally led to the real-time communication platform OpenScape.

We follow this trajectory and outline the characteristics of each project.

The HiPath 5000 Project (1998 – 2000)

When Siemens introduced the Private Branch Exchange (PBX) product family "HiCom" in 1993, the product was an incredible success; its revolutionary bus design architecture enabled it to set the benchmark for business voice networks. With the HiPath product line, Siemens implemented the VoIP technology in enterprise network environments. For Siemens, the HiPath project was a breakthrough because it changed the traditional switchboard technology to data communication standards (IP protocol). The HiPath project built the foundation of VoIP competence at Siemens.

The essence of why VoIP was so important for Siemens is relatively simple. The architecture of a traditional voice network centers on the PBX, the central conduit of information linking all components and subsystems: the telephones, faxes, cordless phones, data adapters etc. and is connected to the public network. This type of architecture (the right part of Figure 32) has essentially characterized all enterprise networks sold in the last thirty years, from large to small companies. Its advantage is that it is simple and flexible. Its main disadvantage is that if performance of components increases, the PBX tends to become the bottleneck in network performance.

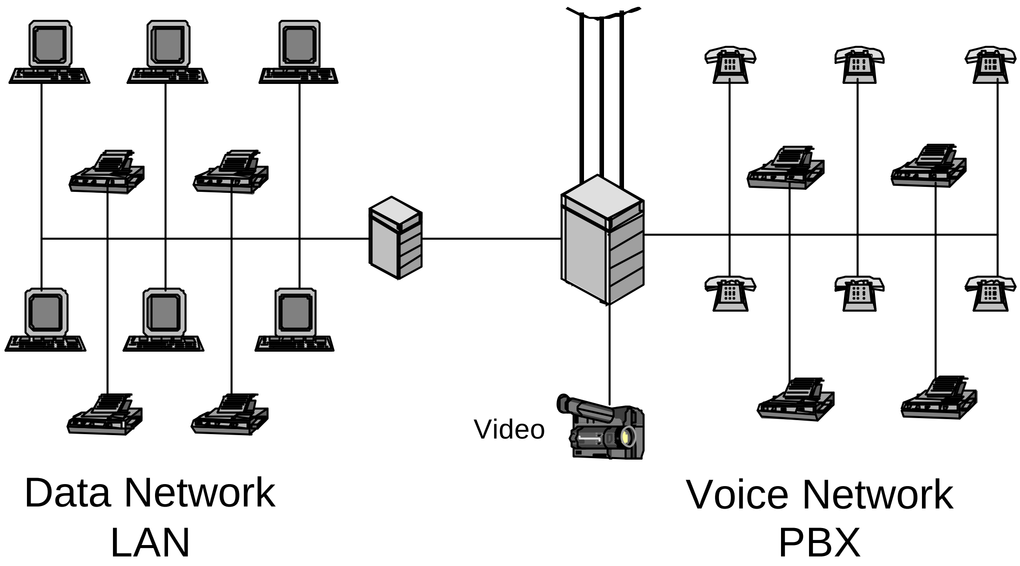


Figure 32 – Separated Voice and Data Networks

The idea behind the VoIP architecture is to resolve the bottleneck problem by eliminating the switchboard character of the PBX and change it to a more open and distributed architecture using the dominant and standardized IP protocol. The new architecture groups bundles voice and data into integrated modules. They are connected to each other in a star configuration that comes together in a router, which controls the information traffic in the computer. This architecture has several advantages.

First, VoIP makes it possible for companies to network Siemens' HiPath communications nodes across IP networks and create a uniform communication platform with distributed components and work points with a single-system image. Second, VoIP allows applications to reside on a standard platform (a PC server) for sharing applications with users across a distributed IP network. By using IP networks for communication and application sharing from a central server, businesses can significantly improve workforce productivity while reducing application, system management and circuit switch-related costs. Third, the architecture is very reliable, since errors can be located in individual modules and hardly in interfaces.

As one manager pointed out

> *"HiPath is a perfect progress in the evolution of our circuit-switched Hicom platform to the world of convergence: With HiPath, our customers will experience the best of both worlds. They get all the reliability and feature benefits of their Hicom systems, and at the same time can leverage their corporate WAN for handling interoffice voice traffic. There is no sacrifice in performance and the transition is made simple."*

Siemens was interested in the VoIP technology for several reasons. First was the relentless drive for innovation and increased performance. In the PBX products, aggressive targets had been achieved by working intensively on the product structure, increasing the capacity to transmit information by more than the factor of twenty at the end of the 90s. This had been very difficult to do, and the possibility of bypassing the PBX altogether was very attractive.

At Siemens, with a VoIP-PBX a new business opportunity was to converge voice and data networks in enterprise network markets. Siemens developed a working system model as a first prototype of the VoIP-PBX. The first trial with customers led to a complete redesign of the product concept. But by then, Siemens was applying what it had learned in the first trial and optimized its product concept.

Experimentation with immature versions of products or services only makes sense if it serves as a vehicle for learning about technology or markets, which applications and market segments are most receptive to the various product and process features, and about the influence of exogenous factors such as changes in customer preferences and the need for regulatory approvals.

Even though the first version of the VoIP-PBX was not a success, it did demonstrate that the market was indeed interested in such a product. Product development at Siemens became an iterative process. The firm enters an initial market with an early version of the PBX, learns from the experience, modifies the PBX based on what they have learned, and then tries again. Development of innovative products becomes a process of successive approximation, learning again and again, each time striving to take a step closer to a winning combination of product and market.

High levels of experimental iterations, which took several forms, drove the VoIP-PBX project. The team built some critical hardware models to test the feasibility of transmitting voice with high quality. In late 1999, a critical test vehicle finally confirmed that high quality voice transmission was feasible. This experimental iteration led to several architectural changes of the product. By December, Siemens finally locked into the design, and the first HiPath products were delivered in early 2000 to start the bring-up stage. Three weeks after the system was turned on it was capable of running reliably, despite the innovativeness of its design.

Concurrent with development of VoIP technology, problems occurred because of the uncertainty and complexity around VoIP technology. Because until the nineties, Siemens operated in an extremely stable, government-regulated market, they still developed their products in a sequential manner (concept development and product implementation). After deregulation of the telecommunication market, such in-depth planning of projects and products was hardly possible in such an uncertain environment and Siemens replaced its linear ‘planning-driven’ process with an iterative ‘learning-driven’ process. Siemens developed the HiPath product family by probing potential use cases with early versions of the product, learning from the experiments, and experimenting again. In effect, they ran a series of market tests – implementing prototypes into a variety of tests. The initial VoIP-PBX was not the culmination of the development process but rather the first step, and the first step of design-build-test was in and of itself less important than the learning and the subsequent steps that followed.

The MobileOffice Project (1999-2001)

The telecommunications application and services market is increasingly outperforming the equipment market by volume. This tendency is driven by the market trend to customized solutions and new software functionality. In order to transform a new technology platform like VoIP into profitable returns, it is necessary to build applications and services around this core technology.

This fact requires a more application- and service-oriented strategy by Siemens. The share of enhanced business services revenues generated by integrating converged systems and applications is strongly outperforming the share of revenues made with traditional voice-based systems. This leads to new business opportunities for hardware suppliers in the application and services business.

This market trend and cost pressures lead to a strategic shift of Siemens. Siemens Enterprise Networks in San José, the former ROLM, changed completely from a hardware manufacturer to a software development company in less than 10 years. Since the late 90s, Siemens in San José has been a pure software development center. The manufacturing of PBX hardware moved to other countries.

Siemens Enterprise Networks developed several IP-based services around VoIP technology with the focus on applications, work points and multi-site connectivity. For Siemens, the MobileOffice project was not a breakthrough because Siemens could build on the VoIP competences of the HiPath 5000 project. The MobileOffice project expanded the network competence through tying enterprise infrastructure to mobile devices like cellular phones, laptop computers, and PDAs. MobileOffice provides "any-device access to information and people anywhere and anytime" (Siemens Press Texts).

The OpenScape Project (2001 – 2003)

While the focus of the first-generation VoIP rollouts is on deploying a cost-effective integrated voice-data infrastructure, the objectives of the second-generation VoIP initiatives is to develop a variety of compelling standards-based integrated communications applications. The goal of the 2nd generation VoIP is to look beyond infrastructure cost-savings and create business value through applications that yield sustained improvements in user-productivity and business process productivity.

The Siemens' OpenScape suite of real-time communications software enables real-time synchronization of people and information and represents the 2nd generation VoIP and is a significant departure from the traditional Siemens HiPath PBX and MobileOffice Application product line. "OpenScape is a modular set of applications that streamline business communication processes for enterprise workgroups" (Siemens Press Texts). It is not a PBX replacement but it seeks to create a platform of 'presence-based communication'. Presence-based communication has been primarily associated with instant messaging (e.g. Microsoft's Windows Messenger), but it actually has broad applications in real-time communication in general. The same presence information behind instant messaging contact list icons that show whether your contact is "out to lunch", "busy", "away", etc., can enable compelling use cases for all media types – use cases such as 'polite calling' (calling others only when their presence shows they are available) and virtual team rooms. Presence information plays an important role in determining the best approach for handling incoming contacts.

There are various facets to real-time communication, but they all reflect the fact that communication becomes an integral part of IT infrastructures. E-mail is an obvious, early example, but real-time communication solutions and applications can also interoperate with data applications and be integrated with corporate directories. Building on the new Greenwich RTC platform from Microsoft, OpenScape works in conjunction with several mainstream IT platforms and provides a platform for enterprise-grade presence and availability management, and extends the new presence-based communication paradigm consistently to multiple media types across a rich set of applications and devices. Through cooperation with IBM, Microsoft, and SAP, OpenScape creates an industry standard that has the potential to establish a dominant design in real-time communication architectures and interfaces.

Companies currently have three principal domains: real-time communications (telephony), information (databases), and IT (network and other services). In today's economy there is a clear need to merge these domains into a common event framework and this development is well advanced on the information front. Enterprise Application Integration (EAI) is taking place and enabling transactions to flow from one system to another. The Gartner Group has coined the term ‘Integration Broker’ to describe the new generation of software that can help bridge the current disparate flows of data and real-time communications. This requires a new generation of VoIP initiatives.

Both previous projects (HiPath 5000 and MobileOffice) became the seed for Siemens’ OpenScape real-time communication, gradually developed under the broader umbrella of Siemens Enterprise Networks USA. The Siemens R&D group collaborated with IT experts of Microsoft and research institutions. All application choices would be optimized for the target business, the network installation at the customer side. The application context of real-time applications had therefore become much more narrowly and precisely defined.

3.3.3 Processes

Along the VoIP trajectory, Siemens was changing the core foundations of its product development efforts. In the words of a senior executive of sales:

> *“Siemens witnessed a massive transition from telecommunication hardware to telecommunication applications and services. We don’t sell sole products anymore; our aim is to offer solutions for real-time communication.”*

The following Siemens presentation slides show the current dominance of applications and services over traditional hardware products and outlines the new focus on “solution development” instead of product development.

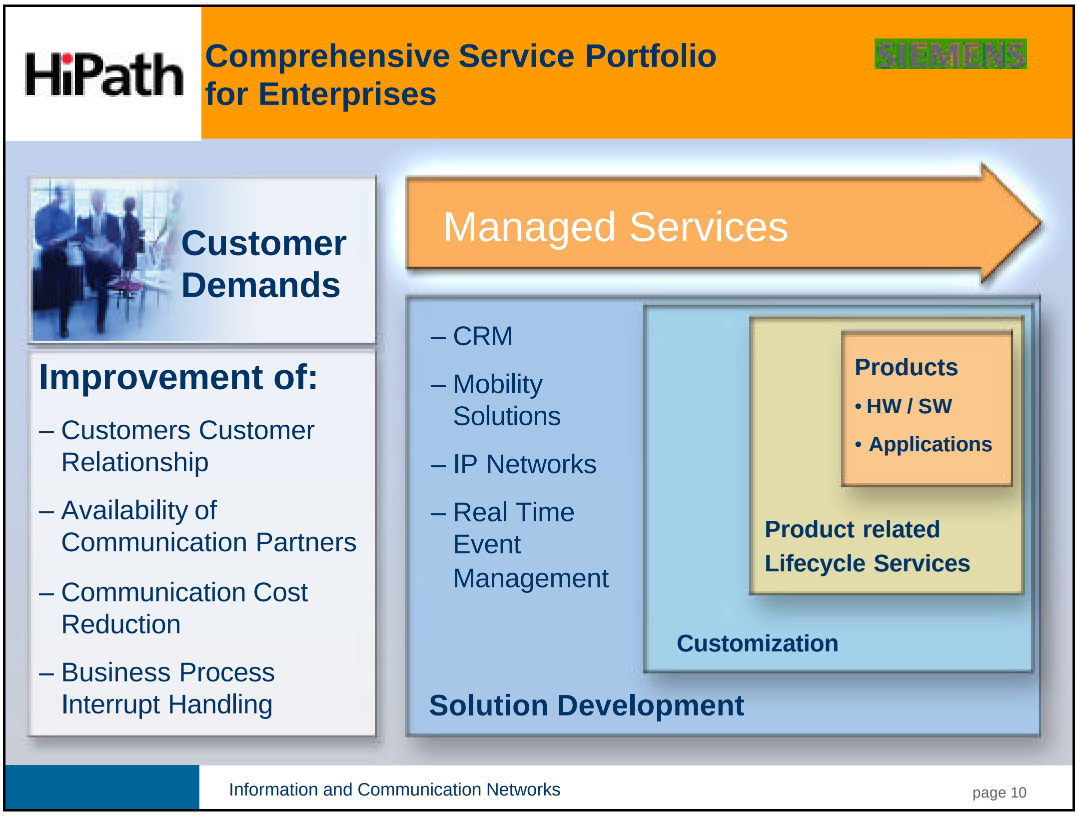


Figure 33 – Siemens' Transition from Hardware Supplier to Solution Provider

Moreover, the opportunities of such 'convergence products' changed product development at Siemens completely. Development efforts were clearly aimed at generating various options for applications and services. The evaluation and selection of all application ideas (provided by internal employees or external customers) was made in a unified, focused way by a single, experienced group of individuals within Siemens ICN-EN. The evaluation and selection was made based on precise targets derived from cost and performance objectives. As noted by the senior executive of sales:

> *"The issue is to determine the relevant customer needs, and then consider what application or service can do this."*

Once the service architecture was finalized, any change in service or application characteristic would need approval from a centralized committee. Figure 34 shows the current application portfolio around HiPath.

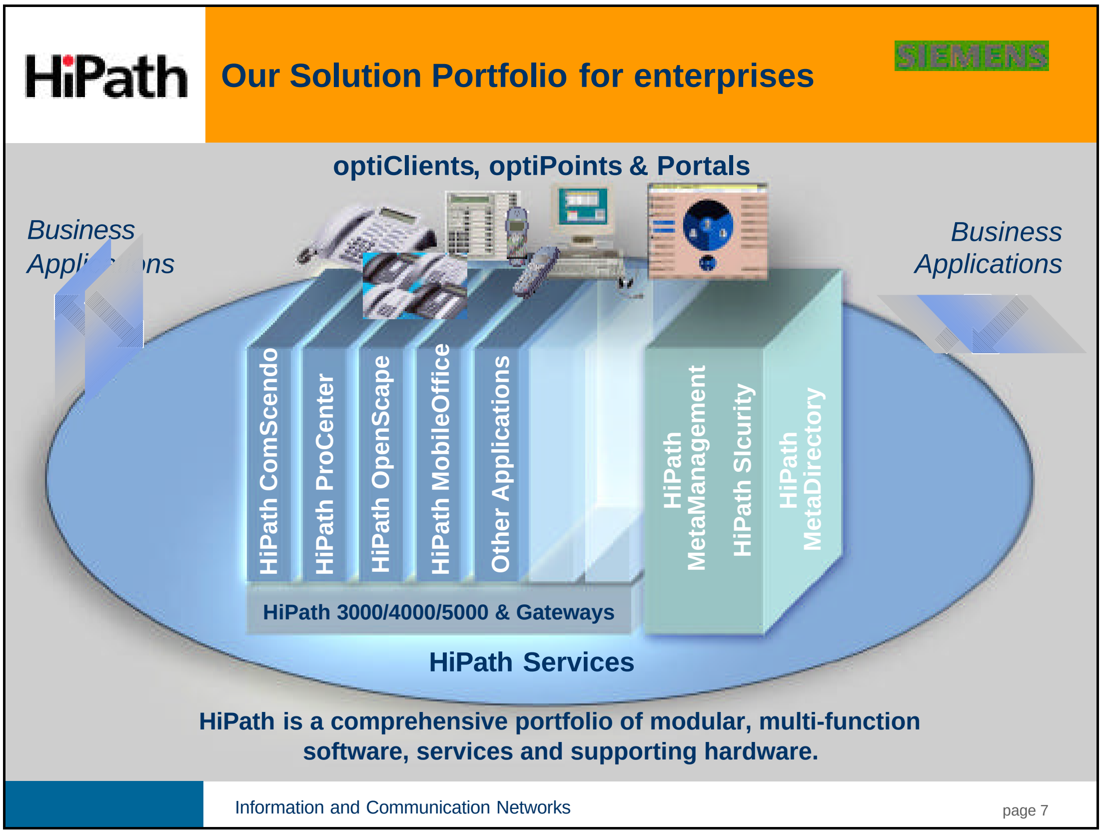


Figure 34 – HiPath as Comprehensive Portfolio of Software, Services, and Hardware

The Siemens case shows that product and service development has to be seen in a broader context than sole projects. Technology and market dynamics require an evolutionary focus where new competences are built and developed through a sequence of projects. At Siemens, the HiPath 5000 project was a breakthrough for Siemens to transfer the traditional voice networks to IP standards. The MobileOffice project developed applications (hardware and software) that empower mobile users with anytime access to enterprise resources. Both together opened the door to communication platforms like OpenScape that provide real time communications solutions for medium to large enterprises - resulting in greater connectivity between people and information.

Dynamic Routines at Siemens

In telecommunication markets, projects must be responsive to rapidly evolving customer requirements, changing product specifications multiple times to make sure that the final product architecture really meets the current needs of its customers. This is necessary because new features sometimes evolve even during the course of a product development effort.

Development of applications and services at Siemens is driven largely by requirements and discussions with the help of a visualized application model. Experimentation with new approaches and the combined expertise and experience of all experts involved help to uncover problems before committing to a final solution. Experimenting with an iterative approach, linking individual design choices to the requirements of the entire application and facilitating the joint optimization before routinization is built are all important factors.

Siemens also relies on external sources to test its applications and search for relevant new information during the course of effort. First, among these, are other ICN subsidiaries. With the development of VoIP applications, some ICN subsidiaries as lead users were invited to evaluate and discuss the product and the implementation was finally done there.

At Siemens, during the OpenScape project, critical decisions were made rapidly and jointly by a dedicated global core business team, usually a group of professionals who met regularly. The core of the global team comprised five managers, three from the US, one from the headquarters in Munich and one from Switzerland. This core business team had the final say in architectural decisions linking product architecture and customer requirements. During the project, this group had to coordinate both software experts and enterprise network veterans. In all cases, managers had both extensive experience with multiple aspects of data processing and network design and a good understanding of changes and their impact on product performance.

These organizational challenges were aided by visualization efforts. In OpenScape the application model changed several times as the effort progressed. The application architecture was designed on wallpaper. This wallpaper performed the function of a living specification; it was a complete representation of the applications, which all members of the project team shared. The wallpaper enabled the overall impact of individual application choices to be rapidly verified. It also facilitated communication among team members, and it integrated individual efforts. All team members could work on the same application model. At Siemens, this model hangs on the wall of the main floor in the R&D department, and when a significant change took place, each key member had to confirm the change. As such, everyone was apprised of the latest version of the overall application and the direction of its evolution.

The use of existing competences is essential for specifying the right product architecture. Many sources of knowledge need to be integrated by team members, who make use of their individual experience to interpret the impact of changes. Product managers should have great depth and breadth of experience and are particularly crucial. In OpenScape, each project team member had worked in the development of application software or enterprise networks before. The group comprised primarily R&D and sales people, although it also included individuals with extensive distribution experience.

One area where experience appeared to have the greatest impact was the early partitioning of a project plan. When OpenScape started, the project manager first focused on a comprehensive activity diagram of the whole project, which serves as a project timetable. The project timetable is not used as a rigid specification, and almost all of the detailed objectives changed repeatedly. Its main role is to identify the basic activities and functional responsibilities and to highlight the most critical interactions among them. This is essential, since the project plan identifies what is likely to change and what is likely to remain the same. It is therefore used as an early roadmap, identifying the most appropriate ways to partition tasks to minimize uncertainty of who is doing what and when.

Moreover, Siemens relies on ties with a research institution for bringing in the outside research experience. PhD students with relevant theses are frequently hired into the company and former PhD students gained consulting contracts in order to support product development activities. The author was one of those PhD students.

Design-Build-Test Cycles

Developing products and services in a deregulated and uncertain environment required a different approach to product development than Siemens had used to date. A senior project member described it like this:

What matters is first choosing the right test measures. These are a set of variables that give us solid, quantitative indication of product and service performance. Especially important is real-time responsiveness of software applications. We then have a focus on measuring a large number of product tests, changing the product until the measures indicate that the right objectives are met. It is essential to run enough trials, both to test with different approaches, and to obtain statistically significant results.

Figure 35 shows a Siemens-specific Design-Build-Test cycle. There are 6 steps that should be carried out in each iteration. Product development is complete only when all product options under consideration had been fully explored, when all product specifications had been fully characterized, specified, and documented and when product performance had been reached and sustained on the development line.

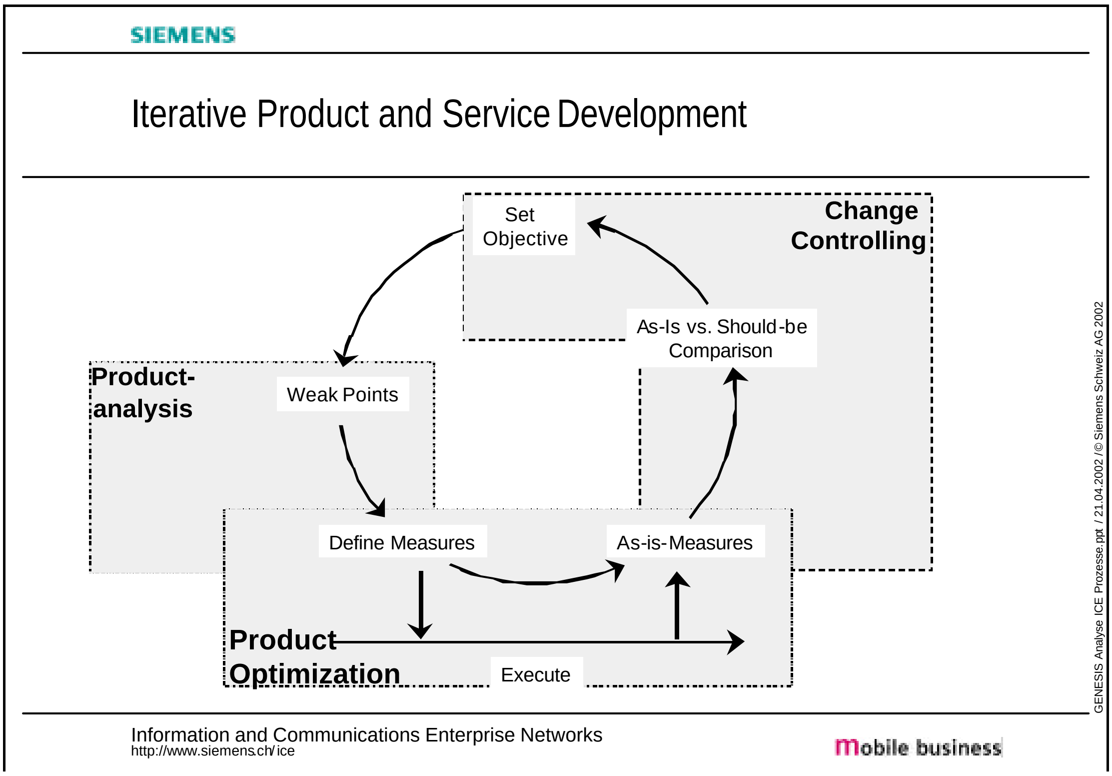


Figure 35 – Siemens Methodology - Iterative Product and Service Development

In successive product generations, Siemens has continued to pursue a focused organizational approach to making product choices, coupled with iterative 'trial and error' for the development of new products and services. Product choices are coherently made by a core business team. With reference to service development, Siemens had by 2001 significantly increased its performance in developing applications and services around the HiPath product family. They also utterly eliminated the learning curves, achieving seamless transfer from development to sales. These factors have entrenched Siemens as a leader in the enterprise network industry worldwide.

4 Analyzing Case Study Evidence

We have just analyzed two very different firms. The first, Audi, develops automobiles that are very complex product systems with a wide variety of technologies ranging from aluminum to wireless communication, from mechanics to electronics. The second, Siemens, develops applications and services around VoIP technology aimed at B2B customers.

Despite the differences, the characteristics of both companies resemble specific patterns of product development capability that allow for sustained product development success in diverse contexts. The case studies of Audi and Siemens show that dynamic routines (learning and reconfiguration) and path dependency are crucial parts of product development capability.

4.1 Pattern of Product Development Capability

Both companies create unique product paths that develop their competence bases and market positions – and this inter-product relationship creates trajectories of long-term product development success. Each product development effort should contribute to build or continue such a path and affects the firm's market position as well as the competence base which are themselves objects for evolution.

With such an observation, one can derive propositions based on the dynamic capability perspective to product development. I argue that pattern of product development capability shows product trajectories that follow or even create evolutions in technology and markets and derive the following propositions:

PROPOSITION 1A. *The closer product trajectories follow evolutions in technologies and markets, the more sustained new product success is likely.*

…and even more desirable:

PROPOSITION 1B. *The more product trajectories create evolutions in technologies and markets, the more sustained new product success is likely.*

At the beginning of such a product trajectory, Audi and Siemens possessed a market position M_0 and competence base C_0. Their trajectories started with a breakthrough project P_1 that realized a product/service innovation and initiated a market position M_1 and competence base C_1. The expansion project P_2 expanded the innovation to other market segments and succeeded the path towards market position M_2 and competence base C_2, and the following project P_3 penetrated the innovation to market position M_3 and competence base C_3.

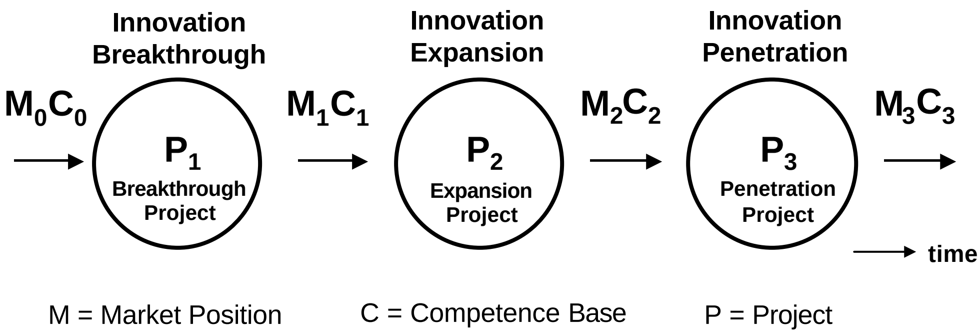


Figure 36 – Product Trajectories and Evolution of Market Positions and Competences

In the following tables, we follow the product trajectories observed at Audi and Siemens and have a closer look at the influence of each project on the market position, the competence base and the project characteristics that reflect the individual product development effort. The analysis is structured along the path of Figure 36. It starts with the initial position M_0C_0 and continues with the breakthrough project P_1, etc.

Position M_0C_0

M_0C_0	Audi	Siemens	Remark
Product Trajectory Position	Before Breakthrough Project Audi A8 (D2)	Before Breakthrough Project HiPath 5000	
Market Position	Audi's entry into the luxury segment came with the 1988 V8, with a four-valve alloy 3.6 liter engine and permanent quattro four wheel drive. The Audi V8 was viewed quite favorably by both critics and customers and built into a satisfying business but it failed to beat its competitors in most performance criteria like riding, handling, comfort etc.	Siemens was a traditional supplier of telecommunication equipment. Customers complained about the poor service quality.	Both companies occupied specific market segments but deficiencies for entering new market segments were evident.
Competence Base	Audi had strong competence in four-wheel drives but less competence in the luxury market segment. Smoothness of drive and most refining requirements were less marked than competitors' products.	Siemens had strong technological competences in voice networks. But they were hardly aware of data communication and Internet technology. Siemens had a mere focus on product and 'hardware'. Customer service was limited to technological support and warranty regulations.	Both companies had strong competences in their core business but lacked competences in future-relevant technologies.

Table 7 – Product Trajectory Position M_0C_0

Project P_1

P_1	Audi	Siemens	Remark
Product Trajectory Position	Breakthrough Project: Audi A8 (D2)	Breakthrough Project: Siemens HiPath 5000	
Project Mission	Develop an innovative product that achieves performance advantages by implementing aluminum as body material for automobiles. Improve Audi's position in the luxury segment of automobiles.	Develop an innovative product that achieves cost and reliability advantages through implementing VoIP technology in the enterprise network market. Potential for Siemens to lead VoIP technology.	Both companies strived for a leadership position with an innovative product.
Dynamic Routines	Audi co-operated with Alcoa to use their aluminum competence for the project. Prototypes were presented in various motor shows to gain feedback of customers on technology acceptance. During product development, the A8 (D2) prototypes were presented in two 'product clinics' to validate the product concept by key users. A product manager function took over responsibility to keep costs within the product concept. It had to report frequently to senior management and Board. The plan shifted from time to time because of experimental results that did not match plans. Many changes in concept design were necessary to meet aggressive targets. .	Siemens acquired a data communication company to build competences in data communication. The reference for product performance was the original PBX HiCom voice network system that set the targets for cost, voice quality and reliability for HiPath 5000. The cost reduction of VoIP compared to traditional PBX was one central argument to develop it and was, therefore, reported frequently. A project plan was the reference for time planning and a prototype was the reference for all product changes.	Both companies acquired and integrated a necessary external competence so that it became internal. Both companies frequently validated the product concept with potential customers. Both companies monitored the performance attributes with which they wanted to be ahead of competition.

Table 8 – Breakthrough Project P_1

Position M_1C_1

M_1C_1	Audi	Siemens	Remark
Product Trajectory Position	After Breakthrough Project: Audi A8 (D2) Before Expansion Project. Audi A2	After Breakthrough Project: HiPath 5000 Before Expansion Project: Siemens MobileOffice	
Market Position	The aluminum technology was Audi's key to beat competitors' performance attributes in the segment of luxury cars. The aluminum technology was more expensive than steel technology but allowed a significant reduction in car weight. Audi decided to realize the technology in the premium segment where one can achieve significant performance progresses and cost pressures are not as high as in smaller cars. Therefore the Audi A8 (D2) was decided on to develop the most light-weighted and sporty car in the luxury segment. With the A8 (D2) aluminum technology, Audi matched the market trend to reduce the weight of automobiles, to reduce fuel consumption and increase driving performance.	The HiPath 5000 project was Siemens' key to expand its market from telecommunication equipment to software applications and services based on VoIP technology. VoIP makes existing voice networks obsolete and improves reliability and comfort of voice communication. It represents the next generation of voice communication.	Both companies became technology leaders in their market segments and built a foundation for future product development projects.

Table 9 – Product Trajectory Position M_1C_1

Position M_1C_1 *(continued)*

M_1C_1	Audi	Siemens	Remark
Competence Base	Audi experimented with aluminum as the body material to replace steel in order to reduce weight and to increase performance and the safety of automobiles. But the organization had only sporadic experience with aluminum material. Most engineers hadn't ever built a car body out of aluminum. Therefore external aluminum competence at the aluminum specialist Alcoa was acquired. To develop the A8 (D2) a strategic alliance was built with Alcoa, a popular aluminum specialist that was chosen as an external development partner. With the A8 (D2), Audi developed the product and process competence internally. Audi demonstrated with the A8 (D2) that it has the competence to reduce the weight of cars with aluminum technology.	Siemens has strong competences in telephony and acquired a data network company. Therefore, all necessary competences were available within Siemens. The problem was more to combine and integrate the traditional voice site with the upcoming data site.	Both companies have built new technological competences in the course of their breakthrough projects. Audi gained aluminum competence; Siemens gained VoIP competence.

Table 11 (Continued) - Product Trajectory Position M_1C_1

Project P_2

P_2	Audi	Siemens	Remark
Product Trajectory Position	Expansion Project. Audi A2	Expansion Project: Siemens MobileOffice	
Project Mission	Develop an innovative car that achieves fuel consumption advantages through implementing aluminum technology in a higher volume car segment. Simplify and optimize production technology of the Audi A8 (D2) for a cost-sensitive market segment.	Establish software applications and services as strategic goal for Siemens. Extend VoIP technology to mobile devices. Pioneer VoIP technology as future investment. Create a new market position for Siemens as software and application producer.	Both companies expanded their technological competence from a niche to a higher volume market. Both companies wanted to leverage their technological competence through the focus on cost reduction and increased reliability.
Dynamic Routines	Many efforts were undertaken to simplify the production process and reduce production time. In contrast to the A8 (D2), the A2 production process was characterized by a high level of automated steps. During product development, the A2 prototypes were presented in two ‘product clinics’ to validate the product concept by key users. Most people assigned in the A8 (D2) project were also assigned to the A2.	Siemens integrated a company with competences in data communication. Siemens used representative application prototypes to validate acceptance and product performance. The most important performance attributes for Siemens were reliability and cost reduction. This required large amounts of product testing by lead users to validate the application.	Audi’s main focus was on deploying a cost-effective high-tech car. Similarly, Siemens’ main focus was to deliver a cost-effective VoIP application in enterprise networks.

Table 10 – Expansion Project P_2

Position M_2C_2

M_2C_2	Audi	Siemens	Remark
Product Trajectory Position	After Expansion Project: Audi A2 Before Penetration Project: Audi A8 (D3)	After Expansion Project: Siemens MobileOffice Before Penetration Project: Siemens OpenScape	
Market Position	The A2 uses the strength of aluminum to increase fuel efficiency. The A2 became the first four-door car with a fuel consumption below 3 liters per 100 km. The A2 wanted to establish a trend to sophisticated and exclusive cars in smaller car segments. It realized low fuel consumption without other disadvantages like less safety or less driving pleasure.	The MobileOffice project implemented data communication technology in voice communications. Strategically, with MobileOffice, Siemens became the technological leader in VoIP applications and offered supporting applications and services that were not possible without VoIP technology.	Both companies expanded their technological competence from niches to higher volume market segments. Both companies became the technological leader in their targeted market segment.
Competence Base	With the A2, Audi became the leader in fuel economical cars. They used the product technology of the A8 (D2) and leveraged this competence by developing automated mass production processes around it. The A2 project increased the profitability of aluminum technology and built the basis for expanding the technology to other product lines.	Siemens experimented with VoIP to reduce costs and increase the reliability of traditional voice networks. With the MobileOffice project, Siemens knew that they had a competitively leading PBX. They used their VoIP competence of VoIP enterprise networks and leveraged this competence by expanding to application and service markets.	Both companies leveraged their competences by optimizing aluminum technology for cost-sensitive smaller cars (Audi) or by using VoIP technology for application and services (Siemens).

Table 11 – Product Trajectory Position M_2C_2

Project P_3

P_3	Audi	Siemens	Remark
Product Trajectory Position	Penetration Project: Audi A8 (D3)	Penetration Project: Siemens OpenScape	
Project Mission	Converge A8 product technology with cost-reduction measures of Audi A2.	Converge VoIP applications with VoIP-PBX.	Both companies profit from competences built through their previous product development projects.
Dynamic Routines	With the functional competence of the A8 (D2) project together with the manufacturing competence of the A2 project, Audi had all the necessary competences available to develop an A8 (D3) that would beat the performance attributes of competitors and simultaneously provide the profitability of an efficient production process. Most people assigned in the A2 project were also assigned to the A8 (D3).	With a state-of-the-art product (HiPath) and the VoIP application competence of the MobileOffice program, with OpenScape Siemens was able to enter the market segment of real-time communication and simultaneously become the leader in enterprise networks.	Both companies built valuable leadership positions through their product trajectory.

Table 12 – Penetration Project P_3

Position M_3C_3

M_3C_3	**Audi**	**Siemens**	**Remark**
Product Trajectory Position	After Penetration Project: Audi A8 (D3)	After Penetration Project: Siemens OpenScape	
Market Position	The A8 (D3) had to penetrate the A8 (D2)'s market position and simultaneously increase profitability. With the help of the cost-orientated production technology of the A2, the A8 (D3) now established a leadership position in product and process technology of aluminum. The Audi A8 (D3) matched the trend to lower car weight in order to achieve better handling and lower fuel consumption.	The OpenScape project is a logical progress from the HiPath 5000 project and MobileOffice project. Strategically, with OpenScape Siemens builds a new market segment of real-time communication and has years of advantage compared to competitors. The project matched latest evolutions in technologies and markets. The customer can choose which technology he wants to have and the 'real-time communication' business shows tremendous opportunities for future innovations.	In both companies, the product trajectory developed valuable market positions. Audi became technology leader in the luxury car segment and Siemens became technology and service leader in enterprise network markets.
Competence Base	Audi demonstrated with the A2 and A8 (D2/D3) that they have the competence to develop and produce an aluminum car that is a profitable business. This competence can now be further replicated to enter new market segments like sports cars where a light-weight car body is important.	Siemens had strong competences in enterprise networks hardware but hardly any experience in the application and service business. With the MobileOffice and HiPath, Siemens became the technology leader in enterprise network markets. This competence can now form the basis to develop further paths and new innovations.	In both companies, the previous projects established competences that formed the basis to continue the trajectory or to establish new ones.

Table 13 – Product Trajectory Position M_3C_3

Concluding Tables 9 to 15, if we follow the product trajectories of Audi and Siemens, breakthrough projects had to explore something new, bringing a technological opportunity from a research status towards a usable product in a small and seizable market. Breakthrough projects build new technological competences. Expansion projects expand the technology to higher volume markets that are more competitive and cost sensitive. The purpose of this project is to leverage the developed competence to the requirements of volume markets. Penetration projects utilize and refine the competences built by the previous projects and stretch advantages.

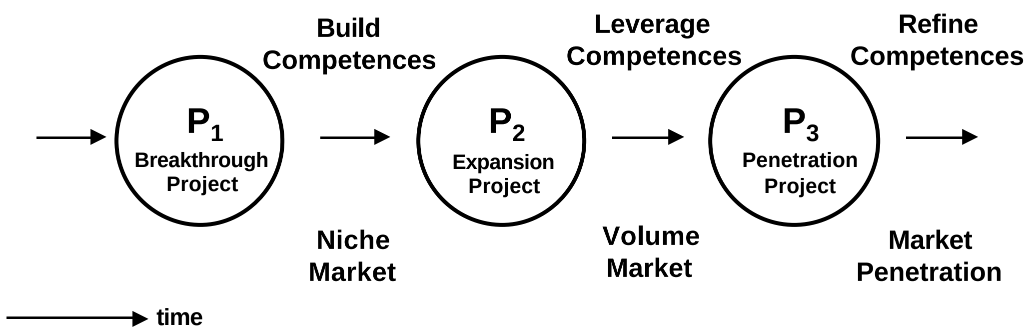


Figure 37 – Product Trajectory and Nature of Projects

With the above, we can argue that the pattern of product development capability shows product trajectories with the following elements: a breakthrough project that builds new competences in small market segments, expansion projects that leverage competences to volume markets and penetration projects that refine competences, penetrate market position, and stretch advantages.

PROPOSITION 2A. *The more breakthrough projects build new competences and are targeted to niche markets, the more likely sustained new product success is.*

PROPOSITION 2B. *The more expansion projects leverage competences and are targeted to volume markets, the more likely sustained new product success is.*

PROPOSITION 2C. *The more penetration projects refine competences and are targeted to penetrate existing markets, the more likely sustained new product success is.*

As the cases of Audi A8–D2 and Siemens HiPath 5000 show, breakthrough projects are associated with high levels of learning indicated by high levels of experiment-based iterations and diverse adaptations in product or service architecture. Breakthrough projects are linked to an approach that creates new product or service architecture. This creation happens through iterative experimental trials, which generate new information about technology-context application and component-system interactions. Product development tasks are strongly affected by such upgrades because each time the product/service architecture has to be upgraded.

With the above, I argue that breakthrough projects show high degrees of design-build-test iterations that create new product/service architecture.

PROPOSITION 3A. *The more breakthrough projects are founded on experimental iterations, the more likely sustained new product success is.*

Expansion projects (Audi A2 or Siemens MobileOffice) are linked to an approach that reconfigures product and process architecture in order to utilize the new technology for volume markets. Iterative experimental trials happen as well but not in the same number as in breakthrough projects because the competence built by the breakthrough project can be utilized. Expansion projects show medium levels of design-build-test iterations that reconfigure product/service architecture. I derive the following proposition:

PROPOSITION 3B. *The better expansion projects find the optimal balance between experiential planning and experimental iterations, the more likely sustained new product success is.*

Penetration projects (Audi A8-D3 or Siemens OpenScape) are linked to incremental refinement of product or service architecture. The architecture remains nearly the same. Design-build-test trials happen to confirm expectations. Product and service development is based on the competences built by the former projects. Penetration projects show low levels of design-build-test iterations that refine product/service architecture. I derive the following proposition:

PROPOSITION 3C. *The more penetration projects are founded on experiential planning based on previous projects, the more likely sustained new product success is.*

The similarities between both firms are striking. Breakthrough projects (Audi A8–D2 or Siemens HiPath 5000) implement a new product/service architecture, expansion projects (Audi A2 or Siemens MobileOffice) reconfigure existent product/service architecture, and penetration projects (Audi A8-D3 or Siemens OpenScape) profit from their predecessors and continue to refine product/service architecture incrementally. Product trajectories proceed via building of new competences at the beginning, then these competences are leveraged and refined at the end. Both Audi and Siemens strive for establishing such trajectories for sustained product development success (see Figure 38).

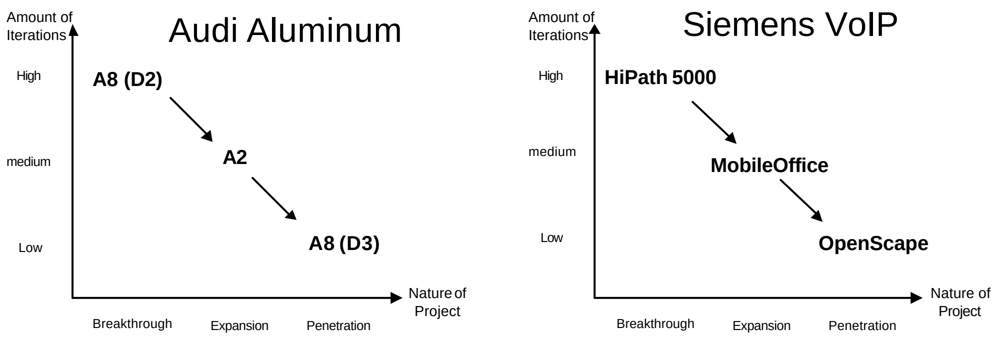


Figure 38 – Pattern of Effective Product Trajectories at Audi and Siemens

4.2 Elements of a Dynamic Capability Perspective to Product Development

We have just seen how Audi and Siemens have built effective product trajectories and we analyzed the nature of such trajectories according to the amount of design-build-test iterations. The next step is to modify theory and develop policy implications.

4.2.1 The Limitations of Existing Theories

Traditional literature on product development has little to say about product trajectories and their path dependency and does not readily explain long-term product development success. It neither explains inter-product relatedness nor its absence. While there is some development of evolutionary explanations for sustained new product success in strategic management literature, these theories are without strong operational implications. Thus, one can 'explain' sustained new product success from an outside-in perspective through notions of product differentiation and market segmentation, but such theories rarely explain why product development success remains over time. The same can be noted for an inside-out perspective where product development structure and process are supposed to be the drivers of long-term product development success. Long-term product development success cannot be built on such static perspectives.

Other approaches are almost equally poor. For instance, the evolutionary perspective focuses on industrial environments and their interaction with organizations over time. Therefore it provides little gain, though it may provide a starting point. Such an approach is quite explicit about the importance of learning and organizational renewal. The concept of dynamic capabilities was first to combine the 'static' inside-out perspective with evolutionary reasoning and provided an argumentation path to explain sustained new product success. Thus, it is from a dynamic capability perspective that we draw our implications for product development.

I argue that if we want to explore a dynamic capability perspective to product development, I find it necessary to put to the side theories of the firm which define firms along their resource position or competence base as well as those which define firms according to their industrial position. The former puts zero weight on the product in its market context; the latter neglects internal aspects of firms. In my view both need to be considered.

Each of the key variables of a dynamic capability perspective to product development will now be analyzed.

4.2.2 Processes

The amount of learning decreases from breakthrough projects to expansion and penetration projects as depicted qualitatively in Figure 39. Breakthrough projects can run many design-build-test iterations during the course of the project, investigating a broad set of product and process alternatives. These are compared against each other, with a relatively well-defined output target in mind. In the Audi A8 (D2) study, these iterations came in an intense, parallel, but relatively short burst. As such, there was ample time to experiment with prototypes and transfer the new technology to the manufacturing setting. The telecommunications environment, in contrast, did not require such long lead times for the bring-up stage. In a relative sense, the more revolutionary a project emerges, the more iterations are required for learning.

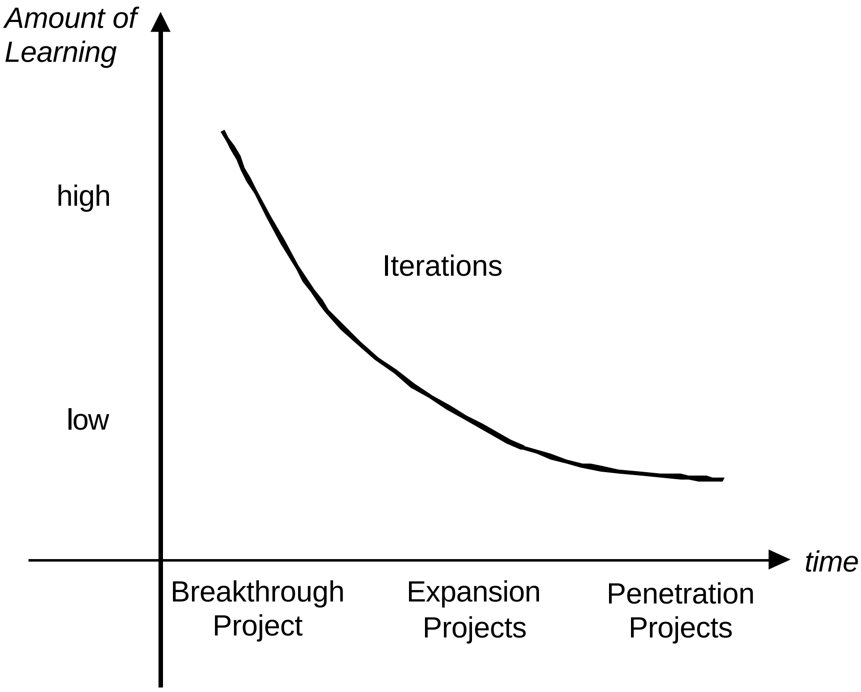


Figure 39 – Product Trajectories and Learning (Dynamic Routines)

While the study found no projects without significant routinization, routinization was not the primary factor in differentiating between more or less effectiveness in breakthrough projects. This can be understood in part by the obsolescence of knowledge in situations of uncertainty. Breakthrough projects overturn the established context. It is thus unsurprising that routinization is not critical to bringing new technologies to market (see Figure 40).

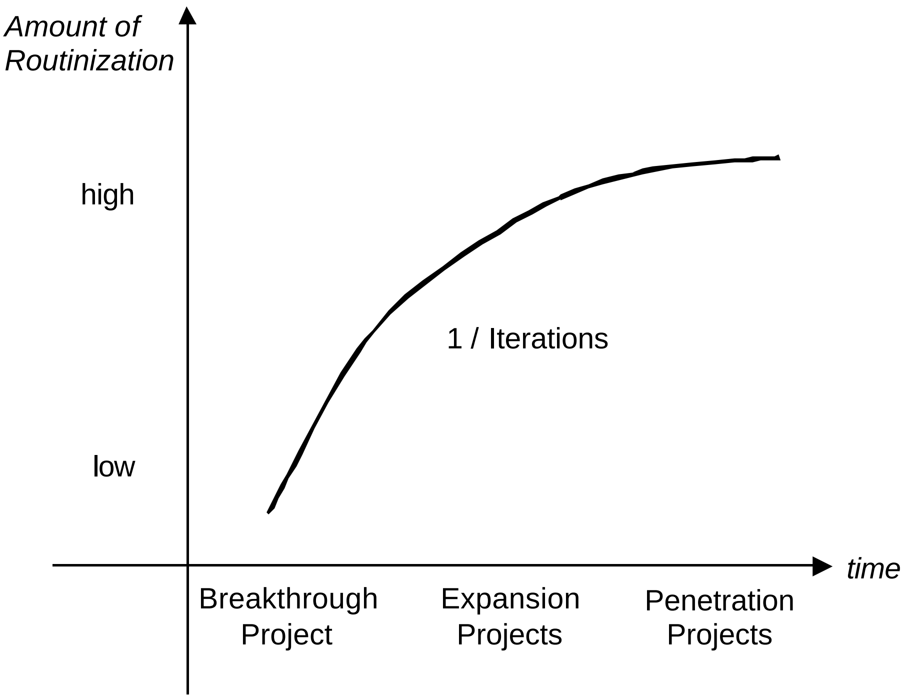


Figure 40 – Product Trajectories and Routinization (Static Routines)

We derive the following propositions

PROPOSITION 4A. *More effective product trajectories show a high amount of learning in the early stages whereas they depend on routinization in the later stages.*

PROPOSITION 4B. *The more learning is facilitated in the early stages and the more routinization is built in the later stages, the more likely sustained new product success is.*

As Audi's A8 (D3) makes clear, large performance increases are possible through breakthrough projects as well as through expansion or penetration projects. Managing penetration projects are associated with a deeply contrasting approach however. The most important factors are the emphasis on product and process refinement and operational excellence. Rather than doing various iterative experiments to learn, effective penetration projects relied on a sequence of analytically driven experiments, gradually confirming expectations. Transferring new technologies to the manufacturing setting does not require as much time, since the projects are making extensive use of existing, mature equipment.

Incremental improvement and refinement is essential for effective product trajectories. Experienced project members drove the A8 (D3) project, obtaining a dramatic improvement in performance by stretching the existing approach of the A8 (D2) and A2 by innumerable refinements of product architecture and manufacturing process. Similarly, at Siemens, some people started with the HiPath 5000 project, went over to the MobileOffice project, and now use their experience in the refinement of OpenScape.

Managing penetration projects is linked to the pattern of product development capability different from those driving breakthrough projects. Rather than an exhaustive focus on learning resulting in product iterations and adaptations, evolution appears to be driven by refining integration of existing competences. The focus is on refinement and optimization. Gaining some new ideas and having a good setup for representative experimentation, however, are important to extend old concepts in effective ways.

In summary, in breakthrough projects, iterative trials and high levels of learning ensure that new competences are built. They are leveraged through expansion projects and refined by penetration projects. Audi discovered early on the necessity of mastering aluminum technology in a high volume production to leverage its aluminum competence. Siemens adopted a similar philosophy for its development of VoIP applications and VoIP-PBXs but focused on B2B customers.

4.2.3 Path Dependencies

The two key aspects of path dependencies in our dynamic capability perspective to product development are the competences being employed and the market into which the new product is to be launched. If firms attempt to enter new market segments with new technologies, failure is likely to be the norm because the effort is likely to be outside the firm's learning range (Teece et al., 1994). Product trajectories show path dependencies between the products and the firm's competence base and market position at the time the product has been developed. I derive the following proposition

PROPOSITION 5. *The better products are aligned with the existent market position and competence base of the firm, the more likely sustained new product success is.*

At Audi and Siemens, we observed that both firms keep a close distance to market and technologies not only at the beginning but also during the course of a new trajectory.

Market Distance

Market position matters, but in turbulent environments a firm's market position is often fragile. In automobiles, the evolving customer perceptions make specific models obsolete after 6 years at the latest and in enterprise networks it is more the technology dynamics that overtake existing product lines.

A more lasting asset is reputation factors that enable the firm to achieve various goals in the market. For product development, reputation is a kind of summary about the firm's current resources and competences and its likely future behavior (Teece et al., 1997).

Keeping a close market distance was considered to be important during as well as before and after each project. This approach is strongly used by Siemens ICN-EN with the project OpenScape, where a lead user helped significantly to evolve the application concept, providing feedback on features and functionality that have been integrated into software prototypes, and suggesting new features and improved functionality that improve the match with customer requirements. Siemens is therefore very capable in keeping a close market distance.

Similarly, Audi obtains a close market distance in motor shows and through 'product clinics' that often give feedback on product design and usability. Quality assurance engineers are expected to validate the product and production process from a user perspective. They continually compare their product with the functionality and features of their main competitors. The extensive internal feedback is then combined with more carefully staged external 'show cars'. This is done to organize market feedback and to limit the risk that imperfections in early product releases would damage the company's reputation.

Technological Distance

New technologies and features must be translated into product and process architecture. Organizations must respond to technology shifts before and even during the course of development projects (Iansiti and MacCormack, 1997). Waiting until all major design issues are resolved before product launch wouldn't be successful because they will never be resolved completely. Product development should therefore expect a significant amount of design work to be thrown away especially in breakthrough and expansion projects.

The Audi A2 project illustrates these dynamics well. After a partially complete prototype had been developed, a main competitor, the Mercedes-Benz A-class, had been struggling in specific driving maneuvers because of chassis problems. These problems occurred because this space-friendly body concept of the A-class had the disadvantage of a high center of gravity compared to other cars. Because the A2 had a similar body concept, Audi conducted a comprehensive review of the product and decided that major revisions were necessary. The chassis was to be redesigned so that even in extreme driving maneuvers the car would be more robust in stability. A new set of features and functionality like the open-sky roof was also developed to better differentiate Audi's A2 from the Mercedes-Benz A-class. As the effort continued, and the new chassis was integrated, the team found that parts of the car's body also had to be redesigned to work with it. As noted, major car components changed during development – meaning that by launch date the development team had rebuilt the car almost twice during the development cycle.

Responsiveness merits further elaboration. It varies significantly with project context. A product will be successful only if it is introduced to the market rapidly, since the customers compare its applied technologies to those of other products on the market at the same time. If an organization is not responsive enough, the product will be introduced with substantial delays, making its potential at the time of introduction low. As such, other factors, such as management behavior and making critical decisions can even there make a difference.

Therefore, product development capability includes responsiveness. Though it is not only market distance, it is also not simply technology distance. Product development capability was consistently linked to responsiveness during and between the development cycles, going well beyond traditional product development tasks found in traditional product development literature. Once the product specification is defined, opportunities for product and process architectures that promise new product success can rapidly appear but also disappear. The achievement of product development success frequently involved fundamental changes in product and process architecture equipment often during development.

I exemplify this statement with the following scenario: Let's imagine being at Audi halfway through the development of the next generation Audi A8 and realizing that one of the key competitors has just presented during a motor show a technology that offers a hands-free voice solution to operate the magnificent features and functionalities. To respond effectively, we need to know where to find the necessary technology, say software algorithms for creating voice processing. We also need to know where to find the necessary programming skill, the necessary usability experts, and the necessary designers who will translate the technology into a usable and reliable application. We need to know how to test the new interface with internal and external users, and we need to know how to interpret the results. We need to know how hands-free voice solutions influence the vast variety of electronic standards. Then we have to make a critical decision: Do we respond by changing the current product specification, which is expected to be launched next year, or do we respond in the next generation, which we expect won't be out for at least another three years? And what about the intention of the competitor? Does he really want to customize the technology or does he only want to throw us off our stride? Responsiveness is an important part of product development capability. I derive the following proposition

PROPOSITION 6. *The more responsive organizations are to environmental disturbances, the more likely sustained new product success is.*

Overall, my observations confirm the extensive literature on product development that outlines the importance of keeping a close distance to markets and technologies (see, for example, Clark and Fujimoto (1991)). But we highlighted the necessity to respond quickly in the case of disturbances.

4.2.4 The Role of Managers

In the above discussion, I did not distinguish the organization's ability to develop products successfully from the managerial influence to do so. In essence, we were focused on organizational routines not on managerial processes.

If firms have the product development capability to develop new products successfully but their managers fail to accomplish that, it would suggest that systematic management rigidities limit firms' product development capability (Barney and Tyler, 1991, Mahoney, 1995). Indeed, based on their observations of managerial decisions and processes, several academics make precisely this argument. Utterback and Kim (1986) argue that managers' familiarity with existing products and markets prevented effective understanding of new markets. Christensen (1997) reported that producers of high fidelity stereo equipment missed the portable market because they discounted the size of the market. We can derive that managers can have a substantial impact on new product success.

In contrast to traditional research on product development, a dynamic capability perspective to product development enables managers to understand their organization's product trajectories and the pattern of product development capability required at each stage. With this background, managers can identify weaknesses and deficiencies in managing product development of their organization. This analysis was the simple part of improving the organization. The more challenging part is to improve the overall product development capability.

Sustained improvement of the ability to develop new products and processes in a path-dependant context can provide significant advantage in long-term competitiveness. Although there are many different starting points and means of improving product development capability, successful efforts share some characteristics. Managers should recognize in the first instance that enhancing product development capability is an evolutionary process and not a destination. Because effective product trajectories require attention to many different elements that cut across functions, disciplines and organizations, sustained improvement requires fundamental change of product and service development activities.

Since product and service development touch much of what a company does, and since sustained and fundamental change must be pervasive to be effective, managerial processes are a critical determinant of product development capability. The importance of managerial processes and leadership has long been recognized in academic studies of product development. Some major issues are

- Improve Market Position

  With an emphasis on products in their competitive context, managers look to products to solve problems in their markets. Change in this sense focuses on the product itself, not the development process. Managerial processes appear bold and decisive: senior managers may direct an overhaul of a product's market position through redesign, or through the addition of new technology and features, or may develop an entirely new product portfolio.

- Improve Competence Base

  Comparisons with competitors or 'benchmarking' can provide managers with important information about how to focus attention and energy. Managers often recognize the importance of external development partners as the key for new product success. Managers may focus on the introduction of strategic alliances, the building of core competences, or launching an educational program to develop own competences further.

Still, these considerations are static. In our dynamic view, managers recognize the importance of building new product trajectories that will begin to change the organization's competitive position. They also recognize the importance of developing those products in a way that is determined by its trajectory position (breakthrough, expansion or penetration).

While managers who have this 'broader' view may do many things that those caught in a static view (redesign products, fill gaps with training, or modify organizational structure), they do so with a broad comprehensive focus. The leadership they exercise focuses on the expansive vision of what the organization ought to become in the future as well as on the substantive details of everyday product development. In this context, effective leaders pay careful attention to both the whole (firm/trajectory) and the part (project). The successful building of new product trajectories over a long period of time is a matter of consistency between the sole project dimension and the overall new product trajectories the firm aims to achieve. I derive the following proposition:

PROPOSITION 7. *The clearer the path the organization seeks, the better the alignment of individual projects to the overall direction and the more likely sustained new product success is.*

With a clear understanding of the path the organization seeks, managers can move to help the organization translate that path into product trajectories designed to build specific types of competences and market positions. Moreover, their support of that effort must include actions to help solve particular problems. In this sense, effective management is much more than encouragement. Senior managers must supply critical energy and focus for the organization’s path to renew and enhance existing competences. They not only coach and counsel with key individuals, but also help define targets and then move to educate the organization in their project application.

Leadership that offers a compelling vision of the evolutionary path – that provides energy and momentum to the organization; leads, encourages, coaches, and supports the organization is the kind of leadership necessary for managing product development capability.

4.2.5 Project Structures

Reconfiguration of organizational structure influences product development capability either by buildup of organizational inertia or by creating routines that support organizational change. At the project–level, Katz and Allen (1982) have found that periodic reconfiguration of product development teams prevents them from developing a ‘not-invented-here’ syndrome. At firm-level, Tushman and Romanelli (1985) argue that reconfiguration reduces inertia thereby keeping the organization adaptable.

Because a dynamic perspective to product development puts emphasis on the market context (breakthrough, expansion, penetration), product development projects cannot rely on formalized organizational structure. In other words, firms cannot predetermine precise patterns in their activities and then impose them on their work through some kind of deliberated structures. Rather, many of their actions must be decided upon individually, according to the project context. Structure proceeds along the new product trajectory and has to be managed. At Audi, a 'process management' unit was responsible for coordinating and managing all process changes in the standard product development process, whereas at Siemens a process management group was responsible for all adaptations of the process model.

At Siemens, a process management team has never been quite sure what it will do next, the structure never really stabilizes totally but is responsive to new evolutions in technologies and markets. Similar things can be said about Audi, although the restructuring process is slightly more formalized here. That is because the organization tends to concentrate its attention on projects, which involve more people. I derive the following proposition.

PROPOSITION 8. *The better project structures are aligned with project contexts, the more likely sustained new product success is.*

4.2.6 The Nature of Effective Product Trajectories

Is sustained new product success really possible? How does a new product trajectory create momentum to create long-term new product success? Many firms focus on short-term results because they are required to do so by international accounting standards. But short-term results are not enough; longer-term survival must be sought. A start must be made to develop new products that increase the chances of durable innovation.

We regard product development capability or creating trajectories of successful products as the essential ingredient for lasting new product success. The task is difficult and often subtle. To ensure that all the attributes of product development capability appear, product development must avoid the "best practices" so beloved by many. Quality function deployment (QFD), venture capital programs or customer and market analyses are usually ineffective if undertaken with insufficient attention to the 'overall' product development capability issues we raised.

Establishing product development capability takes time; it cannot be done with a leap. It is, for example, seldom clear at the outset, because of uncertainty, just where the trajectory should be headed. Even when the direction has become clear, the details of the business remain fogbound. Experimentation is necessary to test the feasibility of ideas. Too early commitment to a new direction can be risky. A way has to be found to build consistently and to link newfound strengths before real and lasting investments are taken.

While there are many ways such new product trajectories can take, the elements can be distilled to identify one path that we feel is more sure than many others. At least, it is a three-stage trajectory creation process that is gradual, requiring many steps over many years. The process has to be managed and momentum for new product success established to allow products to reach for ever more challenging targets.

I address the question of how a new product trajectory can get started. To place that start in context and show where we headed, I begin with a brief summary of the overall model.

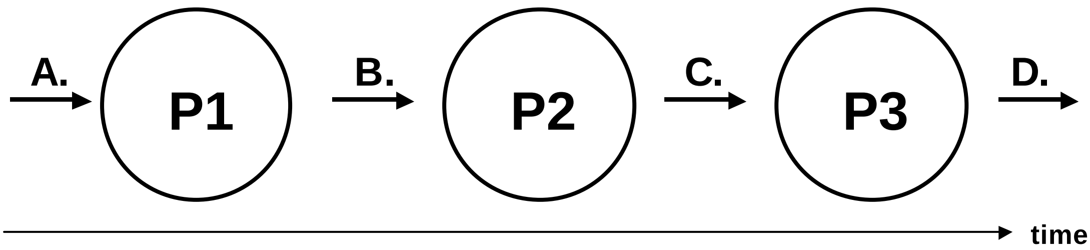


Figure 41 – A Model of Product Trajectories

A. Identify ‘productive’ opportunities

B. Build new competences in small market segments

C. Leverage competences in volume market segments

D. Refine competences and stretch advantages

A. Identify ‘Productive’ Opportunities

Although it seems obvious to begin by identifying productive opportunities, this vital stage is often overlooked. What are these opportunities? Simply stated, opportunities occur in response to or, better yet, in anticipation of major changes in technologies or markets – changes that require more than mutual adjustments. An opportunity arises from one or a combination of the following:

- Industry discontinuities – sharp changes in legal, political, or technological conditions shift the basis of competition within industries. Deregulation has dramatically transformed the telecommunications industry. Substitute product technologies may transform the basis of competition within industries. Similarly, the emergence of industry standards or dominant designs signal a shift in competition away from product innovation and towards increased refinement. Finally, major economic changes (e.g. oil crisis) and legal shifts (e.g. patent protection) also directly affect bases of competition

- Product life-cycle shifts – over the course of a product life-cycle, different strategies are appropriate. In the emergence phase of a product class, competition is based on product innovation and performance, whereas at the maturity stage, competition centers on cost, volume, and efficiency. Shifts in patterns of demand alter key factors for success. For example, the demand and nature of competition for cellular phones was transformed as cellular phones gained acceptance and their product classes evolved.

B. Build New Competences in Small Market Segments

In the second stage, the organization must set about building new advantages for later deployment. It is at this stage that new competences must be developed. Beginning with raised aspirations to do better and resolve old problems, in the course of time new challenges have to be articulated, which will help all to work to a common purpose. Making progress along the chosen trajectory requires managers to experiment and to discover what can work and what fails.

The targeted market segment ought to be small at the start: resources are limited, knowledge about possibilities uncertain, and the risks seem immense. At some experiments pay off, confidence should increase to the point where major investments in new technologies may be required. Learning should be in the scope, though ordinarily some parts of the organization progress more quickly than others. Over time, the organization must invest in deepening existing competences and acquiring new ones.

C. Leverage Competences in Volume Market Segments

As the breakthrough project proved the feasibility of the new technology, the organization can expand the sphere of its innovation into new market segments and new products. Pressures of expansion must be balanced against the danger of too much complexity, slowing down the pace of innovation and forcing the organization to a standstill.

Leveraging competences means to apply the already built competence in volume market segments where requirements are slightly different. If the admired functionality is achieved, the next step is on the product side to improve manufacturability, simplify technology, reduce complexity, replace over-engineered components, etc. Such a leveraging requires market inputs such as customer perceptions of the product and its functionality or tests by the popular press. On the cost side, components have to be evaluated for high quality and cost efficiency. Such an attempt requires the experience of the previous project and in-depth product analysis.

D. Refine Competences and Stretch Advantages

With the refinement phase, the firm profits from its former investments in building and leveraging competences. It's the harvest phase in the trajectory. The developed competences base provides advantages compared to competitors and can now be utilized through better and other products. This happens until new opportunities arise with the potential to make the trajectory and the developed competences obsolete.

Creating successful product trajectories is a process where the stages are not discrete steps but rather activities which merge into each other. Organizations create such trajectories not only once: they may need to do so repetitively and can possess various examples of them. The challenges of one period of time may be resolved, but those of the next may again require a new trajectory.

At the beginning of creating such trajectories, progress is best achieved in small market segments, because resources are limited. Small market segments spread the risks and prevent the organization from betting everything on one project. As the trajectory proceeds, the risks become better understood and progress more secure, allowing the markets to be served to get bigger.

I stress that organizations need time for creating successful product trajectories. It takes years to build a truly innovative company. Organizations that aim to become innovative have to sink deep foundations, rushing for the immediate success is unlikely to result in long-term rewards.

4.2.7 New Content for Product Development Research

Increasing dynamics of technologies and markets has deeply influenced the nature of product development projects. A dynamic capability perspective to product development leads to path dependent considerations emphasizing the building of new competences through breakthrough projects, leverage competences through expansion projects and refining competences through penetration projects.

The 'Broader View'

The aim of traditional product development literature to focus on sole projects with clear objectives, frozen specifications, and proven technologies leads to a narrow 'static' perspective. If management acts in such a scattered fashion many opportunities will be lost. Audi and Siemens have developed product development capability that enables sustained new product success. They invest in new product innovations and regain investments through following successive expansion and incremental refinement.

Developing products in such a generic fashion is more like managing the interaction between two streams, characterizing the evolution of technological and market possibilities as depicted in Figure 42. The challenge for managers is to direct their new product trajectories in interaction with both streams through deciding how and when the current product concept is outdated and new opportunities arise. A breakthrough project offers to users a new technology of the first stream. The resulting product is not a final outcome but simply the next step in the interaction between the two evolving streams. The feedback generated from the market's response to the product will greatly influence its successors.

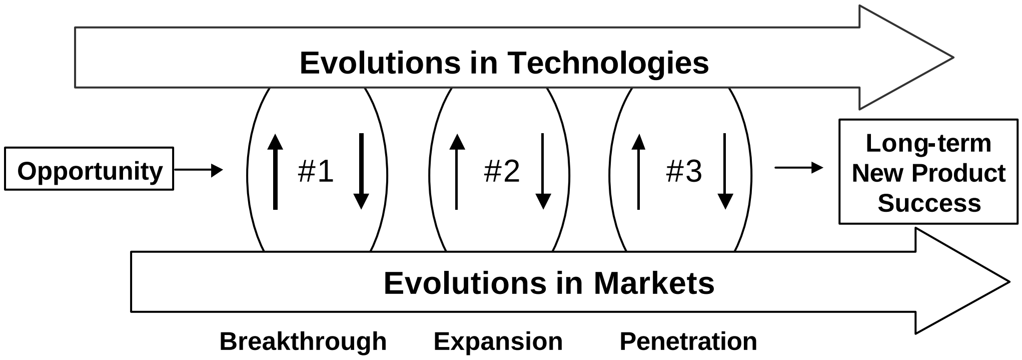


Figure 42 – Managing the Interaction of Streams

This model also implies an emphasis towards externally available resources and competences. It is impossible to develop the needed breadth of competences internally. Even Audi, with its extensive internal expertise in car design, went to Alcoa, an outside aluminum specialist to adopt aluminum competence, which accelerated the introduction of the first Audi A8. The external focus necessary for such dynamic environments is thus not restricted to input from customers, but includes access to a variety of technical and market resources, ranging from companies of other industries to the vast variety of start-up firms possessing interesting technologies. Product development capability thus implies access to external resources coupled with integration of them. In other words, both, technology and market streams are largely external to the firm, and a core competence of a firm acting in such an environment is the interaction between the two, which is part of product development capability.

Neglected Dynamic Routines

While I remain partial to 'static routines' (routinization of activities) in product development that is primarily proposed by traditional product development research[3],

---

[3] see, for example, Cooper (1994)

there is a necessary and useful tension between them and 'dynamic routines' (learning and reconfiguration). 'Learning' benefits from 'routinization' to pinpoint the necessary iterations that have been stumbled upon. The other way round, routinization benefits from learning to stay in touch with 'how it really happens'. In this respect, we can neither avoid routinization or learning; they are in some kind of symbiotic relation to each other.

4.3 Implications for Research

Several results of this work are worth highlighting. First, my results support a dynamic capability perspective to product development. I argued that long-term product development success is rooted in path dependant product trajectories that are part of the overall product development capability. Based on a literature review, I argued that dynamic routines are at least as important as static routines for sustained new product success.

We then turned to empirical considerations and studied positions, paths, and processes at Audi and Siemens. Such a dynamic focus, I argued, could provide a better understanding of the pattern of product development capability for managers and researchers of different management streams where product development plays an integral part. This resulted in a dynamic perspective to product development that helps managers to think in product trajectories and terms of learning and path dependencies rather than in isolated 'best practices'.

Clearly, a dynamic perspective to product development has much to offer. It sheds light on many pressing questions of organization and management while providing practical guidelines. Here I present a starting point, a taxonomy and frameworks for defining, distinguishing, and classifying the major elements of a dynamic capability perspective to product development.

4.3.1 Implications for Product Development Research

A dynamic capability perspective to product development has some deeper implications than 'traditional' product development literature. In contrast to existing product development literature, where empirically observed 'best practices' build the foundation of performance and competitiveness, this work puts such isolated and static views into question. According to this perspective, the dynamic aspects of product development like learning and path dependencies within and across projects particularly need to get more attention in product development research.

Contrary to my and others' arguments, a 'high quality' process (Cooper, 1996), was not found to be the determining source of sustained product development success between projects within one company. One explanation is that all projects within one company have already adopted similar project organization; therefore they can not be the reason for performance differences. Another explanation is that a determined 'high quality' process doesn't suit simultaneously for diverse project contexts (breakthrough, expansion, penetration). This explanation is consistent with earlier work in product development literature that describes how managers in turbulent markets avoid planning because it is a futile exercise when the environment is changing rapidly and unpredictably (Eisenhardt, 1989). Thus, perhaps that 'high quality' process reduces product development success when information is incomplete and uncertain. Consistent with other authors, it may be better sometimes not to 'freeze' the product concept even with negative effects on development cost or project lead time (Iansiti, 1995).

	Traditional Product Development Research	**A Dynamic View to Product Development**
Product Development Success	Sole new product success	New product trajectories with sustained new product success
Level of Analysis	Mostly sole product development projects	Product development projects as part of an unfolding sequence of products
Focus	Static routines: product development process and structure	Interaction between static and dynamic routines. Path dependency of products
Assumption	'Best Practices' are the sources of sustained new product success	Creating valuable product trajectories is the source of sustained new product success

Table 14 – Contrasting Traditional PD Research with PD from a Dynamic Capability Perspective

These findings relate to existing product development literature in several ways. If this analysis is correct, it has rather strong implications for theory building and for management. With respect to theory building, it suggests the inadequacy of standard best practices that have organizational structure and process as the key if not the only determinant of product development success. Clearly, such 'best practices' are poor guides to management. At a minimum, the ability to establish product trajectories where successive projects utilize the competences of their predecessor projects must be recognized as major determinants. This work especially indicates that such evolutionary considerations are an important determinant of product development success, a point made by Leonard-Barton (1992) that has largely gone unheeded by product development researchers.

The dynamic capability perspective to product development developed here is designed to shift the structure-conduct-performance debate beyond the domain where Clark and Fujimoto (1991), Wheelwright and Clark (1992) and others have put it, and into a new domain where path dependencies and learning attain new significance.

4.3.2 Implication for Dynamic Capabilities Research

A dynamic capability perspective to product development has some deeper implications than the traditional concepts of dynamic capabilities (Teece et al., 1997, Eisenhardt and Martin, 2000). Like the concept of dynamic capabilities, the dynamic elements of product development capability put emphasis on the firm but extend this emphasis by the real operative activities of product development projects both within and across projects (see Table 15 for the conceptual contrast between the concept of dynamic capabilities and a dynamic view to product development).

These findings relate to the existing literature of dynamic capabilities in several ways. The integration of diverse strategic management perspectives in one cohesive theory extends current thinking. It challenges the self-containment of strategic management theories because one theory alone cannot adequately explain the pattern of product development capability. In most project contexts, product development capability was associated with a mix of market-based, resource-based and evolutionary contributions out of product development.

	The Concept of Dynamic Capabilities	**A Dynamic View to Product Development**
Aim	Explaining how and why firms create and sustain competitive advantage.	Explaining how and why firms create and sustain new product success.
Pattern	Resource-based perspective with evolutionary considerations.	One cohesive theory that integrates several strategic management theories with the focus on product development.
Level of Analysis	Firm, Industry	Firm, Project, Activities
Operationalization	Analyzing Processes, Resources, Path, Processes	Analyzing the interaction of static and dynamic routines and path dependant new product trajectories and their inter-product relatedness.

Table 15 – Contrasting Dynamic Capabilities with a Dynamic View to Product Development

The insight that competitive advantage is not only based on markets or resources but also on dynamic aspects strengthens the thinking and empirical results of many authors (Grant, 1996, Pisano, 1994, Henderson and Cockburn, 1994, Teece et al., 1997, Eisenhardt and Martin, 2000). Thus, this work joins a small but growing number of studies that challenge the self-contained market-based or resource-based studies of competitive advantage and relates closely to emergent research on dynamic aspects of organizations to overcome the narrow static perspectives.

Second, the link between product development and market dynamics is mixed. Like others, e.g. Teece et al. (1997a), Eisenhardt and Martin (2000), I argued that high levels of learning are needed especially in dynamic markets. Yet, for our analysis here, this relationship was non-significantly exhibited. Why?

It was not the market dynamics itself that influenced the rate of learning. It was the project context that determined the necessary levels of learning. For example, in breakthrough projects (Audi A8-D2; Siemens HiPath 5000), high levels of iterative learning was necessary whereas in penetration projects this was not the fact (Audi A8-D3; Siemens OpenScape). The rate of learning was independent from the market dynamics surrounding the projects.

These mixed results also relate to previous strategic management literature. Static routines have been associated with stable markets while dynamic routines have been associated with turbulent environments, e.g. (Tabrizi and Eisenhardt, 1995, Eisenhardt and Brown, 1999, Eisenhardt and Martin, 2000). What the results here suggest is that these past results may hold true in extreme stable or extreme turbulent environments. In the environments I studied, the relation between static and dynamic routines depended not directly on market turbulence but on the project context. This suggests a contingent view of product development in which static routinization is particularly relevant in penetration phases, while dynamic learning and reconfiguration is more germane to breakthrough phases. In expansion projects with a mix of breakthrough and penetration aspects, a combination of routines is likely to be relevant. Table 16 highlights the differences in pattern of breakthrough, expansion and penetration projects.

	Breakthrough Projects	**Expansion Projects**	**Penetration Projects**
Project Definition	Projects center around radical improvement of product or service architecture.	Projects center around a product or service architecture that has to be adapted for a volume market.	Projects center around incremental refinement of product and process architecture
Impact on Competence Base	Building of competences	Leveraging of competences	Refinement of competences
Outcome	Project outcome is more or less unpredictable	Project outcome is more or less predictable	Project outcome is predictable
Mentality	More dynamic	Mixed dynamic and static	More static
Execution	Many iterations	Some iterations	Linear

Table 16 – Contrasting Breakthrough, Expansion and Penetration Projects

My work also relates to research on the emergence of competitive advantage. There is surprisingly little understanding in strategic management literature of how and why competitive advantage emerges. At best, there are some traditional assumptions that competitive advantage evolves when specific attributes of markets/resources are evaluated: If market positions/resources fulfill the VRIN attributes: Valuable, Rare, Inimitable, Not substitutable (Porter, 1980, Barney, 1991), then competitive advantage evolves. Yet, each of these attributes also impairs the quality and effectiveness of organizations and fails to deal with how and when specific activities or management tasks contribute to this goal. Emphasis on markets and resources is problematic, especially in uncertain contexts, because such dictatorial scope might create rigidity. Emphasis on markets is likely to impair quality and to sap the confidence of managers. So, overall, these sole views are likely to be too simplistic. In contrast, the results here provide new insights about the emergence of competitive advantage. One is that the emergence of competitive advantage is an evolutionary process and not defined by positional attributes of markets or resources.

Finally, my results relate to the literature of strategic renewal and change. Strategic renewal has emerged as an important mechanism when faced with infrequent environmental changes, e.g. (Tushman and Anderson, 1997). Yet strategic renewal can also occur through small, frequent shifts in how firms compete in the marketplace. For example, Henderson and Clark focused on different levels of technological change in the photolithographic industry (Henderson and Clark, 1990). Galunic and Eisenhardt examined domain changes among the strategic business units within a major electronic firm (Galunic and Eisenhardt, 1996). Here, I described product development projects that may provide the same type of change in the automotive and telecommunications industries. The image is responding to evolving markets and technologies through a consistent flow of new products that reposition and ultimately reshape firms. As described in Chapter 3, Siemens evolved from a telephone hardware company to a 'real-time' communications company through successive new products and services, while Audi evolved from a mid-range car manufacturer to a premium car manufacturer through technology leadership in aluminum technologies. This view contrasts with learning by wrenching infrequent changes that break long periods of inertia. In this work, I attempt to shed light on the sources of sustained new product success, or in strategy parlance, the capability that create this type of change.

Overall, the argument is that only a dynamic perspective can help to explain how and why firms enjoy successive and therefore sustained new product success. However, although these links have some substantiation in management literature, they have received little empirical testing and rely on limited theoretical logic.

4.4 Opportunities for Future Research

Many theoretical links of 'product development as a dynamic capability' have been well studied. However, some links are less sharply defined and not well tested. These shortcomings present research opportunities.

One research opportunity is to examine the primary links of the developed conceptualization – that is, for example, the links between static and dynamic routines in product development operation. As was noted, these links have been examined rarely. However, because the methodology in this research often involves subjective, retrospective studies of single cases, the validity of these links is tenuous. Thus, a test of these fundamental theoretical links would be useful. A related research opportunity is determining the relative difference in managing breakthrough and expansion or penetration projects. For example, Tushman and O'Reilly (1996) found that the different nature of projects should be managed ambidextrously. It would be useful to examine the robustness of this claim in the light that in expansion projects the competences built by breakthrough projects are needed.

A second area of research is a broader understanding of product development research. As was noted, product development research has a fairly well-studied understanding that includes practices and their impact on new product success that was developed in the context of empirical observations, e.g. Clark and Fujimoto (1991). A dynamic context, instead, enables a broader understanding and emphasizes learning and path dependencies between development projects; yet this second understanding has received only limited empirical examination. The point is that exploring a contingent understanding of dynamic routines in project-level practices and their impact at the firm-level is an important path for future research.

Third, our understanding of how management affects product development capability is incomplete. Managers are consistently found to be important contributors to product development success, e.g. Clark and Fujimoto (1991), Cooper (1996), Leonard-Barton

(1992). However, the practice-related concepts in management literature are vague. There is also little understanding of the links between management tasks through which managers manage product development projects and dynamic routines. These management tasks have been virtually unexplored. In addition, previous research on product development is vague regarding when and how senior management, project leaders and project teams should act. For example, should senior management respond to competitive moves by changing the product concept even during implementation? Thus, the concepts surrounding managerial processes and their link to product development capability offer opportunities for future research.

5 Conclusions

Dynamic capabilities have often been criticized as tautological, vague and non-operational (Priem and Butler, 2001). To reduce tautology and vagueness from the concept, Eisenhardt and Martin (2000) proposed to see dynamic capabilities as specific processes like product development. I followed their proposition and developed a dynamic capability perspective to product development. With this view, my claim is to explore dynamic capabilities in a way that is neither tautological nor vague and my approach is proved true if the concept of dynamic capabilities provides valuable contributions for product development operation.

In this view, product development is an important organizational capability, yet it is challenging to identify patterns of related product development operation. Therefore, I reviewed a wide range of management literature to identify patterns of product development capability that allows us to explain sustained new product success.

In the course of my literature review, I found that sustained new product success can only be explained by dynamic aspects of product development capability. These dynamic aspects, such as processes of learning, reconfiguration and path dependencies, have hardly been studied within traditional product development literature. I strived, therefore, for empirical evidence looking at how static and dynamic aspects of product development interact in two industrial settings at Audi and Siemens.

Recommendations for Sustained New Product Success

A number of recommendations were generated based on the case studies at Audi and Siemens. Even though these conclusions are context-dependant I think that they can be applied in other industries. My recommendations are in three areas: product trajectories, product development organization, and the management of learning and reconfiguration processes.

a. Product Trajectories

The development of new product success involves sequences of steps that often cannot be achieved all at once. A single product development project may not be an appropriate framework to obtain sustained new product success. Therefore it seems desirable to structure product development projects and technology development into product trajectories and to cluster the nature of the project into breakthrough, expansion, and penetration projects.

Breakthrough projects explore something new, bringing a technological opportunity from a research status towards a usable product in a small and seizable market and build new technological competences. Expansion projects expand the technology to higher volume markets that are more competitive and cost sensitive and leverage the developed competences to requirements of volume markets. Penetration projects utilize and refine the competences built by the previous projects and stretch advantages.

The main benefit of clustering projects along trajectories is the ability to manage projects according to their context. Siemens, for example, performed more iterations in their breakthrough project for VoIP technology 'HiPath 5000' than in their later expansion and penetration projects. So did Audi, where The Audi A8 (D2) had to develop the aluminum competence through extensive iterative learning and the follower projects could reduce their iterations because the necessary competences were available.

b. Product Development Organization

A dynamic capability perspective raises new questions concerning product development organization. Current literature on product development emphasizes a plan-and-execute process where the product should be planned thoroughly before it is to be executed. I think that this view is caught in a static market-based perspective and is only appropriate when necessary competences and targeted markets are available and well-known at the outset. Such an approach can be associated with a follower role in competition because in such a context firms avoid coping with uncertainty.

But if firms strive to take the leader role in competition they sometimes have to explore something new where the required competences and markets need to be built. In such a 'breakthrough' context, a probe-and-learn process seems to be more appropriate that iterates between planning and execution. Audi keeps 'its window of opportunity' open as long as possible before the concept is frozen in order to improve the product concept when new information or insights arise. So does Siemens with the aim to integrate latest evolutions of technologies and markets. Both firms showed that they can do both: using a probe-and-learn process in 'breakthrough' contexts and later utilize these competences through plan-and-execute approaches.

c. Managing Learning and Reconfiguration

Processes of learning and reconfiguration are often neglected in popular literature on product development. I found that such dynamic routines are at least as important as an effective sequence of product development activities.

Learning within product development projects happens primarily through design-build-test cycles. Audi and Siemens applied many iterations in their breakthrough projects but less iterations in the following projects. Both vary design-build-test iterations according to the nature of project and balance learning and routinization.

Reconfiguration within product development projects needs an existing product configuration. Such product configurations can be reference prototypes or working system models. Audi installed a so called "ÄKO-process" to manage product changes in a controlled manner even in later project phases. Siemens adapts continuously a working system model as a reference model. Both institutionalized reconfiguration in their product development operations.

New Content for Product Development Research

With our dynamic focus, we have seen how Audi and Siemens build new competences through breakthrough projects and how they leverage and refine these competences in path-dependant trajectories of product development projects. We explored dynamic routines such as learning and reconfiguration as a crucial element of product development capability. This work has identified some key issues that may become the basis for a new content of product development research. First, the dynamic focus may help firms to develop from mere 'follower' to active 'leader' of strategy, ensuring that learning and product trajectories are properly used as competitive weapons.

Second, a dynamic view offers a number of lessons for the management of product development in diverse contexts, providing clear rules to develop, leverage, and refine competences through effective product trajectories. Moreover, in order to overcome major failures in the implementation of "best practices", a dynamic capability perspective may help managers to better understand the coherence of such practices as part of an unfolding sequence of activities that altogether form the overall product development capability.

Essentially, the new rules emerging from a dynamic view of product development may change the fundamental beliefs of product development. These beliefs may eventually evolve from mere taking charge of the functioning of processes, toward processes that enable learning and manage reconfigurations required for bringing a new technology from a breakthrough status to a penetration status.

While the integration of product development operation and dynamic considerations is only starting, there are reasons to believe it may be a major research issue within the next few years. Going beyond the market-based paradigm of product development where pre-development planning and design is emphasized, we may be able to infer that a new paradigm will emerge focusing on probing and learning at the heart of effective product development. This new paradigm could be geared toward ensuring that organizational structures are both supportive and generative of effective product development capability.

Consequently, several new research issues may be addressed within the dynamic view to product development. For example, researchers could explore through what kind of processes and structures firms institutionalize learning and reconfiguration. In the same way, product development may become concerned with the creation of new product trajectories, where key sources of new product success may be better rooted. Finally, in order to build a strong momentum for new product success, product development may provide a new outlook on the design of product development activities that balance learning and routinization.

To conclude, as a new paradigm of product development may be emerging, going back to the operational roots of product development, a new integrated research agenda could emerge between the research on product development and research on strategic renewal and change. This may overcome some of the unresolved issues of sustained new product success. But more importantly, the dynamic view to product development may help refocus product development as a truly creative and future oriented activity, geared toward integrating and building new strategic advantages through learning and fruitful product trajectories.

I end this work by looping back to the research question. I asked if the concept of dynamic capabilities can provide valuable contributions for product development operation. From my point of view, the answer is 'yes' and I can outline the following contributions.

The important characteristic of a dynamic capability perspective to product development is that it involves a pattern of variables that is different from those of traditional approaches. From a dynamic capability perspective, product development is seen as routines of learning, reconfiguration, and integration, shaped by path dependencies and positions of resources and markets (Teece et al., 1997).

Such a perspective provides a fundamentally different account to explain how and why product development success occurs: as we have seen, it puts into question the traditional 'plan and execute' paradigm and suggests a 'probe and learn' strategy in order to take an active leader role instead of a follower role in competition. Moreover, this perspective is not merely focused on the creation of a single new product success; rather it is concerned with how companies create trajectories of new product success.

The work has several conclusions. One is that a dynamic capability perspective to product development may be one singular and narrow perspective but can reduce the tautology and vagueness from the concept of dynamic capabilities. As noted at the outset, there is much research work done from a firm-level perspective (Teece et al., 1994, Grant, 1996, Kogut and Zander, 1997, Teece et al., 1997, Pisano, 2000, Zollo and Winter, 2002) where highly aggregated concepts like 'routines-to-learn-routines' are supposed to be the source of sustained new product success. There is also much research work done from an operation-level perspective (Myers and Marquis, 1969, Cooper, 1979, van de Veen, 1986, Cooper and Kleinschmidt, 1987, Little, 1991, Cooper and Kleinschmidt, 1995), where e.g. effective project organization has been observed as the source of truth.

Both views reveal important aspects. The problem for researchers and managers is to balance and combine these views. One way is see ‘product development as dynamic capability’.

Bibliography

Abell, D. F. (1999), *Competing Today while Preparing for Tomorrow*, Sloan Management Review, 40 (3), 73-82.

Abernathy, W., Utterback, J. (1978), *Patterns of Industrial Innovation*, Technology Review, 2, 40-47.

Amit, R., Schoemaker, P. J. H. (1993), *Strategic Assets and Organizational Rent*, Strategic Management Journal, 14, 33-46.

Ancona, D., Caldwell, D. (1990), *Beyond Boundary Spanning: Managing External Development in Product Development Teams*, High Technology Management Research, 1 (2), 119-136.

Anderson, P., Tushman, M. (1990), *Technological Discontinuities and Dominant Design: A Cyclical Model of Technological Change*, Administrative Science Quarterly, 35, 604-633.

Andrews, K. R. (1971), *The Concept of Corporate Strategy*, Homewood, IL, Dow Jones Irwin.

Ansoff, H. I. (1965), *Corporate Strategy*, New York, McGraw-Hill.

Aoki, M. (1990), *The Participatory Generation of Information Rents and the Theory of the Firm*, in: Aoki, M., Gustafsson, B., Williamson, O. E. (eds.), The Firm as a Nexus of Treaties, London, Sage, 26-52.

Bacon, G., Beckman, S., Mowery, W., Wilson, E. (1994), *Managing Product Definition in High-Technology Industries: A Pilot Study*, California Management Review, 36, 32-57.

Barney, J. (1991), *Firm Resources and Sustained Competitive Advantage*, Journal of Management, 17 (1), 99-120.

Barney, J. B. (1986a), *Organizational Culture: Can it be a Source of Sustained Competitive Advantage*, Academy of Management Review, 11, 656-665.

Barney, J. B. (1986b), *Strategic Factor Markets: Expectations, Luck, and Business Strategy*, Management Science, 32 (10), 1231-1241.

Barney, J. B. (2001), *Is the Resource-based "View" a Useful Perspective for Strategic Management Research? Yes*, Academy of Management Review, 26 (1), 41-56.

Barney, J. B., Tyler, B. (1991), *The Attributes of Top Management Teams and Sustained Competitive Advantage*, in: Lawless, M., Gomez-Mejia, L. (eds.), Managing the High-Technology Firm, Greenwich, CN, JAI Press.

Beinhocker, E. (1999), *Robust Adaptive Strategies*, Sloan Management Review, (Spring 1999), 95-106.

Bharadwaj, A. S. (2000), *A Resource-Based Perspective on Information Technology Capability and Firm Performance: An Empirical Examination*, MIS Quarterly, 24 (1), 169-196.

Bower, J. L., Christensen, C. M. (1995), *Disruptive Technologies: Catching the Wave*, Harvard Business Review, (Jan-Feb 1995), 43-53.

Brown, S. L., Eisenhardt, K. M. (1995), *Product Development: Past Research, Present Findings, and Future Directions*, Academy of Management Review, 20 (2), 343.

Brown, S. L., Eisenhardt, K. M. (1997), *The Art of Continuous Change: Linking Complexity Theory and Time-Paced Evolution in Relentlessly Shifting Organizations*, Administrative Science Quarterly, 42 (1), 1-34.

Burgelman, R. A., Rosenbloom, R. S. (1997), *Technology Strategy: An Evolutionary Process Perspective*, in: Tushman, M. L., Anderson, P. (eds.), Managing Strategic Innovation and Change, Oxford, Oxford University Press.

Burns, T., Stalker, G. M. (1966), *The Management of Innovation*, in: Edition, n. (ed.), London, Associated Book Publishers.

Christensen, C. M. (1997), *The Innovator's Dilemma. When Technologies Cause Great Firms to Fail*, Boston, MA, Harvard Business School Press.

Clark, K. B. (1985), *The Interactions of Design Hierarchies and Market Concepts in Technical Evolutions*, Research Policy, 14 (5), 235-251.

Clark, K. B., Fujimoto, T. (1990), *The Power of Product Integrity*, Harvard Business Review, 68 (6), 107-118.

Clark, K. B., Fujimoto, T. (1991), *Product Development Performance*, Boston, MA, Harvard Business School Press.

Clark, K. B., Wheelwright, S. C. (1992), *Organizing and Leading Heavyweight Teams*, California Management Review, 34 (3), 9-28.

Clark, K. B., Wheelwright, S. C. (1993), *Managing New Product and Process Development*, New York, Free Press.

Cohen, W. M., Levinthal, D. A. (1990), *Absorptive Capacity: A New Perspective on Learning and Innovation*, Administrative Science Quarterly, 35, 128-152.

Cooper, R. (1979), *Identifying Industrial New Product Success: Project Newprod*, Industrial Marketing Review, 8, 124-135.

Cooper, R. G. (1990), *Stage-Gate Systems: a new tool for managing new products*, Business Horizons, 33 (3).

Cooper, R. G. (1994), *Third Generation New Product Processes*, .

Cooper, R. G. (1996), *Overhauling the New Product Process*, Industrial Marketing Management, 25, 465-482.

Cooper, R. G., Kleinschmidt, E. J. (1987), *New Products: What Separates Winners From Losers*, Journal of Product Innovation Management, 4, 169-184.

Cooper, R. G., Kleinschmidt, E. J. (1994), *Determinants of Timeliness in Product Development*, Journal of Product Innovation Management, 11, 381-396.

Cooper, R. G., Kleinschmidt, E. J. (1995), *Benchmarking the Firm's Critical Success Factors in New Product Development*, Journal of Product Innovation Management, 12, 374-391.

Daft, R. (1983), *Organization Theory and Design*, New York, West.

D'Aveni, R. A. (1994), *Hypercompetition: Managing the Dynamics of Strategic Maneuvering*, New York, Free Press.

D'Aveni, R. A. (1999), *Strategic Supremacy through Disruption and Dominance*, Sloan Management Review, 40 (3), 127-136.

Day, G. (1990), *Market-driven Strategy: Processes for Creating Value*, New York, Free Press.

Day, G. S., Schoemaker, P. J. H. (2000), *Avoiding the Pitfalls of Emerging Technologies*, California Management Review, 42 (2), 8-33.

Deng, Z., Len, B., Narin, F. (1999), *Science and Technology as Predictors of Stock Performance*, Financial Analysts Journal, 55 (3), 20-26.

Dougherty, D. (1990), *Understanding New Markets for New Products*, Strategic Management Journal, 11, 59-78.

Dougherty, D. (1992), *A Practice-Centered Model of Organizational Renewal Through Product Development*, Strategic Management Journal, 13 (Special Issue), 77-90.

Dougherty, D., Hardy, C. (1996), *Sustained Product Innovation in Large, Mature Organizations: Overcoming Innovation-to-Organization Problems*, Academy of Management Journal, 39 (5), 1120-1153.

Duysters, G., Hagedoorn, J. (1998), *Technological Convergence in the IT Industry: The Role of Strategic Technology Alliances and Technological Competences*, International Journal of the Economics of Business, 5 (3), 355-359.

Eisenhardt, Bourgeois (1988), *Politics of Strategic Decision-Making in High-Velocity Environments*, Academy of Management Journal, 31 (4), 737-770.

Eisenhardt, K. M. (1989), *Making Fast Strategic Decisions in High Velocity Environments*, Academy of Management Journal, 32 (3), 543-576.

Eisenhardt, K. M. (1991), *Building Theories from Case Study Research*, 532-549.

Eisenhardt, K. M., Brown, S. L. (1999), *Patching: Restitching Business Portfolios in Dynamic Markets*, Harvard Business Review, 77 (3), 72-82.

Eisenhardt, K. M., Martin, J. A. (2000), *Dynamic Capabilities - What are they?*, Strategic Management Journal, 21 (Nov/Dec), 1105-1121.

Galunic, C., Eisenhardt, K. M. (2001), *Architectural Innovation and Modular Corporate Forms*, Academy of Management Journal, 44 (6), 1229-1249.

Galunic, C. D., Eisenhardt, K. M. (1996), *The evolution of intracorporate domains: Changing divisional charters in high-technology, multidivisional corporations*, Organization Science, 7, 255-282.

Garwin, D. A. (1994), *Building a Learning Organization*, Business Credit, 96 (1), 19-29.

Garwin, D. A. (1998), *The Processes of Organization and Management*, Sloan Management Review, 39 (4), 33.

Ghemawat, G., Costa, J. (1993), *The Organizational Tension between Static and Dynamic Efficiency*, Strategic Management Journal, 14, 59-73.

Gioia, D. A., Pitre, E. (1990), *Multiparadigm Perspectives in Theory Building*, Academy of Management Review, 15, 584-602.

Glaser, B., Strauss, A. (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Chicago, Aldine.

Gould, S. J. (1987), *The Panda's Thumb of Technology*, Natural History, (January), 14-23.

Grant, R. M. (1991), *The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation*, California Management Review, 33, 114-135.

Grant, R. M. (1996), *Towards a knowledge-based theory of the firm*, Strategic Management Journal, 17 (Summer Special Issue 1996), 109-122.

Hage, J. (1988), *Futures of Organizations*, Lexington, MA, Lexington Books.

Hagedoorn, J., Narula, R. (1996), *Choosing Organizational Modes of Strategic Technology Partnering: International and Sectoral Differences*, Journal of International Business Studies, 27 (2), 265-285.

Hamel, G. (1989), *Strategic Intent*, Harvard Business Review, 67, 63-76.

Hammer, M. (1990), *Reengineering Work: Don't Automate, Obliterate*, Harvard Business Review, 68 (July-August), 104-112.

Hammer, M., Champy, J. (1994), *Reengineering the Corporation: A Manifesto for Business Revolution*, New York, .

Hammer, M., Stanton, S. (1999), *How Process Enterprise Really Works*, Harvard Business Review,.

Hannan, M. T., Freeman, J. (1984), *Structural Inertia and Organizational Change*, American Sociological Review, 49, 149-164.

Helfat, C. E., Raubitschek, R. S. (2000), *Product Sequencing: Co-evolution of Knowledge, Capabilities and Products*, Strategic Management Journal, 21 (10-11), 961-980.

Henderson, R., Clark, K. (1990), *Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms*, Administrative Science Quarterly, 35 (1), 9-30.

Henderson, R., Cockburn, I. (1994), *Measuring competence? Exploring Firm Effects in Drug Discovery*, Strategic Management Journal, (15), 63-84.

Houser, D. E., Clausing, D. (1988), *The House of Quality*, Harvard Business Review, (May-June), 63-73.

Iansiti, M. (1995), *Shooting the Rapids: Managing Product Development in Turbulent Environments*, California Management Review, 38 (1).

Iansiti, M., Clark, K. B. (1994), *Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe Computers*, Oxford University Press,, 557.

Iansiti, M., MacCormack, A. (1997), *Developing Products on Internet Time*, Harvard Business Review, Sept-Oct (5), 108-118.

Jick, T. D. (1979), *Mixing Qualitative and Quantitative Methods: Triangulation in Action*, Administrative Science Quarterly, 24, 602-611.

Johnson, G. (1988), *Rethinking Incrementalism*, Strategic Management Journal, 9, 75-91.

Juran, J. M., Gyrna, F. M. (1988), *Juran's quality control handbook*, New York, McGraw-Hill.

Kaplan, S. M. (1999), *Discontinuous Innovation and the Growth Paradox*, Strategy & Leadership, 27 (2), 16-21.

Katz, R., Allen, T. J. (1982), *Investigating the Not-Invented-Here (NIH) Syndrome: A Look at the Performance, Tenure, and Communication Patterns of 50 R&D Projects*, R&D Management, 12 (1), 7-19.

Katzy, B., Dissel, M., Blum, M. (2001), *Measuring Value - Creating Value: A Solution for Process Innovation in High-tech Company Networks*, in: Proceedings of the e2001, .

Katzy, B. R., Wilson, S., Dissel, M. C., Probert, D. R. (2003), *Sustaining Product Innovation in the New Economy: The Case of Siemens Switzerland*, Working Paper, CeTIM gGmbH, University BW Munich.

King, A. A., Tucci, C. L. (2002), *Incumbent Entry into New Market Niches: The Role of Experience and Managerial Choice in the Creation of Dynamic Capabilities*, Management Science, 48 (2), 171-186.

Kogut, B., Zander, U. (1997), *Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology*, in: Foss, N. J. (ed.), Resources, Firms, Strategies. A Reader in the Resource-Based Perspective, Oxford, , 306-326.

Lawrence, P. R., Lorsch, J. W. (1967), *Organization and Environment: Managing Differentiation and Integration*, in: Administration, D. o. R. G. S. o. B. (ed.), Boston, MA, Harvard University.

Leonard-Barton, D. (1992a), *Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development*, Strategic Management Journal, 13 (Summer Special Issue), 111-126.

Leonard-Barton, D. (1992b), *The Factory as Learning Laboratory*, Sloan Management Review, 34 (1), 23-39.

Lewin, K. (1951), *Field Theory of Social Science*, Greenwich, CT, Greenwood Press.

Lieberman, M. B., Montgomery, D. B. (1988), *First-Mover Advantage*, Strategic Management Journal, 9 (1), 41-58.

Lieberman, M. B., Montgomery, D. B. (1998), *First-Mover (Dis)Advantages: Retrospective and Link with the Resource-based View*, Strategic Management Journal, 19, 1111-1125.

Little, A. D. (1991), *Worldwide Survey on Product Innovation*, Report, Arthur D. Little, Cambridge M.A.

Lorenzoni, G., Lipparini, A. (1999), *The Leveraging of Interfirm Relationships as a Distinctive Organizational Capability: A Longitudinal Study*, Strategic Management Journal, 20, 317-338.

Lutz, R. A. (1994), *Implementing Technological Change with Cross-Functional Teams*, Research Technology Management, 37 (2), 14-18.

Lynskey, M. J. (1999), *The Transfer of Resources and Competencies for Developing Technological Capabilities - The Case of Fujitsu-ICL*, Technology Analysis & Strategic Management, 11 (3), 317-336.

Madhok, A., Osegowitsch, T. (2000), *The International Biotechnology Industry: A Dynamic Capabilities Perspective*, Journal of International Business Studies, 31 (2), 325-336.

Mahoney, J. T. (1995), *The Management of Resources and the Resource of Management*, Journal of Business Research, 33, 91-101.

Mahoney, J. T., Pandian, J. R. (1992), *The Resource-Based View Within the Conversation of Strategic Management*, Strategic Management Journal, 13, 363-380.

Maidique, M. A., Zirger, B. J. (1985), *The New Product Learning Cycle*, Research Policy, 14, 299-315.

Markides, C. C. (1999), *A Dynamic View of Strategy*, Sloan Management Review, 40 (3), 55-64.

Mc Grath, R. G., MacMillan, I. C., Venkataraman, S. (1995), *Defining and Developing Competence: A Strategic Process Paradigm*, Strategic Management Journal, 16, 251-275.

Medcaf, J. (1999), *Identifying 'Super Technology' Industries*, Research Technology Management, 42 (4), 31-36.

Miller, D., Shamsie, J. (1995), *A Contingent Application of the Resource-based View of the Firm: The Hollywood Film Studios from 1936 to 1965*, Academy of Management Journal, Best Papers Proceedings 1995, 57-65.

Mintzberg, H. (1979), *The Structuring of Organizations*, in: Hall, P. (ed.), .

Mintzberg, H. (1988), *Generic Strategies Toward a Comprehensive Framework*, in: Advances in Strategic Management, Greenwich, JAI Press, 1-67.

Mintzberg, H. (1994), *The Rise and Fall of Strategic Planning*, New York, The Free Press.

Mintzberg, H., McHugh, A. (1985), *Strategy Formulation in an Adhocracy*, Administrative Science Quarterly, 30, 160-197.

Montgomery, C. A. (1995), *Of Diamonds and Rust: A new Look at Resources*, in: Montgomery, C. A. (ed.), Resource-based and Evolutionary Theories of the Firm, Boston, , 251-268.

Moorman, Slotegraf (1999), *The Contingency Value of Complementary Capabilities in Product Development*, Journal of Marketing Research, 36 (2), 239-257.

Moorman, C., Slotegraaf, R. J. (1999), *The Contingency Value of Complementary Capabilities in Product Development*, Journal of Marketing Research, 36 (2), 239-257.

Mosakowski, E., McKelvey, B. (1997), *Predicting Rent Generation in Competence-Based Competition*, in: Heene, A., Sanchez, R. (eds.), Competence-based Strategic Management, Chichester, Wiley, 65-85.

Myers, S., Marquis, D. G. (1969), *Successful Industrial Innovations*, Washington DC, National Science Foundation.

Neff, M. C., Shanklin, W. L. (1997), *Creative Destruction as a Market Strategy*, Research Technology Management, 40 (3), 33-40.

Nelson, R., Winter, S. (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA, Havard University Press.

Nonaka, I., Takeuchi, H. (1995), *The Knowledge-Creating Company*, New York, Oxford University Press.

O'Reilly III, C. A., Tushman, M. L. (1997), *Using Culture for Strategic Advantage: Promoting Innovation Through Social Control*, in: Tushman, M. L., Anderson, P. (eds.), Strategic Management of Innovation and Change, New York, Oxford University Press.

Orlikowski, W. J. (1992), *The Duality of Technology: Rethinking the Concept of Technology in Organizations*, Organization Science, 3 (3), 398-425.

Penrose, E. (1959), *The Theory of the Growth of the Firm*, London, Basil Blackwell.

Peteraf, M. A. (1993), *The Cornerstones of Competitive Advantage*, Strategic Management Journal, 14 (3), 179-191.

Peters, T. (1992), *Liberation Management: Necessary Disorganization for the Nano-Second Nineties*, New York, Knopf.

Pisano, G. P. (1994), *Knowledge, Integration, and the Locus of Learning: an Empirical Analysis of Process Development*, Strategic Management Journal, (15), 85-100.

Pisano, G. P. (2000), *In Search of Dynamic Capabilities: The Origins of R&D Competence in Biopharmaceuticals*, in: Dosi, Nelson, Winter (eds.), The Nature and Dynamics of Organizational Capabilities, Oxford, Oxford Press.

Porter, M. (1980), *Competitive Strategy*, New York, Free Press.

Porter, M. E. (1986), *Competition in Global Industries: A Conceptual Framework*, Harvard Business School Press.

Porter, M. E. (1996), *What is Strategy?* Harvard Business Review, (November/December 1996), 61-78.

Prahalad, C. K., Hamel, G. (1990), *The Core Competence of the Corporation*, Harvard Business Review, (May-June), 79-91.

Priem, R. L., Butler, J. E. (2001), *Is the Resource-Based View a Useful Perspective for Strategic Management Research?* Academy of Management Journal, 26.

Rice, M. P., O'Connor, G. C., Peters, L. S., Morone, J. G. (1998), *Managing Discontinuous Innovation*, Research Technology Management, 41 (3), 52-58.

Rindova, V. P., Kotha, S. (2001), *Continuous "Morphing": Competing through Dynamic Capabilities, Forms, and Function*, Academy of Management Journal, 44 (6), 1263-1280.

Roberts, E. (1988), *What We've Learned: Managing Invention and Innovation*, Research Technology Management, 31 (1), 11-29.

Romanelli, E., Tushman, M. L. (1994), *Organizational Transformation as Punctuated Equilibrium: An Empirical Test*, Academy of Management Journal, 37, 1141-1166.

Schilling, M. A., Hill, C. W. L. (1998), *Managing the New Product Development Process: Strategic Imperatives*, The Academy of Management Executive, 12 (3), 67-81.

Schoonhoven, C. B., Jelinek, M. (1990), *Dynamic Tension in Innovative, High Technology Firms: Managing Rapid Technological Change Through*

Organizational Structure, in: Glinow, M., Mohram, S. (eds.), Managing Complexity in High Technology Organizations, Oxford, Oxford University Press, 90-118.

Schumpeter (1942), *Capitalism, Socialism, and Democracy*, New York, Harper.

Schumpeter, J. A. (1934), *The Theory of Economic Development*, Cambridge, M.A, Harvard University Press.

Selznick, P. (1957), *Leadership in Administration*, New York, Harper and Row.

Sharma, A. (1999), *Central Dilemma of Managing Innovation in Large Firms*, California Management Review, 41 (3), 146-164.

Stalk, G., Evans, P., Shulman, L. E. (1992), *Competing on Capabilities: The New Rules of Corporate Strategy*, Harvard Business Review, (March-April), 57-69.

Steensma, H. K., Corley, K. G. (2000), *On the Performance of Technology-Sourcing Partnerships: The Interaction between Partner Interdependence and Technology Attributes*, Academy of Management Journal, 43 (6), 1045-1067.

Stringer, R. (2000), *How to Manage Radical Innovation*, California Management Review, 42 (4), 70-88.

Stuart, I., McCutcheon, D., Handfield, R., McLachlin, R., Samson, D. (2002), *Effective Case Research in Operations Management: A Process Perspective*, Journal of Operations Management, 20, 419-433.

Tabrizi, B., Eisenhardt, K. (1995), *Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry*, Administrative Science Quarterly, 40, 84-110.

Takeuchi, H., Nonaka, I. (1986), *The New Product Development Game*, Harvard Business Review, 64 (1), 137-146.

Teece, Pisano, Shuen (1997), *Dynamic Capabilities and Strategic Management*, Strategic Management Journal, 18 (7), 509-533.

Teece, D. J. (1996), *Firm Organization, Industrial Structure, and Technological Innovation*, Journal of Economic Behavior & Organization, 31, 193-224.

Teece, D. J. (1998), *Capturing Value from Knowledge Assets*, California Management Review, 40 (3), 50-78.

Teece, D. J. (2000), *Strategies for Managing Knowledge Assets: the Role of Firm Structure and Industrial Context*, Long Range Planning, 33, 35-54.

Teece, D. J., Rumelt, R., Dosi, G., Winter, S. (1994), *Understanding Corporate Coherence - Theory and Evidence*, Journal of Economic Behavior and Organization, 23, 1-30.

Tushman, M., Romanelli, E. (1985), *Organizational Evolution: A Metamorphosis Model of Convergence and Reorientation*, in: Cummings, L. L., Staw, B. (eds.), Research in Organizational Behavior, Greenwich, CT, JAI Press, 171-222.

Tushman, M., Romanelli, E., Virany, B. (1992), *Executive Succession and Organization Outcomes in Turbulent Environments: An Organization Learning Approach*, Organization Science, 3 (1), 72-91.

Tushman, M. L. (1996), *Technology cycles, innovation streams, and ambidextrous organizations: Organization renewal through innovation streams and strategic change*.

Tushman, M. L., Anderson, P. (1997), *Managing Strategic Innovation and Change*, New York, Oxford University Press.

Tushman, M. L., O Reilly, C. A. (1996), *Ambidextrous organizations: Managing evolutionary and revolutionary change*, California Management Review, 38 (4), 8-30.

Tyre, M., Orlikowski, W. (1994), *Windows of Opportunity: Temporal Patterns of Technological Adaptation in Organizations*, Organization Science, 5.

Tyre, M. J., Orlikowski, W. J. (1993), *Exploiting Opportunities for Technological Improvement in Organizations*, Sloan Management Review, (Fall 1993), 13-26.

Utterback, J. (1994), *Mastering the Dynamics of Innovation*, Cambridge Mass., Harvard Business School Press.

Utterback, J., Kim, L. (1986), *Invasion of a Stable Business by Radical Innovations*, in: Kleindorfer, P. R. (ed.), The Management of Productivity and Technology in Manufacturing, New York, Plenum Press.

van de Veen, A. (1986), *Central Problems in the Management of Innovation*, Management Science, 32, 590-607.

van de Ven, A. H., Poole, M. S. (1995), *Explaining Development and Change in Organizations*, Academy of Management Review, 20 (3), 510-540.

Verona, G. (1999), *A Resource-based View of Product Development*, The Academy of Management Review, 24 (1), 132-142.

von Hippel, E. A., Tyre, M. J. (1995), *How learning by doing is done: problem identification in novel process equipment*, Research Policy, 24, 1-12.

Wacker, J. G. (1998), *A Definition of Theory: Research Guidelines for Different Theory-Building Research Methods in Operations Management*, Journal of Operations Management, 16, 361-385.

Wernerfelt, B. (1984), *A Resource-based View of the Firm*, Strategic Management Journal, 5 (171-180).

Wheelwright, S. C., Clark, K. B. (1992), *Revolutionizing Product Development*, New York, The Free Press.

Wheelwright, S. C., Clark, K. B. (1994), *Accelerating the Design-Build-Test Cycle for Effective Product Development*, International Marketing Review, 11 (1), 32-42.

Wild, R. (1995), *Production and Operations Management*, New York, Wellington House.

Williamson, O. E. (1999), *Strategy Research: Governance and Competence Perspectives*, Strategic Management Journal, 20 (12), 1087-1108.

Winter, S. (1995), *Four R's of profitability: Rents, Resources, Routines, and Replication*, in: Montgomery, C. (ed.), Resource-based and Evolutionary Theories of the Firm: Towards a Synthesis, Boston, Dordrecht, London, , 147-178.

Winter, S. G. (2000), *The Satisficing Principle in Capability Learning*, Strategic Management Journal, 21 (10-11), 981-996.

Yin, R. K. (1994), *Case Study Research - Design and Methods*, Applied Social Research Method Series, London, SAGE Publications.

Zahra, S. A. (1999), *Corporate Entrepreneurship, Knowledge, and Competence Development*, Entrepreneurship Theory and Practice, 23 (3), 169-186.

Zander, U., Kogut, B. (1995), *Knowledge and the Speed of the Transfer and Imitation of Organizational Capabilities*, Organization Science, 6 (1), 76-92.

Zollo, M., Winter, S. G. (2002), *Deliberate Learning and the Evolution of Dynamic Capabilities*, Organization Science, 13 (3), 339-351.