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Technological Competence Assessment within the Firm: Applications of Competence Theory to Managerial Practice

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1. Introduction

The Center for International Management and Innovation has developed concepts and tools for assessing technological competences within firms. These methods represent a core building bloc within our Masters Curriculum on International Management of Technology, and they are constantly refined through research projects and Ph.D. dissertations. Research, concept development and implementation takes place in close collaboration with a number of technology-intensive corporations in Germany, Switzerland, as well as in other countries. This paper will outline the basic concepts of technology competence assessment, and will describe some practical experiences and case examples.

Some of the concepts used for technological competence assessment build on well-established methods of strategic planning, strategic management of technology, as well as R&D portfolio planning. The author gained practical experiences while developing and implementing these tools at Arthur D. Little International between 1983 and 1990. Basic concepts were further refined and formulated as teaching notes on „Strategic Management of Technology“ and „Technological Competence Assessment“ at the Universities of St. Gallen and Stuttgart-Hohenheim. Several companies in the automotive industry, in machine-tools, chemicals and pharmaceuticals, as well as in electronics and scientific instrumentation have successfully implemented these tools. As part of our ongoing research program, we are reviewing and benchmarking corporate business practices in this area, and we are continuously refining and implementing proven concepts and tools.

Even though strategic management of technology and various forms of benchmarking and technological competence assessment have by now become common business practice within large, technology-intensive corporations,[2] there is still need for research, for further refinement of concepts and business practices, as well as for greater diffusion to other firms. During our research program, we have focused on the following lines of improvement:

- Our approach has theoretically been made compatible with recent thinking of competence-based competition;

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2 A good survey of the state-of-the-art of corporate management of technology can be found in Roberts (1995a and b) and Goodman, Lawless (1994).

- we have developed a new, comprehensive method for mapping competences in large multi-technology and multi-product firms;
- we have extended existing methods for assessing technological competences beyond the boundaries of a single firm. Our methods have been applied to inter-firm consortia, and this has led to an improved understanding of the dynamics of competence alliances and knowledge-distribution patterns within technological cooperation projects;[3] in addition
- Technological competence assessment has been adapted to analyzing location decisions within large multinational firms. Our ongoing research program „International R&D and Innovation Studies (INTERIS)“ focuses on the building and leveraging of competence centers at different locations in the world.[4]

2. Defining Technological Competence within the Firm

The term „technological competence“ is used in a very comprehensive sense, based on an in-depth understanding of the complexity of industrial innovation processes. According to the most recent OECD guidelines for collecting and interpreting technological innovation data,[5] innovations are defined in the following way.

> „*Technological product and process (TPP) innovations* comprise implemented technologically new products and processes and significant improvements in products and processes. A TPP innovation has been *implemented* if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organizational, financial and commercial *activities*.“ (OECD 1997, p. 47)

This definition emphasizes the interplay of product and process innovation, the role of implementation, as well as the complexity of interrelated technological and non-technological activities. Technological competence is directed towards the achievement of successful product and process innovation.

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3 The method developed for inter-firm projects has been called „distributed competence assessment“. See Gerybadze (1998, chapter 8, and 1995, chapter 5) for this new method of structuring technological cooperation projects, for which the evaluation of distributed competence pools and collaborative forms of managing intellectual property are crucial.

4 See Gerybadze and Reger (1997) and Gerybadze, Meyer-Krahmer and Reger (1997, forthcoming in English 1998).

5 See the most recent Oslo-Manual (OECD 1997), which builds on several earlier versions of the Frascati-Manual developed by the Organization for Economic Cooperation and Development in order to harmonize basic notions of R&D and innovation across countries.

> „*Competence* is an *ability to sustain the coordinated deployment of assets* in a way that helps a firm *achieve its goals*. Here we use the word ability in the ordinary language meaning of a „power to do something“. To be recognized as a competence, a firm’s activity must meet the three conditions of *organization, intention and goal attainment*.“[6]

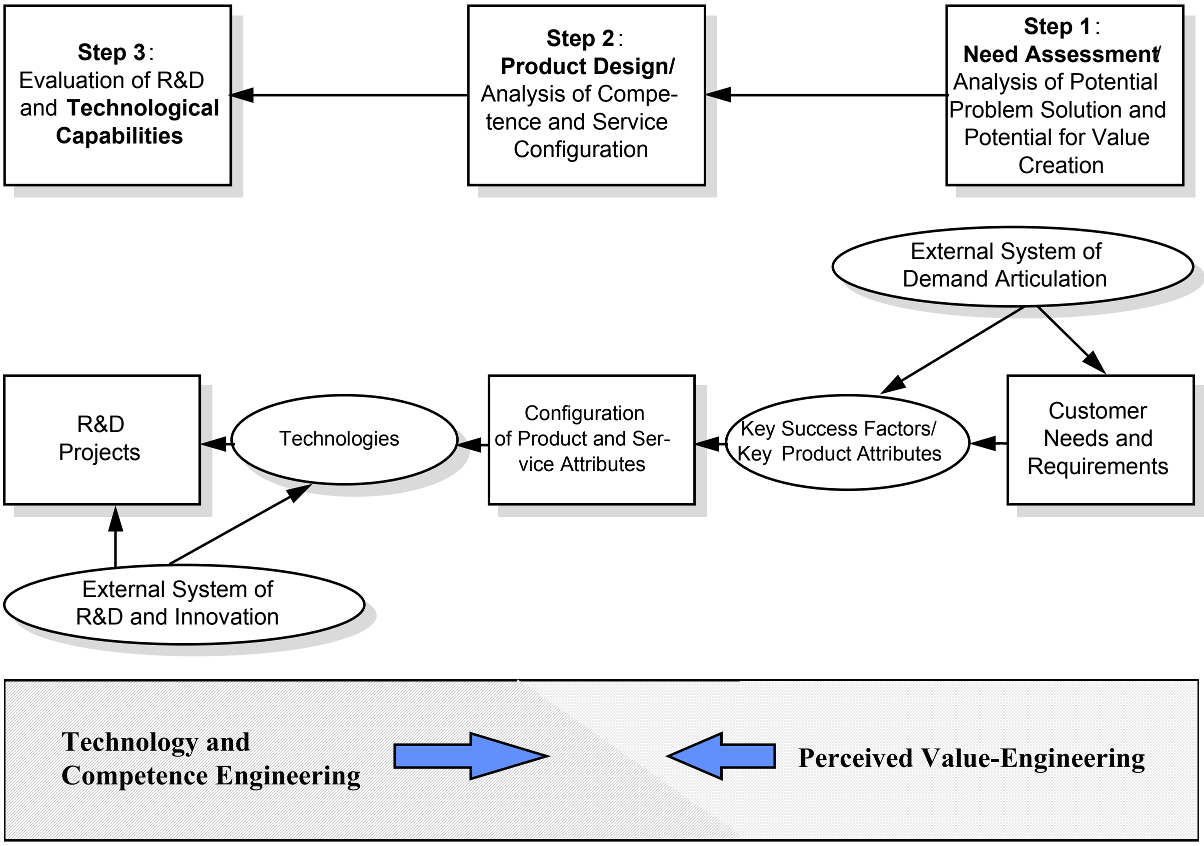
Technological competences of a firm, according to our view, consist of three areas of expertise that have to be mastered simultaneously: (1) the ability to understand new trends in science and technology, to manage R&D projects, and to generate useful new technologies. (2) The ability to design and manufacture products and to reconfigure products and services, which are useful and which generate a measurable competitive advantage. This requires (3) a profound understanding of customer needs and requirements, of changing trends in the external system of demand articulation, and the ability to formulate new value propositions. Effective innovation builds on a very close correspondence between these three areas of expertise. While the term „technological competence“ is often interpreted in a rather narrow sense, covering primarily R&D capabilities and product or process technologies, we believe that the full spectrum of the innovation value chain outlined in Figure 1 has to be taken into account.

The *technological competences* of a firm is accordingly defined as the ability to deploy complex bundles of resources in a directed, value-enhancing mode. The innovation value chain may be used to structure an effective linkage between R&D, product and process attributes. This process of effective linkage may be conceptualized as a movement from left to right (technology and competence engineering), and/or as a process from right to left (perceived value engineering). More research-driven firms may emphasize the first mentioned process of *technology and competence engineering* (see the lower left hand side in Figure 1). R&D projects and products as well as process technologies, for which the firm is particularly strong, will influence product design as well as the configuration of product and service attributes. These products and services must be directed at customer groups, and they have to address particular customer needs and requirements. Some configurations of products and service attributes have a closer correspondence with key success factors than other configurations. These „winning combinations“ generate relatively high values in the market, and they will lead to a greater renumeration for scarce technological resources. Such

6 Sanchez, Heene and Thomas (1996, 8). Basic concepts and definitions have evolved during the first three conferences on competence-based management. See also Heene and Sanchez (1997, chapter 1 and 2).

technology-push type strategies can be modelled as an evolutionary process. Firms that happen to make the right technological choices will realize a greater margin and will be able to fund more R&D to nurture their technological competence base.[7]

Figure 1: Technological Competences and the Innovation Value Chain



This process of building and leveraging technological competences can be approached in a more customer-oriented way, i.e. from left to right in Figure 1. Such a customer-oriented process of *perceived value engineering* requires effective capabilities at the front-end; firms must have pronounced strengths in customer interaction and need assessment. The analysis of a potential problem solution and the exploration of value creation opportunities in close interaction with users will lead to a better understanding of key success factors and of critical product attributes (Step 1). This front-end information is then „translated" into effective product designs and product/service configuration activities. (Step 2). This transfer process of

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7 Such evolutionary models of technological choice have been developed by Nelson and Winter (1982) and by Anderson (1994).

connecting Step 1 and Step 2 can be described as a transfer „from customer to product concept". Some firms like 3M or Hilti have developed very strong capabilities in lead-marketing, and in developing products and technologies based on close interaction with their customers.[8] These capabilities represent an integral element of the technological competence base of these firms.

Even though some firms may specialize more on these front-end capabilities, while others tend to be more research and technology-driven, effective technology-market linkage requires close integration of value-engineering with technology and competence engineering. This integration process may be achieved through intra-corporate management of technology, or alternatively, through effective inter-firm consortia and customer-supplier networks. Technological competence assessment must address this issue by asking whether all three steps can be integrated effectively, be it within a particular firm or within a clearly defined group of agents. The assessment and evaluation of R&D projects and of technological competences (step 3) can only lead to useful results if it is integrated and contextualized with both step 1 (market context) and step 2 (product and service configuration). This integration process, and the proposed value-oriented view of „technology" and „competence" is distinctly different from older concepts of R&D portfolio management and technology planning and assessment.[9]

3. Technology Competence Assessment: Finding the Appropriate Unit of Analysis

Technological competence assessment can be applied in large corporations, in medium sized companies as well as in specialized small firms. While the methods to be used are very similar on a project or business unit level, their application in large firms requires sophisticated techniques of segmentation, decomposition and portfolio management. Our following description focuses on technology competence assessment in large, multiproduct firms. For these firms, too generous evaluations of „the technology base" or „the customer

8 See von Hippel (1988), Herstatt (1998) and Gerybadze, Meyer-Krahmer and Reger (1997, Chapter 2 and 3).

9 Older concepts were more „supply- or discovery-driven". Yves Doz has emphasized during a presentation at the OECD-Workshop on June 30, 1997, that architectural knowledge, integration and contextualization are much more important than the discovery process, and more important than the pure definition of technologies.

base" are often meaningless. Assessments of effective linkages between customer needs, product design and technology require in-depth, context-specific and often tacit information. Technological competence assessment thus builds on a detailed understanding of product focus and customer needs within a very specific business context. It is based for less on objective, quantitative data-gathering, and more on subjective evaluation and interactive design involving inter-functional groups of experts.[10] Alternative methods for evaluation and assessment have to be differentiated according to:

- the *scope* and *breadth* of technological competence assessment; and
- the *openness* and *novelty* of competences investigated.

In terms of *scope* and *breadth*, we can distinguish between single-technology/single product firms (narrow scope), multi-technology and multi-product corporations (wide scope), as well as mixed forms (e.g. multi-technology/single-product firms).[11] In terms of *openness*, we can distinguish between in-paradigm and extra-paradigm competence assessment.[12]

3.1 Technology Competence Decomposition in Large Firms

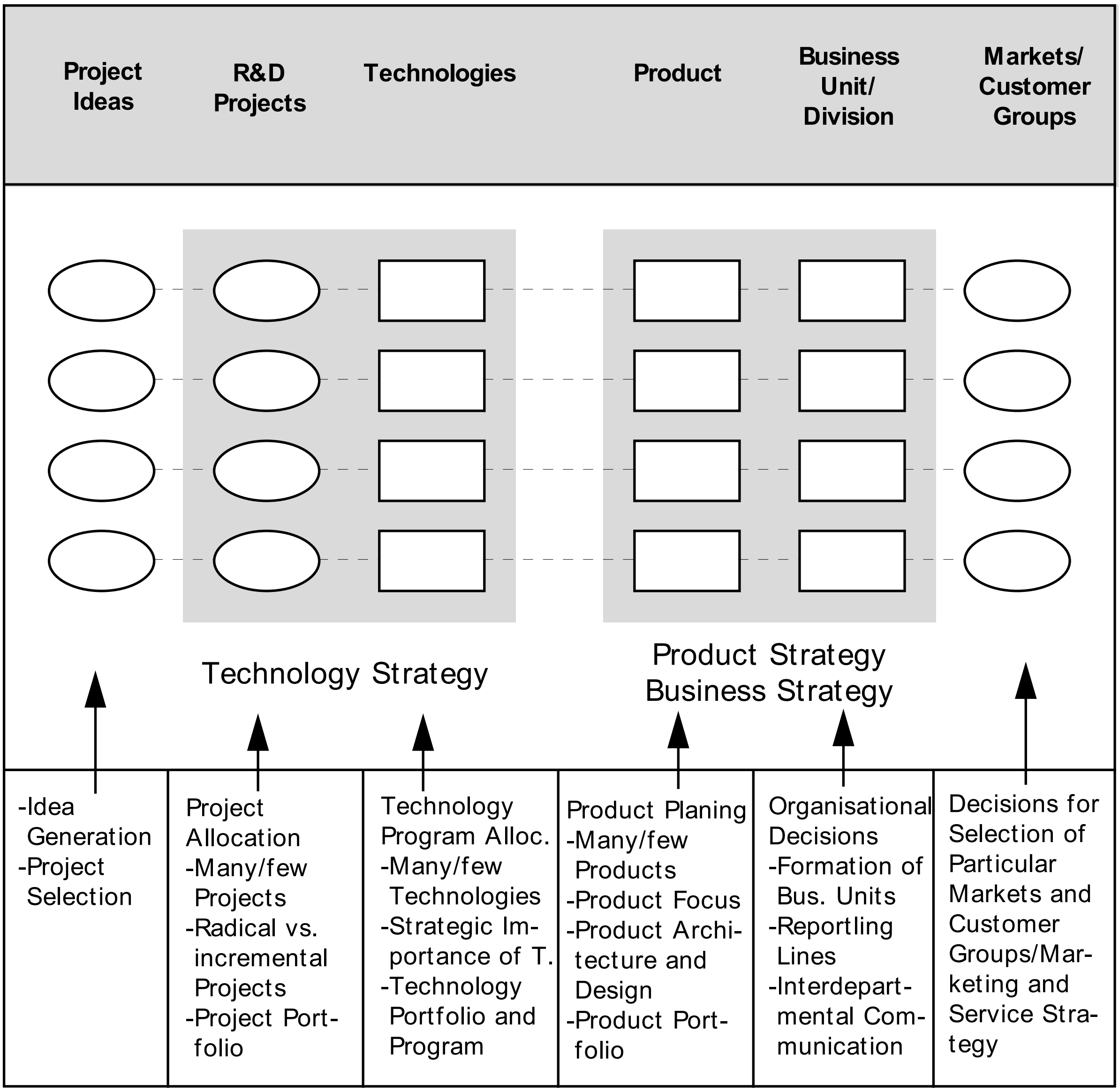
The most sophisticated methods for technology competence assessment have been developed for large corporations with many business units, multiple areas of technological expertise, and large R&D programs. Typical examples are large technology-intensive corporations in electronics or in the chemical industry, often represented by multi-business and multi-technology firms such as ABB, Siemens, DuPont or Hoechst. Technology competence assessment within such firms requires a detailed analysis of business-technology-correspondences, as well as an understanding of technology interrelatedness and synergies. Figure 2 provides a mapping of technology-related *upstream activities* on the left hand side (these include project ideas, R&D projects and technologies). Market-related *downstream*

[10] Technology assessment and R&D evaluations exercises are often overemphasizing data-gathering and „number-crunching" based on bibliometric or patent data. Every experienced evaluator knows that effective evaluations require a combination of several methods and tools (both quantitative *and* qualitative), as well as informed subjective reasoning.

[11] Grånstrand, Oskarsson (1994), Grånstrand (1997), as well as Grånstrand, Patel and Pavitt (1997) have developed methods for analyzing the degree of product as well as technology diversification within large firms. These methods are further refined and implemented within an international working group on „Technology and Corporate Diversification"

activities (on the right hand side) differentiate between products, business units or divisions, as well as between markets or customer groups.

Figure 2: Mapping Technology and Business Profiles within Large Firms



Technology competence assessment can be pursued on a product by product basis, represented by horizontal strings in Figure 2. This is the focus of our paper: we will focus on the assessment of technological competences to be deployed for a particular product group or business. We will not address questions such as „how strong is company X in microelectronics?“ Instead we will raise the question: „how competent is firm X in

12 In-paradigm assessments are based more on incremental changes following established trajectories. Extra-paradigm assessments have to deal with the formation of new trajectories. Needless to say that extra-

developing and implementing microelectronics for its automotive electronics business?“ This requires a careful segmentation, business unit analysis as well as technology decomposition. In addition, some more generic technologies serving different businesses, as well as large, synergetic R&D programs require different methods of corporate technology management not to be addressed in this paper.[13]

3.2 Strategic Competence Units Within the Firm

For analytical as well as for strategic purposes, technological competences must be decomposed into separable chains of activities. Concepts used are similar to the identification of strategic business units (SBU) in traditional strategic planning. Businesses within a corporation are decomposed in order to allow for a coherent strategic mission. In a related way, technological competences can be decomposed and clustered around missions. Similar to the concept of an SBU, we can speak of a strategic competence unit (SCU), or a strategic technology unit (STU). For this purpose, competences must be decomposed into lines of related activities and knowledge, which address the same mission, e.g. microelectronic design for a particular market or for a customer group with very specific requirements. This is illustrated in Figure 3, where one technology (e.g. ASIC chip design) addresses a particular product and customer group (e.g. the automotive electronics business). Technological competences are thus interpreted as knowledge or skills along value chains; this can be illustrated by horizontal strings (see the shaded vertical zone in Figure 3).[14]

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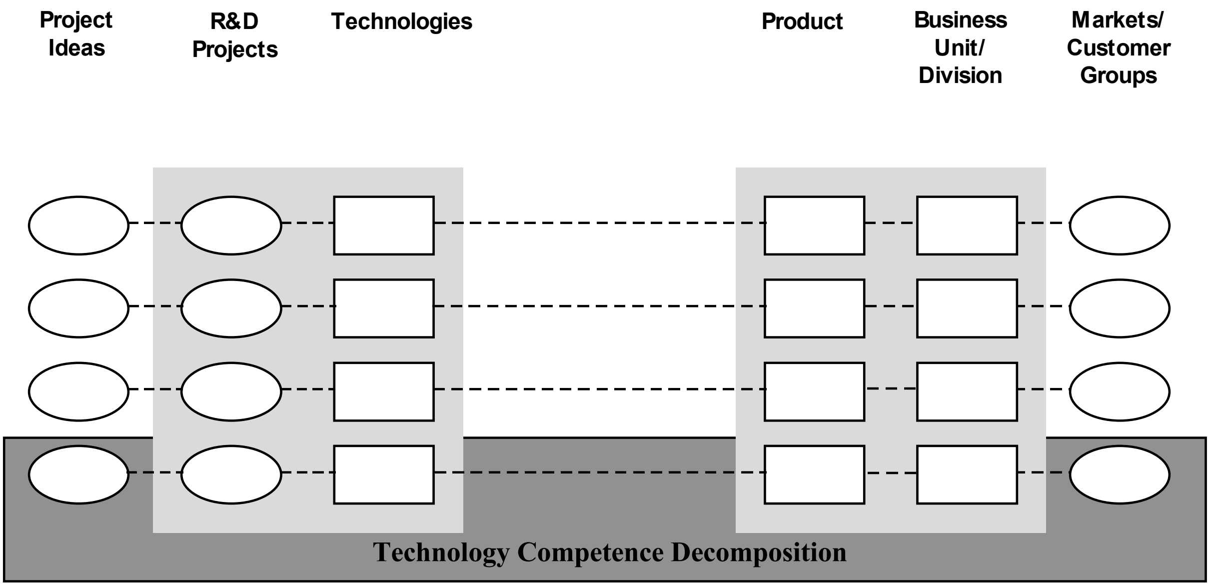
paradigm competence assessment is typically much more complicated than in-paradigm assessment.

13 The unit of analysis would then have to be chosen differently. Instead of horizontal slices in Figure 2, we would have to analyze vertical cross-sections of projects or technologies.

14 This corresponds closely to the interpretation of technological competences as the ability to deploy complex bundles of resources in a directed, value enhancing mode (Sanchez, Heene and Thomas (1996). R&D projects are transformed into technologies and product designes, which address particular customer groups and their needs. Effective linkage between these elements and a new reconfiguration of complementary assets and interrelated competencies will result in value creation and innovation rents (Christensen 1995, Teece 1986).

Figure 3: Technological Competence Decomposition

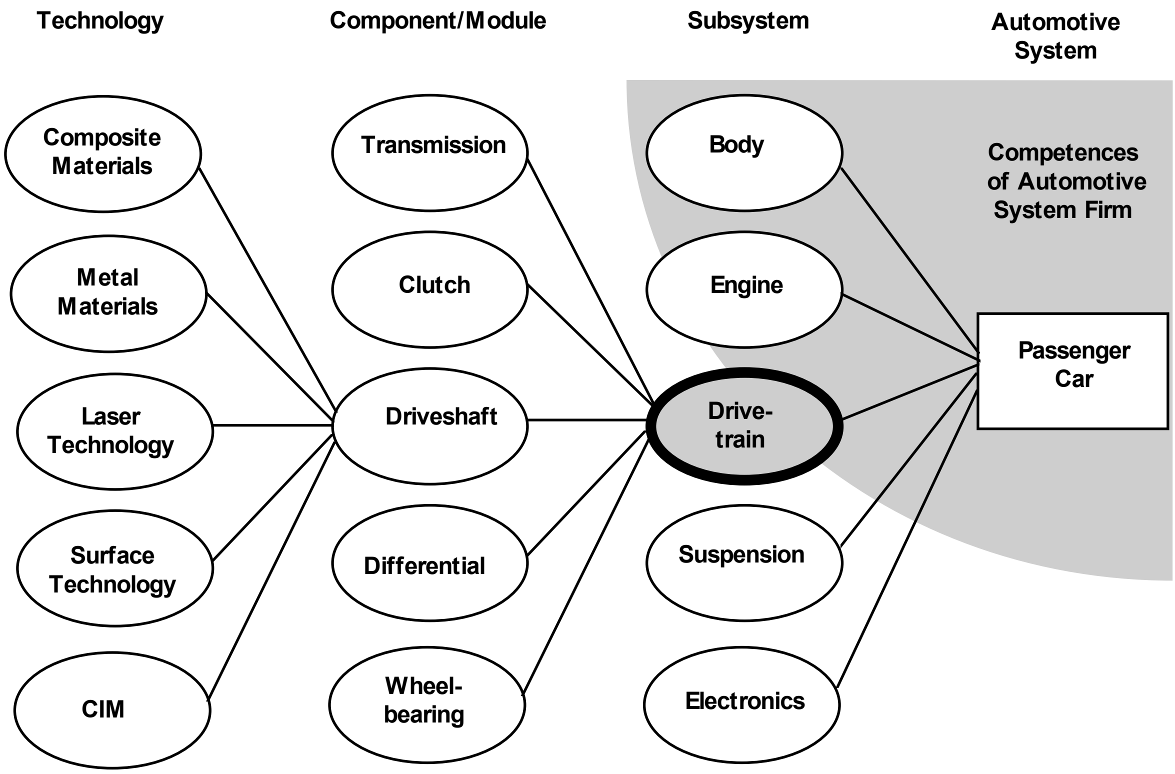


3.3 Defining Competence Boundaries and Domains

Technology and value chain decomposition can be done differently for each firm, even in the same industry. Business focus and innovation strategies are firm-specific; effective technological competence assessment thus requires a detailed understanding of product missions and strategies for a particular firm. Firms can differentiate their activities by product group, customer function, as well as by system integration level. Each segment and integration level leads to a different competence decomposition. Relevant fields of technological expertise are different for large automotive systems manufacturers (e.g. GM, Toyota, Volkswagen), for subsystem suppliers (e.g. Bosch or Allied Signal), as well as for component manufacturers. In Figure 4, the task of automotive system integration on the right hand side can be decomposed into the following subsystems: (1) automotive body, (2) engine, (3) drivetrain, (4) suspension system and (5) electronics. The automotive system manufacturer, often described as OEM, will consider body design and manufacturing as well as engine development and manufacturing as a „core competence“; this „core“ will be controlled in-house. In addition, automotive systems firms will develop some „intelligent user competences“ for „less strategic“ subsystems such as drivetrains, suspension systems and electronics. The competence domain of an automotive system firm is illustrated by the shaded zone on the upper right side in Figure 4.

Competence domains and relevant fields of expertise may change over time, depending on corporate strategies, vertical integration or dis-integration and industry restructuring. Structural change in the automotive supply industry has led to the formation of subsystem integration firms, with full responsibility for development, design and manufacturing for a major sub-part of a car. As an example, the subsystem integrator for the drivetrain will have to build up design, development and/or manufacturing capabilities for the following components or modules: transmission, clutch, driveshaft, differential and wheel-bearing. Some of these components will represent a „core capability“ for the subsystem integrator, and firms will then tend to develop and manufacture these components in-house. „Non-core“ activities, by contrast, will be subcontracted and sourced out to independent component suppliers.

Figure 4: Technological Competence Decomposition in the Automotive Industry



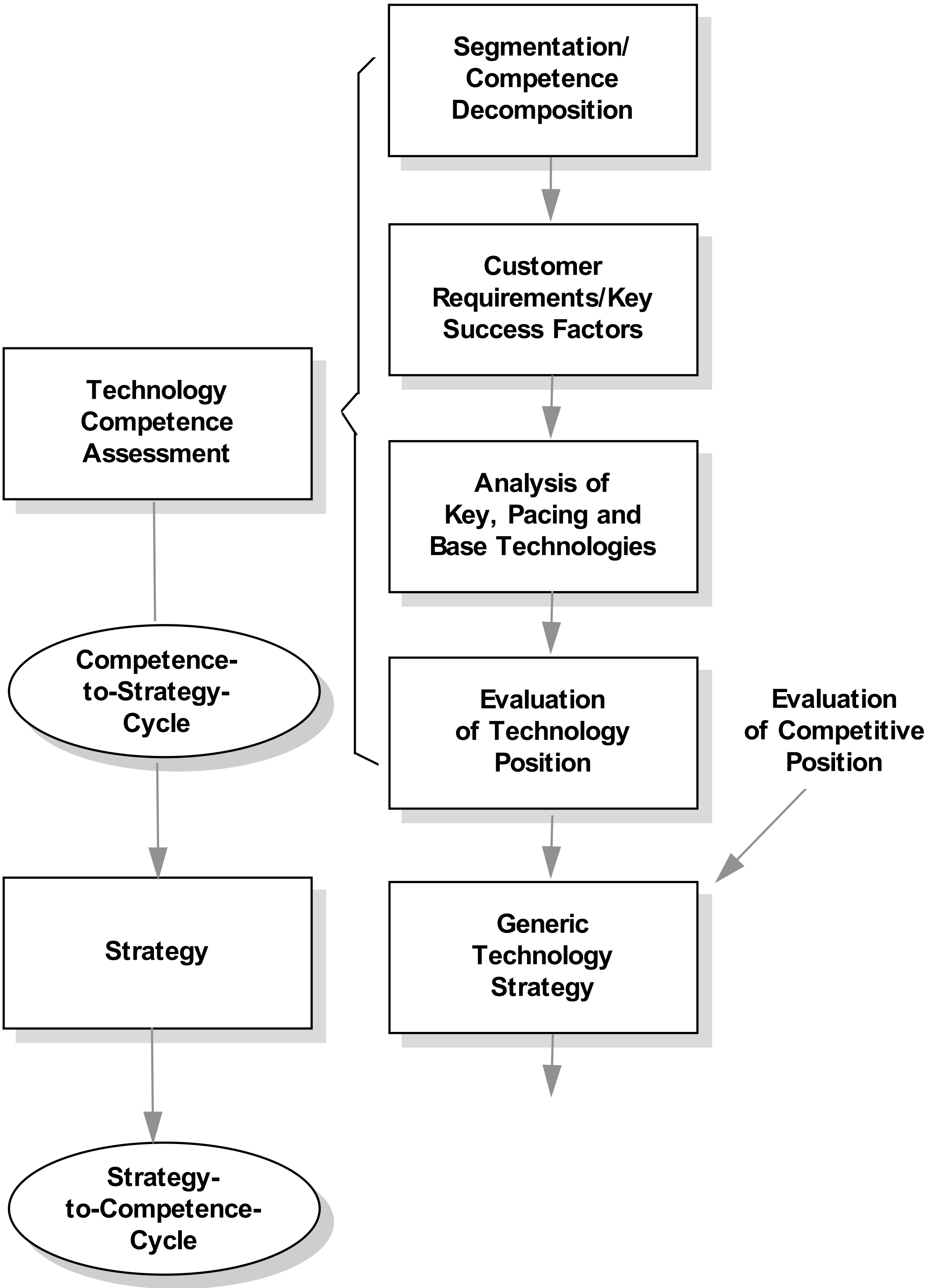
4. Strategic Focus for Competence Assessment

4.1 Finding the Most Critical and Valuable Technologies

Technological competence decomposition leads to a strategic preselection of a relatively narrow set of important technologies, that have to be mastered in order to fulfill a particular mission within the selected market. Only those technologies count, for which the company is particularly strong, and which will generate a measurable value contribution in the market segment addressed. As an example, a drivetrain systems integrator must be highly competent in driveshaft development and manufacturing. This firm must be able to integrate and control technologies in the field of materials (metal materials as well as composite materials) and processing (laser technology, surface technology, computer-integrated manufacturing). For a detailed unbundling of technologies for automotive drivetrains see the illustration on the left hand side in Figure 4. Some of these technologies will be highly critical for a particular product attribute demanded by the customer (the automotive system firm). Some technologies will generate a high value contribution (or cost saving) for the final product and its user, and these technologies will receive the greatest attention.

Technological competence levels must be assessed on the basis of their value contribution. Firms can be competent, but it is also important to perform at just the „right level“ of competence. In this sense, firms can be both underqualified as well as overqualified. Low performance with respect to particular technologies and product features is one mistake. Misdirected over-achievement is another mistake, particularly for research-intensive companies. Such firms often measure technological competence on the basis of scientific achievements or patents. However, knowledge which does not result in a measurable value creation in the market is not considered as a „competence“ defined in section 2. Over-achievement and „gold-plating“ does not represent competent behavior. Furthermore, companies that misdirect their R&D activities cannot be considered competent either: a firm focusing on driveshafts is not well advised to develop in-depth knowledge for other material or processing technologies, which are only useful for other, quite unrelated subsystems (such as engine ceramics). The automotive systems integrator, on the other hand, is well advised to focus on systems integration capabilities, while developing in-house technological competence only for selected, highly-critical components or subsystems.

Figure 5: Analytical Steps during the Competence-to-Strategy Cycle



4.2 The Competence-to-Strategy Cycle

In order to find out what is critical, and which areas of technological expertise are „core“ or „non-core“, a firm has to answer the following questions:

- what are the particular market segments and customer groups we focus on?
- which factors are value-drivers and what are the key success factors within these market segments?
- what are the particular product features and performance characteristics, for which our customers are willing to pay a high premium?
- which of these features and performance characteristics are effectively addressed by particular technologies?
- for which areas of technological expertise are we particularly strong?
- what explains our competitive advantage vis-á-vis other firms and how effectively can this advantage be secured?

These questions must be addressed during the four steps of technological competence assessment outlined on the right hand side in Figure 5. Following the process of segmentation and competence decomposition just described, the firm will have to analyze customer requirements and key success factors. This knowledge is important for the appropriate evaluation of key, pacing and base technologies. Detailed analytical studies will then converge in the „competence to strategy cycle“: based on an evaluation of a firm’s technology position and its competitive position, meaningful technology strategies can be derived.

4.3 Evaluation of Key, Pacing and Base Technologies

Firms can invest in a wide array of technological expertise, but they need a focusing device in order to transform undirected knowledge into technological competence. The competence-to-strategy-cycle just described is such a focusing device. Based on this process, areas of technological expertise are preselected and ordered. Important criteria for determining the relevance and strategic importance of technological competences are:

- which factors explain the added value and rent that can be appropriated by a firm using this particular technology?
- which factors characterize the diffusion of this particular technology within the relevant group of competitors?

Technologies and areas of technological expertise follow a more or less stringent *technology life cycle*.[15] In our empirical work we distinguish between *four maturity classes* of technological competence:

- *Emerging technologies*: certain fields of expertise are generated as a result of pre-competitive basic research. These often represent speculative areas of knowledge creation with highly uncertain commercial application potential only in the distant future.
- *Pacing technologies:* some new areas of technological expertise are considered „pacing“ for commercial success, and these will often be applied by early innovators on a trial basis. However, these technologies still involve considerable risk, and expected benefits may never materialize.
- *Key technologies* are areas of technological expertise, which strongly influence competitive advantage, and which are of high concern for an increasingly dominant group of firms. These technologies generate considerable rents, and they lead to strong investment activities of firms.
- *Base technologies* have become widely diffused; they represent a basis of competition, an area of expertise which is highly relevant to survive, but which allows no further competitive differentiation.[16]

Key technologies generate a high value-added and, in some cases, very high rents for firms which have decided early enough to invest in this particular area of technological expertise, and which can thus exploit an effective lead in commercializing this capability. Consider the temporary lead that Intel can exploit after introducing the next generation of microprocessors. Base technologies, by contrast are widely diffused and typically generate no rents (take as an example 486 chips, which are still in use for some applications, but which hardly generate any rents). A firm must be strong for particular key technologies, which generate a high-enough revenue stream, part of which may be used to invest for the next generation of products and for technological competences which are still in their pre-paradigmatic phase (see the left part of the graph in Figure 6). Some emerging and pacing technologies will be selected which,

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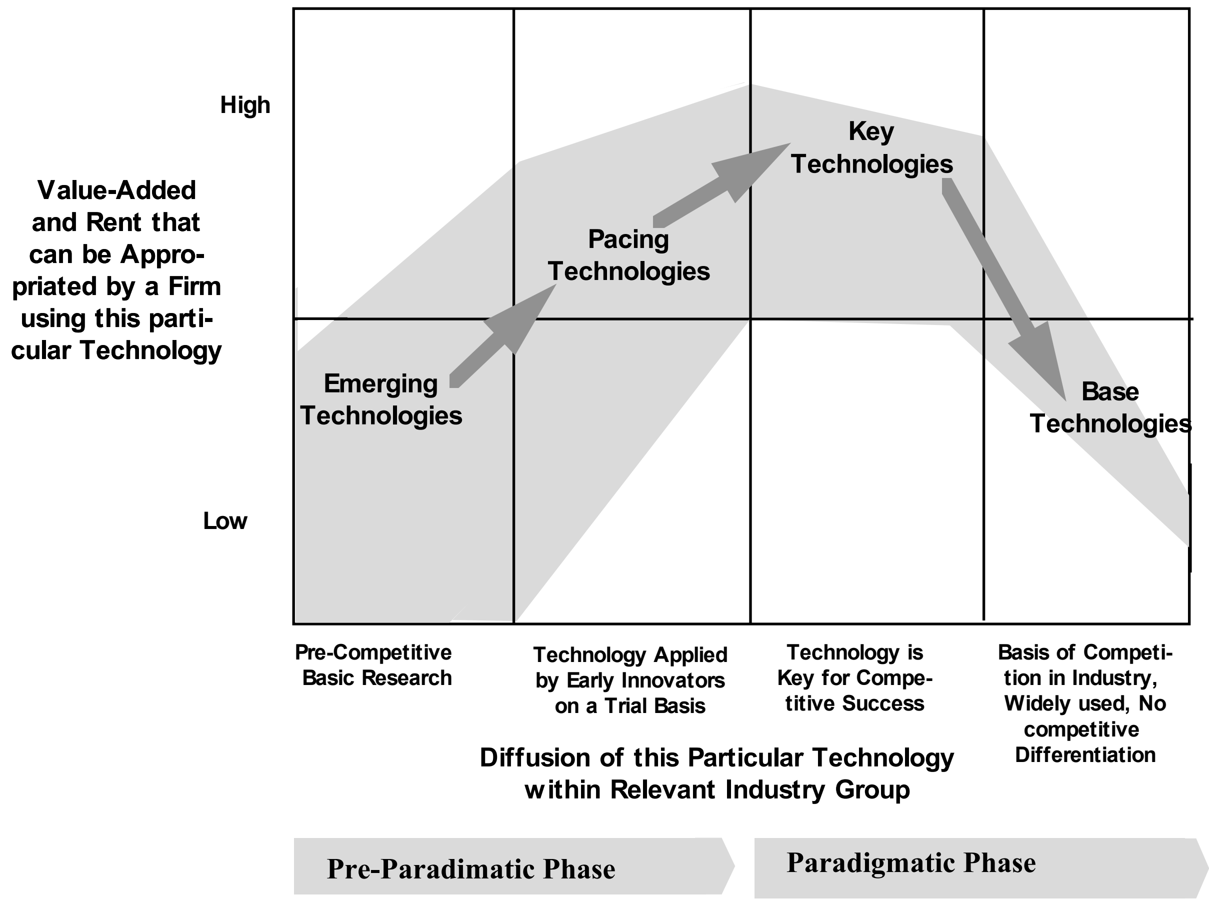
[15] For the concepts of the *technology life cycle* and *technology maturity* see Utterback (1994), Arthur D. Little (1983), and Burgelman, Maidique and Wheelwright (1996).

[16] Within the marketing literature, this would be expressed as a „hygiene factor“, a feature customers expect as given, but for which they are not willing to pay a premium.

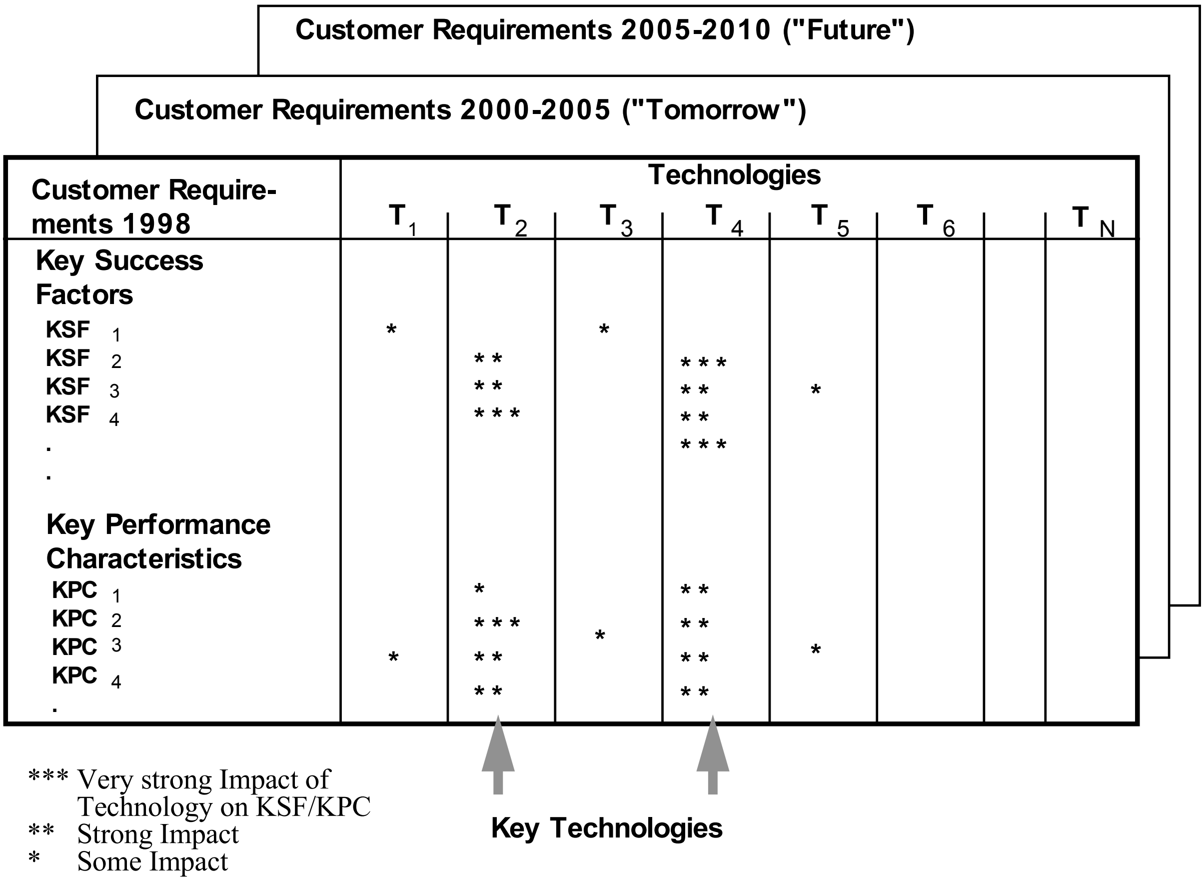
however, are highly risky with respect to their timing and rent-earning potential (see the shaded development funnel for technological competences in Figure 6).

Figure 6: Analysis of the Rent-Generating Potential of Key, Pacing and Base Technologies



A useful tool for classifying different areas of technological expertise with respect to maturity classes is described in Figure 7. It is somewhat related to quality function deployment (QFD), but is more robust, and better applicable to a wider class of development projects.[17] Informed decision-makers (marketing and sales representatives as well as customers) are asked to list key success factors (KSF) and the key performance characteristic of products (KPC). These are ranked and listed along the vertical axis in Figure 7. Technology experts (R&D specialists within the firm as well as external experts) are asked to provide a list of relevant technologies (columns in Fig. 7). For each of the listed area of technological expertise the following question will be raised: if our company is strong for this technology, will this have a strong, medium or low impact on the fulfillment of a particular key success factor (a particular key performance characteristic)? As a result of this assessment, some technologies (T_2 and T_4) turn out to be key for attaining a strong leadership position in the market. While customer requirements in 1998 are the basis for this evaluation of key technologies, the role of pacing technologies and of emerging technologies is assessed on the basis of predicted customer requirements for the next two planning cycles (e.g. 2000-2005 for „tomorrow“ and the years 2005-2010 for the „distant future“).[18]

Figure 7: Method for the Identification of Key, Pacing and Base Technologies



Customer Requirements 1998	Technologies T_1	T_2	T_3	T_4	T_5	T_6		T_N
Key Success Factors								
KSF_1	*		*					
KSF_2		**		***				
KSF_3		**		**	*			
KSF_4		***		**				
.				***				
.								
Key Performance Characteristics								
KPC_1		*		**				
KPC_2		***	*	**				
KPC_3	*	**		**	*			
KPC_4		**		**				
.								

17 Quality function deployment (QFD), and the so called House of Quality (HoQ) have primarily been developed for incremental product improvement projects. Our method is simpler and applicable also for development projects involving high degrees of change.

18 The appropriate planning horizon will depend on cycle speed within the industry. Fast-cycle products (e.g. semiconductors) require much shorter planning horizons than slow-cycle products (e.g. energy production systems).

5. Technology Strategy and Technology Competence Profiles

The formulation of technology strategy serves as a focusing device for building and leveraging areas of technological expertise with the highest impact. Technological investments in the past explain a firm's competence levels of today (in terms of a firm's technology position, and its competitive position). These competence levels represent options as well as constraints for a firm's technology strategy: to aim for technological leadership in a particular product field such as automotive engines or drivetrains, a firm must have a strong track-record and will have to control the most critical technologies. This relationship is explored during the competence-to-strategy cycle (see the following section 5.1). On the other hand, a technology strategy once formulated will guide ongoing competence-building activities. Some areas will be developed more actively than others, since they are more in line with strategy. Firms will define which areas of technological expertise they are going to build in-house, as opposed to external technology sourcing. Furthermore, strategies lead to implications for technology leveraging decisions (in-house vs. external exploitation of capabilities). This relationship is explored during the strategy-to-competence cycle (see sections 5.2 and 5.3).

5.1 Technology Position of a Firm and its Generic Technology Strategy

The list of technological competences relevant for a particular business can be grouped according to different maturity classes. What is key for one particular segment, can be considered a base for some other segment. The type of maturity and strategic relevance of an area of technological expertise may also depend on the position of a firm along the value chain. A component manufacturer will consider other technologies as strategically relevant than a subsystem integrator, while a large automotive systems firm again focuses on other types of technological competence. Figure 8 provides a list of relevant technologies for a drivetrain subsystem integrator within the automotive industry. Key technologies are listed first, and get a higher weighting than pacing technologies and base technologies. Emerging technologies were excluded as being „too long-range“ for this type of firm.[19] For each of

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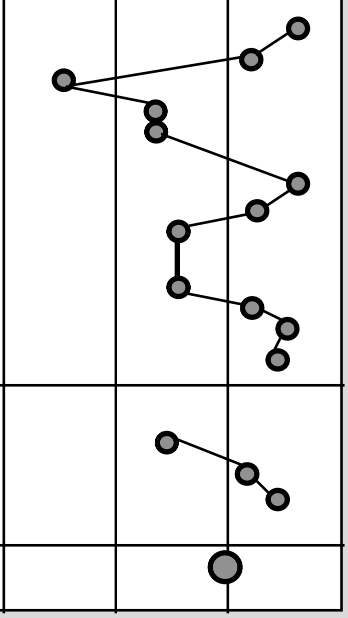
[19] Automotive suppliers typically are not involved in basic research and emerging technologies. They tend to establish more open, external arrangements with universities, public or semipublic research institutes or very large, research intensive corporations (such as chemical firms). Large R&D intensive QEM firms, by contrast, may to some extent be also involved in emerging technologies.

these areas of technological expertise listed in Figure 8, a group of specialists were asked to evaluate the competence level attained by our firm on a scale between 1 and 5, and to compare this level with the major competitors (C_1, C_2,...C_k). A competence level of 5 would indicate a very strong performance.

On the right hand side in Figure 8, the technology competence profile of the firm has been summarized. The upper part provides a detailed profile differentiating by areas of technological expertise; the lower section contains an assessment of the aggregated technology position for key, pacing and base technologies. The firm was strong for pacing as well as for base technologies, but had somewhat neglected important key technologies. Due to the relative strong weighting of key technologies, this led to an overall medium score for the technology position. This came somewhat as a surprise, since several decision-makers in R&D, due to their overemphasis on pacing and base technologies, had originally believed that the firm was still in a very strong technology position.

Figure 8: Evaluation of a Firm's Technology Position and its Technology Competence Profile

Technologien	Gewich-tungs-faktor	Bewertung eigenes Unternehmen	Bewertung der Wettbewerber W_1	W_2	W_3	. . .	W_K	Relative Technologie-Position stark	mittel	schwach
Schlüssel-Technologien	(3-5)									
o Applikations-Know-how		5	3	5	3		4			
o Meß- und Prüftechnik		4	4	4	3		3			
o CAD/CAM		2	4	4	4		3			
o Flexible Fertigungssysteme		3	2	3	2		2			
o Werkzeugtechnik		3	4	4	3		3			
Schrittmacher-Technologien	(2-4)									
o Lasertechnik		5	4	2	2		1			
o Verbundwerkstoffe		4	3	2	2		1			
o Integration Radlager		3	3	4	4		2			
Basis-Technologien	(1-3)									
o Integration Differential		3	3	3	1		1			
o Gußstahlverarbeitung		4	4	4	4		4			
o Oberflächentechnik		5	2	4	2		1			
o Kugellager		5	4	5	5		4			
Technologie-Position für										
- Schlüssel-T.										
- Schrittmacher-T-										
- Basis-Technologien										
Bewertung insgesamt										



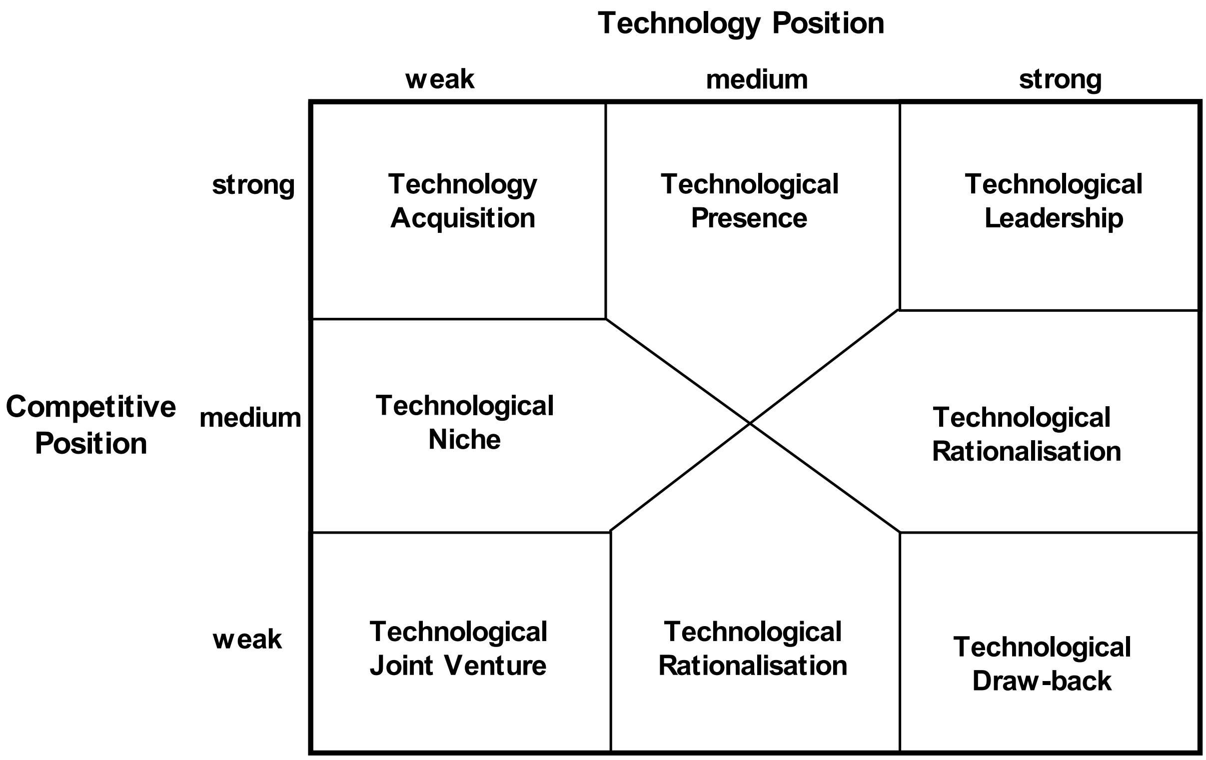
Firms are active in two related competitive arenas: (1) in the market for products and services and (2) in competition for technological competences. The position in the first arena can be measured by „classical“ strategic planning tools (competitive position, market share, product-performance indicators etc.), which we shall exclude in this paper.[20] The position in „technology competence space“ is determined on the basis of evaluation methods just described. It is summarized by the term *technology position*, measured along the horizontal axis in Figure 9. This position can be strong (equal to or better than technically most advanced firms), medium or weak. This technology position is one major determinant for the formulation of technology strategy; a firm’s competitive position is another, since firms compete in product markets and in technology competence space inter-alia. Competition in product markets generates revenues and rents, which are used for further investments in R&D and for competence building. While the technology position of a firm defines which part of the competence trajectory can be further developed, its competitive position will determine

[20] See classical textbooks on strategic management such as Hax and Majluf (1984) and Porter (1980, 1985).

the financial strength for further R&D investments, as well as the power to commercialize new products within existing customer networks and distribution channels.

In Figure 9, the technology position of a firm has been measured along the horizontal axis, while the vertical axis measures its competitive position. The stronger the firm is positioned in the „north eastern territory“, the more offensive will be its technology strategy, and the more comprehensive can be its in-house competence-building activities. A weaker position along both axes will constrain the firm's technological search activities, which will lead to more defensive strategies and to a lower competence-building profile.

Figure 9: Generic Technology Strategies of a Firm

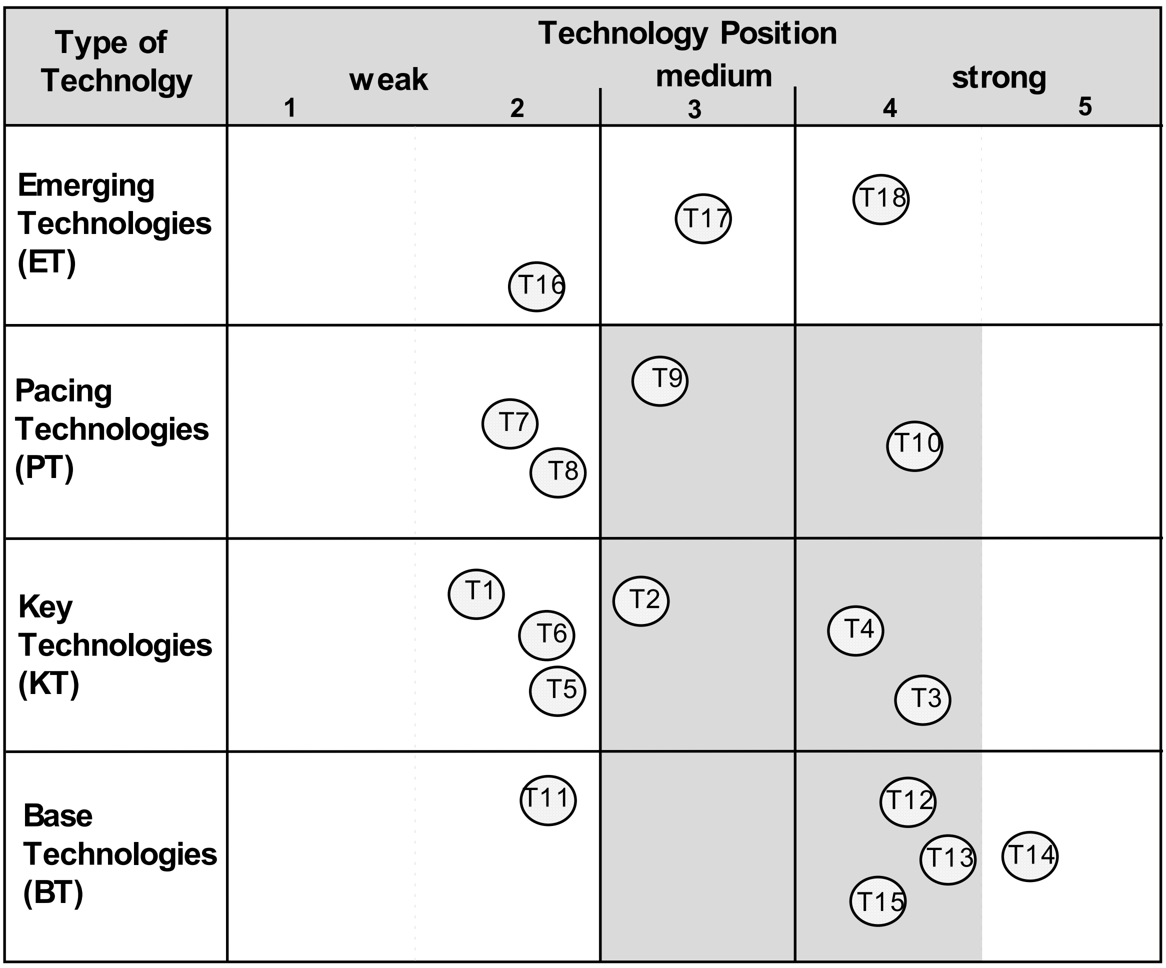


5.2 Strategy-to-Competence Cycle: Technology Competence Profiles and R&D Portfolios

Technology competence assessment is a crucial input for the strategy formulation process: a firm's strategy to play the role of an active innovator in a particular business requires an existing strong position both in terms of technological capabilities, as well as the power to implement inovation in the marketplace. Once a strategy has been decided and agreed upon, the detailed information gathered during the evaluation of technological competences can be used for further reviewing of projects, for R&D portfolio planning and during several consecutive phases of strategy implementation. We call this the strategy-to-competence building and leveraging cycle.

During the strategy-to competence cycle, we are primarily concerned with the question whether a particular technological competence is „in line“ with the overall strategy or whether it is „out of tune“. A useful diagnostic instrument is described in Figure 10. Along the horizontal axis, we measure the technology position along a scale of 1 to 5. (five again indicating „very strong“). Each area of technological expertise is numbered and grouped according to its maturity class. The distribution of technological competences within this portfolio, together with a first sketch of the desired or accessible range, provides a first plausibility check.

Figure 10: Technology Competence Profiles of a Firm



In Figure 10, the management of a firm has decided to attain a medium to strong position for the full range of key, pacing and base technologies. The actual distribution of competences shows: (1) there are some critical weaknesses with respect to key technologies (T1, T5 and T6); (2) there are some under-performing pacing technologies (T7 and T8). (3) While the company has a relatively strong position for base technologies, two areas are characterized by under-performance (T11) resp. by an overachievement (T14). Finally (4), some researchers tend to „play around“ with emerging technologies outside the core mission of the firm (T16 to T18).

In our research studies we often found a mismatch between technology strategy and R&D budget allocation.[21] An effective technology strategy requires that the R&D budgeting process, portfolio planning and strategy development are effectively coordinated. A very useful diagnostic tool uses the same portfolio described in Figure 10 and addresses the following two questions:

1. What is our actual technology position for areas of technological expertise within each of the four maturity classes (illustrated by the position along the horizontal axis)?
2. What percentage of the R&D budget is allocated to this maturity class (illustrated by the size of the circles in Figure 11)?

Figure 11 illustrates an extreme type of competence misallocation; however it does not represent an unrealistic profile, and such a pattern can be found in a number of firms. More than 50% of R&D is allocated for improvements of base technologies. Key and pacing technologies, by contrast, are under-represented, while very risky projects for emerging technology are over-represented. As a result of such an R&D allocation profile, the firm is strong for base technologies, which generate minor comparative advantages, while a considerable share of R&D (up to 20%) is „sunk“ into dubious long-range projects. Both types of technologies exert a „crowding-out“ on more promising key and pacing technologies, which, as a result, receive no appropriate funding.

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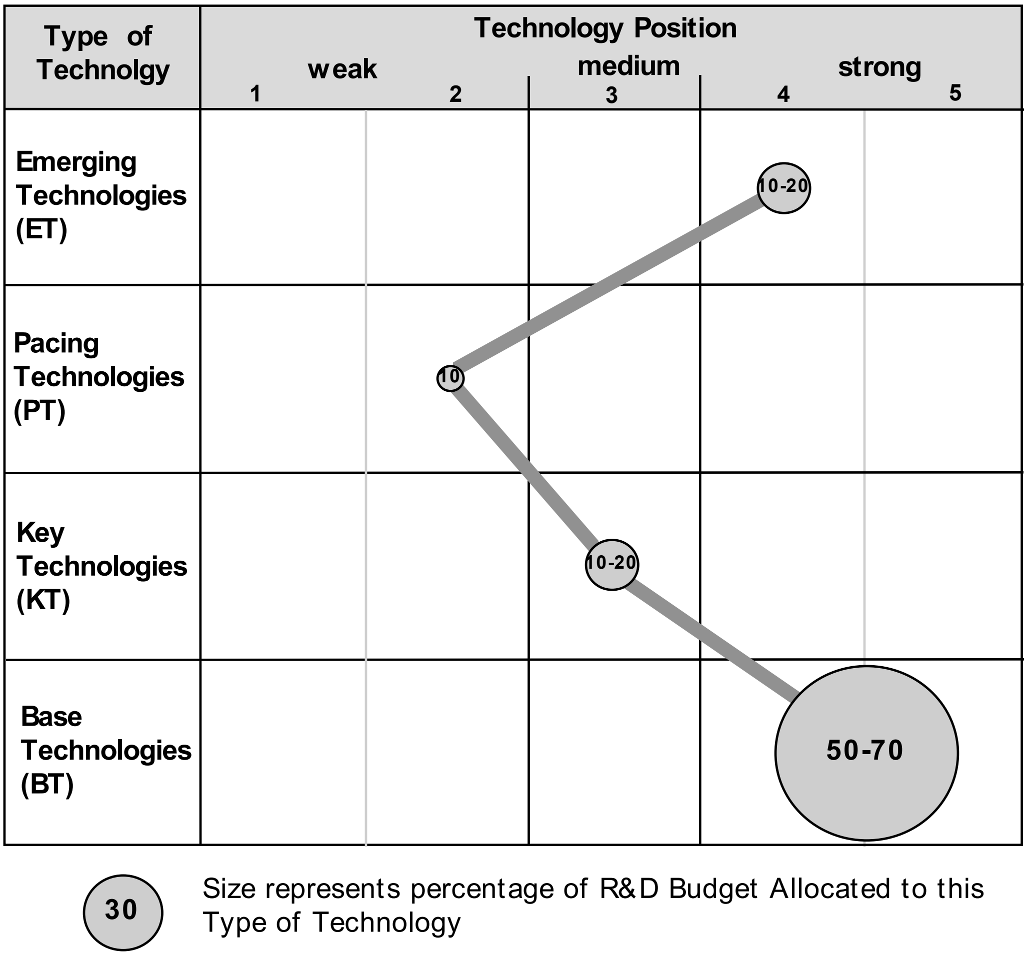
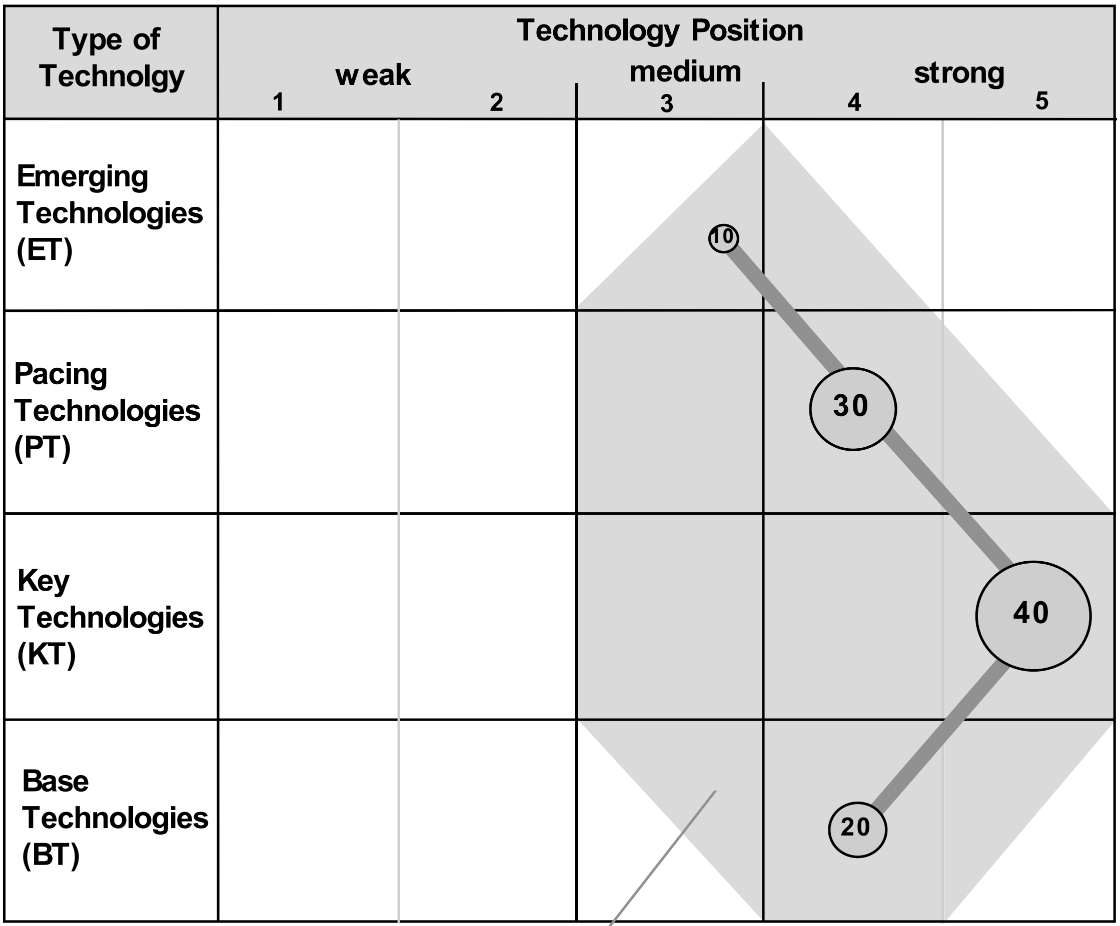
21 See Gerybadze (1998, Chapter 6) for a detailed description of budget allocation and R&D resource allocation practices within large, European-based firms.

Figure 11: Unbalanced Competence Profile and R&D Budget Allocation



A more balanced technological competence profile would certainly be more in line with a firm's strategy. The distribution of the R&D budget should follow suit. What is „balanced" and „appropriate" will depend on the underlying technology strategy. A firm pursuing a *technology leadership strategy* must be strong for the full range of key, pacing and base technologies. Prime attention should be given to key technologies, for which a very strong position leads to high comparative advantages and above-average rents; these can be channeled into competence building for pacing technologies and into competence leveraging for base technologies. A suitable R&D budget breakdown would follow the distribution indicated in Figure 11, with approximately 40% allocated to key technologies, 30% to pacing technologies, 20% to base technologies and 10% to emerging technologies.

Figure 12: **Balanced Competence Profile and R&D Budget Allocation for Firms with a Technology Leadership Strategy**

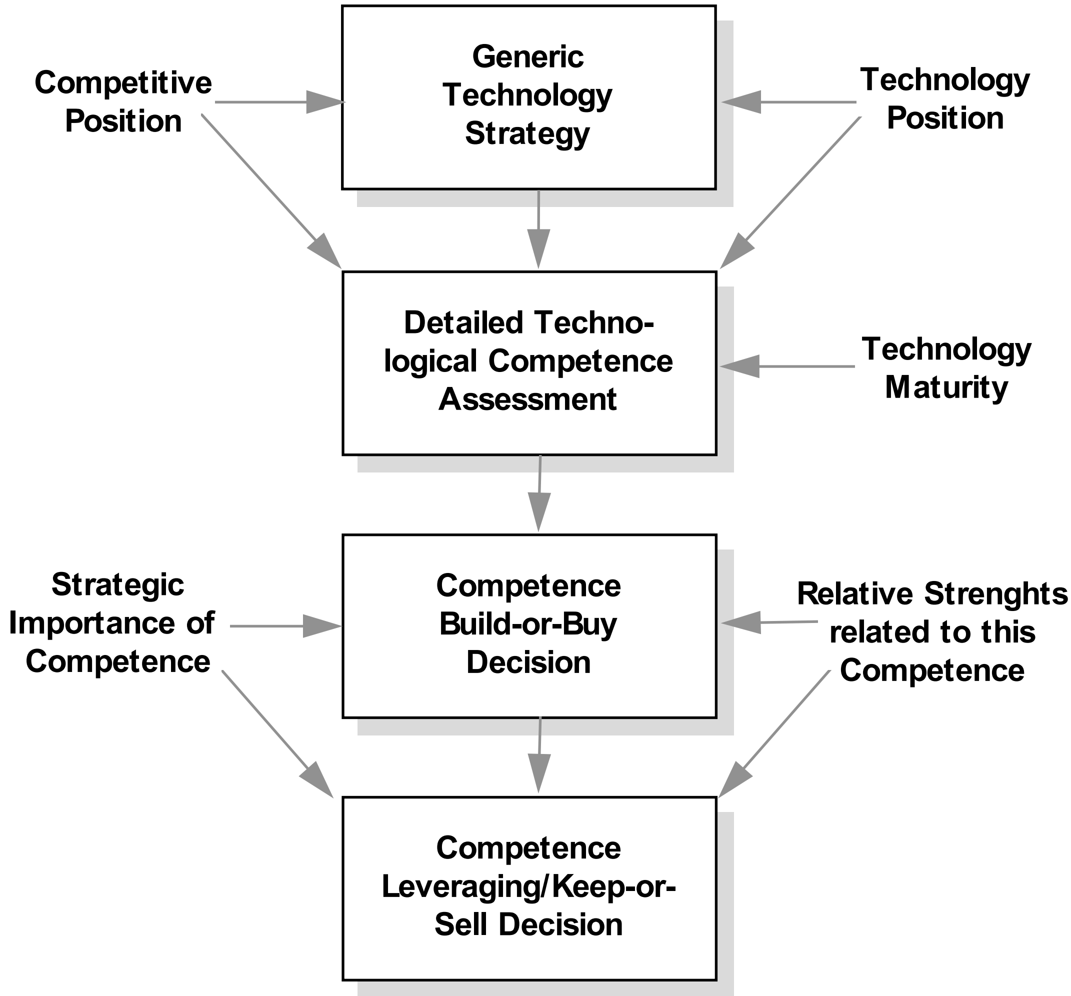


Shaded area represents ideal type of competence distribution. Weaknesses (left of shaded zone) and Overshooting/"Gold-plating" (right of shaded zone should be overcome

Based on the analysis of both its technology position as well as its competitive position, a firm will formulate generic technology strategies. These define the scope and opportunity set for ongoing competence building and leveraging activities. Should technological competences be actively build and „pushed into" new product designs, and should these new products be commercialized in an aggressive way?; or should the firm be more defensive, and respond to actions set by others? How many different fields of technological competence can be covered simultaneously (*breadth* of competence)? What is the expected competence level to be attained in each field (*depth* of competence)?

In addition to these more generic strategic objectives related to a firm, a business unit, or a comprehensive area of technological expertise (e.g. technologies related to automotive drivetrains or mobile phone technology), clear statements must be formulated for particular fields of expertise, as well as for the composition of the competence portfolio. Should the firm be involved at all in very risky emerging and pacing technologies, or should its competences be constrained to key and base technologies? Which strengths and competence levels are attainable and desired for different maturity classes, and for particular types of technological expertise? What are the characteristics of the appropriate R&D budget allocation?

Figure 13: Formulation of Competence Build-or-Buy and Competence Leveraging Strategies (Strategy-to-Competence-Cycle)



5.3 Defining Competence Boundaries of the Firm

Strategic choices on competence levels and preferred areas of technological expertise have a strong influence on the boundaries of the firm. How deep will an automotive systems manufacturer have to be involved in competence building, in-house R&D and manufacturing for drivetrain or electronic subsystems. How far will a subsystem integrator for automotive electronics have to enter into the most sensitive domains of the automotive systems firm?[22] Is the distribution of competences between different firms along the value-chain clearly defined? Is there a strong competence overlap, and how do firms define and negotiate their „competence territory"?

Our methods that were originally developed for technological competence assessments *within* firms, have been extended to negotiate differentiated competence arrangements between partnering firms. Each firm will formulate its competence build-or-buy strategy (step 3 in figure 13) on the basis of its generic technology strategy (step 1), and on a detailed technological competence assessment (step 2). In a fourth step, firms will formulate their competence leveraging strategies, and more or less explicit competence keep-or-sell strategies. In many cases there is ample opportunity for competence-sharing and negotiating arrangements between two firms. Each potential partner will evaluate his competence portfolio based on the following criteria:

- What is the strategic importance of a particular technological competence for us?
- How strong is our firm with respect to this particular competence?

[22] More recent developments of integrated automotive computer and passenger information systems, which are developed by IBM or Siemens, may to a certain extent endanger the systems integrator capability of automotive firms.

Figure 14: Criteria for the Formulation of Generic Build-or-Buy and Keep-or-Sell Strategies

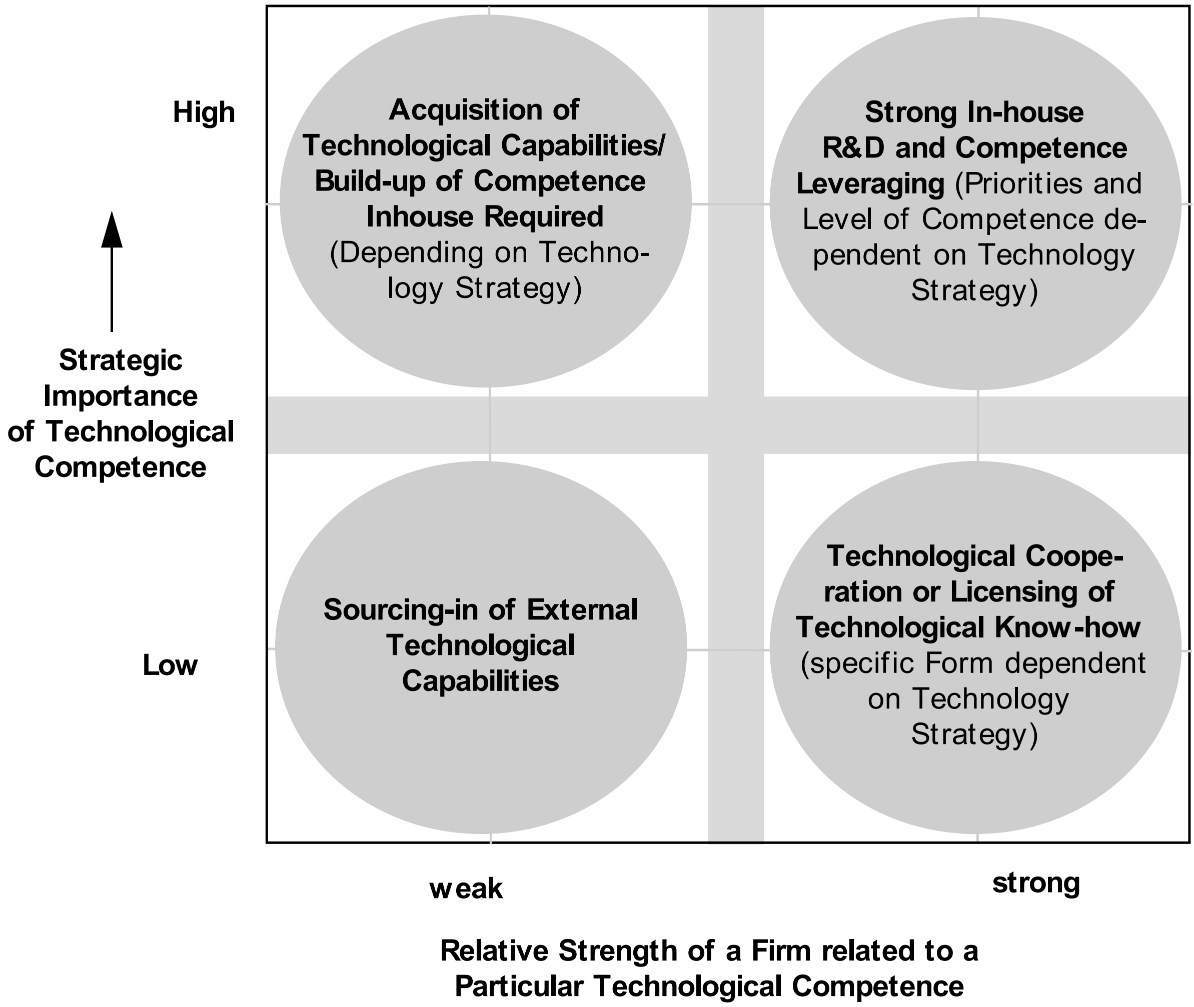


Figure 14 provides some decision criteria for formulating generic build-or-buy resp. keep-or-sell strategies for technological competences. A firm which is strong for a strategically important technological competence (upper right zone) will strongly invest in in-house R&D to maintain its leadership position. This firm will attempt to exploit its capabilities as much as possible through competence leveraging, typically by selling a superior product or service at a high margin. If a competence, for which the firm is very strong, turns out to be strategically less important in its product market, the appropriate form of competence leveraging may be more in the form of technological cooperation or licensing of technological know-how (lower right zone in Fig. 14).

Firm A in the lower right zone is, under certain conditions, a potential cooperation partner for firm B, which has limited strengths for a strategically important technological competence x.

If firms A and B do not compete in product markets, and if B can offer other competences to A in exchange for competence x, this may turn out to result in a „win-win situation“ for both firms.

Another symbiotic relationship involves exchange agreements between firm A in the upper right zone (strong for strategically important competences), and firm B positioned in the lower left zone (weak, strategically less important). A typical example is an automotive systems firm (B) which considers drivetrains and suspension systems capabilities as strategically less important, and which has thus developed only limited capabilities in this area. A specialized subsystem supplier, by contrast, is more dedicated to this area. This last firm has accumulated strong capabilities, and considers this area of expertise as strategically important. Both firms A and B may develop a powerful customer-supplier relationship, or even a long-term co-development strategy. Any relationship between two firms along the diagonal in Fig. 13 is more conducive for effective competence alliances. Other arrangements with greater overlap, i.e. if both firms are strong for a particular competence, or if both consider this competence to be strategically important in related markets, are less likely to result in a sustainable cooperation agreement.[23]

[23] For a more detailled discussion of competence-based technological cooperation arrangements see Gerybadze (1995, chapter 5), and Gerybadze (1998, chapter 8).

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