2 Measuring Technology Maturity: Theoretical Aspects

It is the goal of this book to propose an approach with which existing theoretical technology maturity models can be operationalized to allow for valid, reliable, objective and useful statements regarding the maturity of a technology. When it is part of a strategic technology management approach, such a model can be used to obtain strategic advice based on the values of certain indicators. There are plenty of different such approaches, but within the scope of this book only one will be operationalized as a proof of concept. Thus a suitable technology maturity model needs to be selected which ideally is part of a useful strategic technology management approach. There is no standard nomenclature for such models, so a working definition of key concepts needs to be established. And for the operationalization approach to be universal, a suitable operationalization mechanism is necessary.

One particularly integrative (semi-)theoretical technology maturity model by SOMMERLATTE & DESCHAMPS from the year 1986 (Sommerlatte & Deschamps 1986, pp.37–76) is described in detail in section 2.1. The model was chosen mainly for two reasons: for its relatively well-defined maturity states and for its popularity. The well-defined maturity states made it well-suited for operationalization in the first place. And the popularity of the model led to many subsequent approaches relying on it and providing relevant improvements until this day such as different approaches by ALBERT et al., GAO et al., HAUPT et al., HÖFT and ERICKSON et al. (Albert et al. 2015; Gao et al. 2013; Albert et al. 2011; Haupt et al. 2007; Haupt et al. 2004; Höft 1992; Erickson et al. 1990). This section also discusses recent developments which may aid in an improved use of the S&D approach but have not yet been integrated. Section 2.2 sets out to define working definitions for key concepts in technology maturity, create a technology maturity model typology, and compare the model from the previous section 2.1 to other models which address the same subject with different means. As a result, the strengths and weaknesses of each model can be identified much more easily. And finally, section 2.3 offers thoughts on how the weaknesses of the model described in section 2.1 can be tackled, and especially what a suitable operationalization approach could look like. It presents an operationalization mechanism which is designed in a way to make it compatible with most media types and thus can help operationalize model factors of other theoretical technology maturity models, too.

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2.1 Details of the Sommerlatte & Deschamps Strategic Technology Management Approach and Maturity Model

In the 1980s, two employees of the strategic consultancy Arthur D. Little published a widely noticed book on strategic technology management (Sommerlatte & Deschamps 1986, pp.37–76). The book contains a structured 8-step approach (henceforth "S&D approach") to determine firm-internal needs and resources and align them with external conditions, very much in line with the concept of dynamic capabilities. Strategic handling options are pointed out for a set of common scenarios to give managers an overview of opportune behavior. The S&D approach features a set of components widely received with great interest. Still today, as this book will show, a section describing a technology maturity model (henceforth "S&D model") is regularly referenced in the pertinent literature. However, some components of the approach, especially those connected to assessing technology maturity, require detailed analyses: for each relevant technology, field experts have to be schooled in a complex system outside of their original expertise. Large quantities of hard-to-access data from multiple sources need to be processed. This may effectively have rendered part of the approach for which these are required impossible to implement on a larger, firm-wide scale.

The S&D approach was put forward ahead of its time for several reasons. The information technology had not been developed to a level that permitted it to sufficiently assist management in several of the tasks deemed necessary. Much has changed since 1986. According to a conservative approximation with a carefully recalibrated Moore's law (Kurzweil 2005, p.65; Kanellos 2003; Moore 1965), between the years 1986 and 2015 computer processing speed and memory capacity has increased by a factor of

$$2^{\frac{(2015\,-\,1986)\cdot 12\ months}{20\ months}} \approx \mathbf{174{,}000}.$$

Moreover, computer literacy among managers has greatly increased and the necessary data is available digitally and at low cost. Furthermore, new discoveries in strategic intellectual property (IP) management such as the open paradigm or a modification of the project management office in the form of a technology management office can add to the approach.

The development of the past 30 years could not have been assumed at the time the S&D approach was put forward. Several functional and structural aspects of the approach have therefore been rendered obsolete today. At the same time it has not lost its conceptional ideas and may even be more relevant than ever before. Even though

relevant data sources have been identified, what is now missing is a way to integrate current computer capabilities into the approach.

The following sections will therefore respond to the question, what parts of the S&D approach need reconsideration and how they can be transferred to the state of the art. The next section 2.1.1 presents the functional components of the original S&D approach, featuring useful realization techniques of more recent years in section 2.1.2, effectively disclosing and grouping improvement potential of the year 1986 S&D approach to identify the main drawbacks of the model and make it fit for the current management world. Later on, it will focus on newly enabled capabilities to assess technology maturity automatically as a functional option in section 2.1.3 and focus on a technology management office as a structural option in section 2.1.4.

2.1.1 Benefits of a Firm-Wide Technology Strategy

The objective of the S&D approach is to create a technology strategy well appropriate for a firm. The technology strategy of a firm is its overall plan concerning the objectives, principles and tactics relating to use of technologies. It is defined with a persisting competitive advantage and the long-term success of the firm in mind (Floyd & Wolf 2010). The technology strategy provides general rules for managing technologies deemed relevant for the firm. The S&D approach is based on a strategic management framework made popular by PORTER in the 1980s called the market-based view (Porter 2004; Porter 1980). The goal of this view is to achieve a sustainable competitive advantage on top of the internal capabilities by incorporating forces of the market into a firm's business and competitive strategy. A technology strategy is a component of such a business and competitive strategy which is essentially built from parameters dictated by external environment and internal capabilities and skills with the competitive advantage in mind (See figure 2.1 for the position of the technology strategy in the strategic setup of a firm). Little has changed regarding the elements as displayed in figure 2.1.

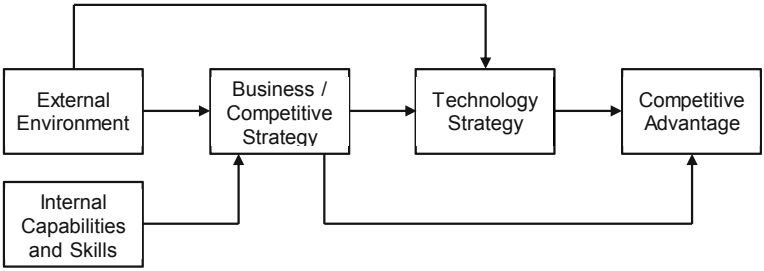

Fig. 2.1 Hierarchical view of the technology strategy according to ZAHRA et al. (1999). The arrows stand for factors of the former element directly influencing the latter

However, due to an increased pace at which new technologies and products are being developed, the original goal of the market-based view to achieve a sustainable competitive advantage has been rendered obsolete. Instead a sheer competitive survival must be aimed for, which can be achieved only through dynamically mixing and matching internally and externally sourced competences and resources (Shuen 2008, p.162). This new goal is approached by the dynamic capabilities view, which better reflects contemporary business realities and therefore replaces the market-based view of the original S&D approach in the sections, where applicable. "*Accordingly, companies and their executives should coordinate their technological and competitive choices in order to achieve superior performance. Companies need strategies that capitalize on the* synergy *between their technology and other resources"* (Zahra et al. 1999). An according integrated view on the competitive advantage of the firm would thus not be hierarchical. Instead it would focus on the available resources, as in figure 2.2.

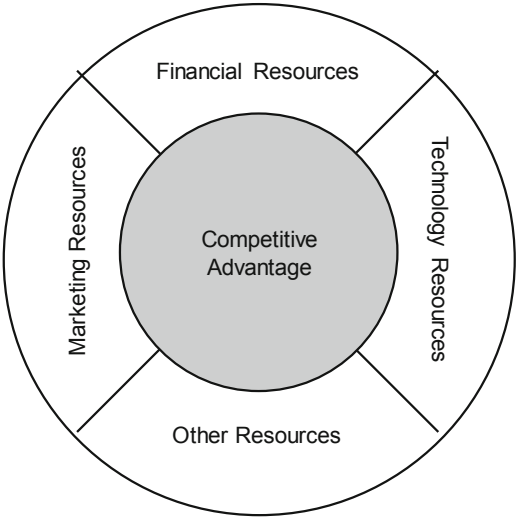

Fig. 2.2 Technology as a component of competitive strategy according to ZAHRA et al. (1999)

In either way, the technology has a direct impact on the competitive advantage of a firm. Since it is intended to remain unchanged over a long period of time, it should be built with care. The competitive advantage resulting from a good technology strategy influences a number of different business characteristics. The following advantages are the most obvious (Burgelman et al. 2009, pp.113–129; Zahra et al. 1999; Sommerlatte & Deschamps 1986):

- Cost decrease (economies of scale)
- No doubling of development
- Increased transparency (for all strategic business units and board)
    - Objectives and scope
    - Internal capabilities
    - External forces
    - Opportunities
    - Threats
- Precise instructions
- Reaction time improvement
- Increased dynamic capabilities

Since it has such a great impact on a firm's success, and since it requires a general overview of the firm and its competitive environment, it is the task of the executive board (and its staff) to draw up a technology strategy which serves the business units of the firm. In a large firm, the executive board is unable to implement and maintain this strategy on its own. For this reason, SOMMERLATTE & DESCHAMPS identify three layers at which the technology must be managed (Sommerlatte & Deschamps 1986, p.39): 1.) the executive board itself, 2.) its strategic business units, and 3.) the product-market-combinations (see figure 2.3). A successful technology management requires feedback from all these layers. This is represented by the "internal capabilities and skills" box in figure 2.1 and the arrows in figure 2.3.

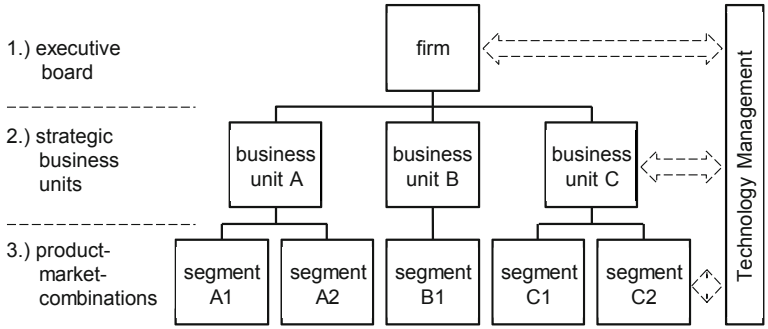

Fig. 2.3 Technology management on different management levels according to SOMMERLATTE & DESCHAMPS (1986)

Obviously, as can be seen in the "external environment" box in figure 2.1 above, the technology strategy is not limited to factors inside the firm. It is therefore essential to consider certain information from outside the firm as well. The following aspects need to be integrated into a viable technology strategy and will be described in greater detail in the subsequent sections (Sommerlatte & Deschamps 1986):

- The **maturity state of a technology** is an industry-independent judgment of the current and hypothetical performance of a technology. There are various interpretations what performance parameters are, as will be discussed in subsequent sections (Sommerlatte & Deschamps 1986, p.52).
- The **maturity state of an industry** reflects the degree of an industry's stability concerning factors such as growth rate, market saturation, intensity of product changes, competitor count, buying habits, and market share. A technology can be commercialized in different industries and an industry usually is based on

commercialization of different technologies (Sommerlatte & Deschamps 1986, pp.12–13).

- The **competitive position of a firm** is its business performance in comparison to other firms in the same industry. It depends on the market share of the firm, its relative cost structure, and internal factors which influence current strengths and weaknesses. (Sommerlatte & Deschamps 1986, p.15).
- The **technological position of a firm** depends on its capability of employing a technology to its advantage in comparison to other firms in the same industry. It thus depends on the firms know-how in key and pacing technologies as well as the availability of technological resources. This is an interpretation of the definition intended by SOMMERLATTE & DESCHAMPS, which unfortunately contains a self-reference (Sommerlatte & Deschamps 1986, p.57).
- The **strategic relevance of a technology for that industry** is the importance of that technology in comparison to other technologies for commercialization in that industry (Sommerlatte & Deschamps 1986, pp.50–52).

2.1.2 Reconstruction of the Sommerlatte and Deschamps Approach

The last section 2.1.1 presented the benefits of a firm-wide technology strategy, offered the market-based view and the more resource-focused dynamic capabilities view as theoretical foundation of technology strategy considerations, and collected competitive advantages which result from a well-defined technology strategy as well as important aspects from outside of a firm that should be integrated into a technology strategy.

The goal of this section is to reproduce the original 1986 S&D approach for strategic technology management, point out its weaknesses, and then successively "rejuvenate" it to incorporate relevant recent findings in each of the steps. The main point of action for rejuvenation lies in harnessing interim development of information technology into the process, facilitating implementation of the model's functional elements. The main effect can be expected for evaluation of independent external information as necessary for technology maturity.

The original S&D approach is described by SOMMERLATTE & DESCHAMPS (Sommerlatte & Deschamps 1986, p.76). It takes on all important interfaces mentioned in section 2.1.1 above and proposes an order for collecting and processing the relevant information and putting the outcomes to use. This section is built up according to the S&D approach for developing a technology strategy displayed in figure 2.4, each step representing a sub-section of this section:

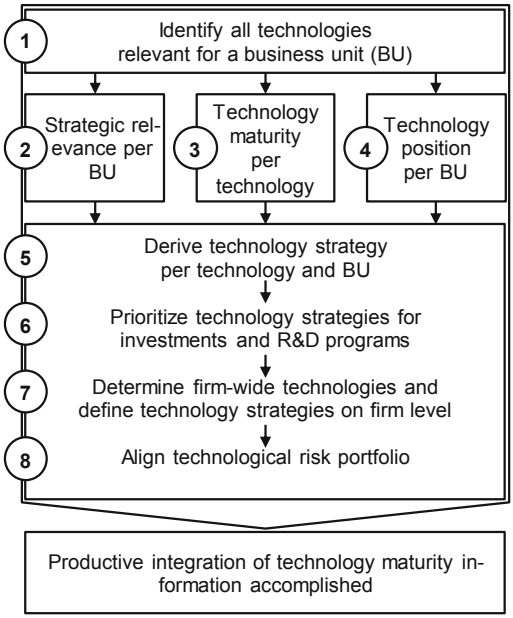

Fig. 2.4 A variation of the originally strictly sequential approach for strategic technology management by SOMMERLATTE & DESCHAMPS (1986)

Steps 1 and 2 were originally integrated and have been separated to display better the possible parallel evaluation of steps 2 through 4. Parallelization allows an increase in the speed of the approach, especially when it is automated such as described in section 2.1.3.

2.1.2.1 Identifying all Technologies per Business Unit

A business unit typically needs to employ multiple technologies to work. Therefore, a first step in the technology strategy building process comprises the identification of all relevant technologies. Not only are those technologies which are directly used within a business unit relevant, but also those which the competition develops and uses (Sommerlatte & Deschamps 1986, pp.48–49) and such which could potentially be used and thus are possibly relevant for future strategy development. The Open Paradigm (Chesbrough 2005) is worth mentioning in this context: in the traditional or *closed innovation process,* inputs come from internal and some external sources – customer inputs, marketing ideas, marketplace information or strategic planning inputs. Then,

the R&D organization proceeds with the task of inventing, evolving and perfecting technologies for further development, immediately or at a later date (Docherty 2006). By contrast, in open innovation, *firms look inside-out and outside-in, across all three aspects of the innovation process*, including ideation, development, and commercialization. In doing so, much more value is created and realized throughout the process (Cooper 2009). Thus, on top of an "inventory" collection of all technologies already present, as suggested in the S&D approach, a scanning which is meant to discover new subject areas, developments and potential surprises is a suitable tool for this purpose (Pillkahn 2008, p.95)

It is necessary to evaluate the interdependence of the relevant technologies (Burgelman et al. 2009, pp.690–705). Some technologies can be developed autonomously, some may depend on other technologies in the same product (Sommerlatte & Deschamps 1986, p.49). The S&D approach does not propose an exact method to survey this interdependence, but a basic system dynamics causal loop diagram (Palm 2014) is probably sufficient to understand, discuss, and communicate the technological environment. If a more thorough understanding of the interdependence becomes necessary, e.g. because there are many external influences to consider, technology roadmapping and related techniques may become a solution to establish the necessary overview (Moehrle et al. 2013; Lizaso & Reger 2004). It is possessing knowledge about this interdependence which helps the management to understand a technology's strategic relevance for each BU in the next step.

2.1.2.2 Determining Technology's Strategic Relevance per Business Unit

A technology's strategic relevance for a BU depends on two main factors:

- Impact on product and service performance parameters (market advantages)
- Impact on production and servicing process (cost advantages)

The strategic relevance must also be seen in relation to the capabilities of market competitors. SOMMERLATTE & DESCHAMPS therefore distinguish between the following strategic relevance categories (Sommerlatte & Deschamps 1986, pp.50–52):

Base Technologies

Base technologies are technologies a firm has to master in order to participate in the industry. They are the foundation of most all products and without them the industry would not exist. They are of elemental importance. However, there are limited opportunities to use them to gain a competitive advantage. Little effort should be put into

developing them further. Their strategic relevance is therefore low (Sommerlatte & Deschamps 1986, pp.50–52).

Key Technologies

Key technologies have a major impact on the competitiveness of a firm and thus are of high strategic value. Competitors do not yet master them, which is why they represent a great unique sales proposition (for a limited time). They directly influence critical performance parameters and cost structure of its products. Evaluating the impact of a technology on competitive dynamics can reveal key technologies (Sommerlatte & Deschamps 1986, pp.50–52).

Pacing Technologies

Pacing technologies are still being developed and typically are in an early maturity state. They have a good chance of becoming the key technologies of the future, giving them also a high strategic relevance. A close monitoring is advisable (Sommerlatte & Deschamps 1986, pp.50–52).

These strategic relevance categories of technologies change over time such that some pacing technologies become key technologies and some key technologies become base technologies. It is important to re-evaluate the strategic relevance of a BU's technologies at regular intervals to avoid developing those technologies further which have lost their strategic relevance (Sommerlatte & Deschamps 1986, pp.50–52).

What is considered the strategic relevance in the S&D approach is really an industry-specific technology maturity which can be evaluated with the S&D model: e.g. at a given point in time, the technology of highly integrated circuits gained and lost its strategic relevance for the computer industry much earlier than it did for the automotive industry or the consumer goods industry. The maturity it had for an industry at a given point in time directly influenced its strategic relevance for that industry. The reason for this is, that the industry-specific technology maturity advanced quicker for the computer industry than it did for the automotive industry. The strategic relevance can therefore be assessed exactly like the technology maturity, only that it needs to focus on a particular industry. An analyst who is not aware of an industry in which a technology is applied may therefore draw wrong conclusions about its strategic relevance. This is why determining a technology's strategic relevance should not be left to technology experts alone. According to the S&D approach, the management should be involved closely (Sommerlatte & Deschamps 1986, p.52).

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