FRAMEWORK FOR DEVELOPING A CONTEXT-BASED TECHNOLOGY PLANNING APPROACH FOR MANAGING DISCONTINUOUS TECHNOLOGICAL CHANGE

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ABSTRACT

Technologies, i.e. product, material and production technologies constitute a key success factor for technology oriented companies. Often the question arises how companies can plan their technologies according to their specific context in order to increase a company’s effectiveness as well as efficiency. In this paper a framework for designing a context-based technology planning approach for managing discontinuous technological change will be introduced.

In the recent decades many disruptive and radical technologies have displaced established technologies. Thus, imposing massive challenges on technology-oriented organizations how to manage these technologies. Discontinuous technological change describes the change from an established technology to a radical or disruptive technology. Technology planning constitutes an useful instrument for the management of technological questions and defines which technologies need to be provided for which period for the realization of which products. Technologies can be described via different characteristics such as technology life cycle, technology complexity etc. which influence a company’s technology planning. Other contextual factors are a company’s external environment as well as the company itself. In practice, however, many companies are struggling with the challenge of designing and conducting technology planning consistently and according to their dynamic and complex environment. Several studies and expert interviews have proven that many companies either fail to integrate technology planning at all or only integrate individual elements of technology planning (e.g. technology roadmap) according to single demands as a response to changes. Thus, the high potential of planning technologies systematically and context-based are lost. Therefore, an overall technology planning approach is required which describes the main settings of a company towards its technology planning. Based on this approach companies are able to conduct their technology planning more efficiently and systematically.

Scholarly contribution is required in terms of defining the possible design options of a technology planning approach as well as contextual factors which influence technology planning’s performance. Further, the relationship between contextual factors and design options needs to be analyzed. There is a great need for concrete recommendations of action for technology managers. Therefore, in this paper the current version of a framework for developing a context-based technology planning approach is being presented. In future design guidelines can be developed considering the interdependencies between different contextual factors and design options.

Key words: technology planning approach; context-based planning; typology
INTRODUCTION

For technology-oriented companies technologies are crucial for their competitiveness. A particularly high innovation rate, reduced product as well as technology life cycles, more intense competition and increasing derivateization are currently affecting various industries such as climate and energy, health and nutrition, mobility, safety and communication. Especially in the recent two decades many technological changes, i.e. disruptive and radical technologies have challenged companies cross-industry wide. These challenges are in the first place the identification of major technological changes at the right time, the dependable assessment of its anticipated impact on a company and the definition of the right measures which need to be taken in order to retain a company’s competitive advantage.

Technology planning constitutes an useful management instrument, specifically for technological questions and defines which technologies need to be provided for which period for the production of which products (Bullinger, 1994; Schuh, 2011; Gomeringer, 2007). A technology planning approach defines a company’s basic setting or understanding with respect to its technology planning system, its process, contents, organizational structure etc. Based on this approach, technology managers, notably the research and development managers are able to align their activities to these basic guidelines and are given a profound orientation for the conduct of the various technology planning process steps. For instance, managers are provided with information on whether they should proactively enhance the development of internal knowledge regarding a new technology or mainly observe and wait for competitors to make the first move. Further, managers will be provided with information on the style of planning, whether a synoptical or incremental approach is more suitable for their context. In the next section “Present approaches and gaps in literature” the synoptical and incremental approach will be shortly described. Also existing studies with regard to possible design dimensions and context factors of general planning will be illustrated. In a following section the gaps in literature will be highlighted in order to stress the lack of knowledge towards the relevant design dimensions and contextual factors of a technology planning approach.

Examples for discontinuous technological changes are the switch from analogue cameras to digital cameras, from wired phones to cellular phones, from light bulbs to LED or from ray tube television to plasma and LCD television. A common trait of those examples is the high potential of new technologies to change established market structures which may even result in the displacement of incumbent organizations. Christensen (2008) has stated that many of the established companies focus too much on their existing customers’ requirements and often underestimate the potential of new, i.e. disruptive and radical technologies. The initial stage of disruptive technologies is often characterized by low performance in comparison to established technologies. But disruptive technologies usually offer new, different features, which are being valued by niche segment customers. Though, they are not being appreciated by mainstream customers at first (Christensen, 1997). As the majority of incumbent companies focus on serving mainstream customers they often underestimate the power of technologies or products with “non-standard” features. Radical technologies involve methods, materials etc. that are novel to established companies and promise large price reductions and better performance even in their initial stage. Radical technologies have the potential to substitute established products (Benner, 2007). In contrast to disruptive technologies, radical technologies are characterized by standard features and focus on optimizing rather than the creation of new features.
This paper aims at introducing and explaining a framework for developing a technology planning approach which considers the influence of the characteristics of radical and disruptive technologies and as well as a company’s context (internal and external). Therefore, the relevant modules will be described.

This paper is structured as follows: in the section “present approaches and gaps in literature” existing work studying the terms disruptive and radical technologies are being described. Also the established and well-known synoptical versus incremental planning approach as well as the corresponding design dimensions and context factors will be presented. This section ends with depicting the research gap with respect to a technology planning approach. The next section “objectives and structure of the proposed approach” deals with the development of a technology planning approach and describes the different modules. Final comments will conclude the paper.

PRESENT APPROACHES AND GAPS IN LITERATURE

Definition of discontinuous technological changes

The question why incumbent organizations do or do not adapt to discontinuous technological changes has been intensively examined in organizational science and as well in technology management (Chesbrough, 2001; Christensen, 1997; Hill, Rothaermel, 2003). Still, there are little satisfactory answers to this question. A first challenge is a common understanding of discontinuous technological changes and its characteristics. Often discontinuous technologies are also called disruptive or radical technologies (Christensen, 1997; Benner, 2007; Hill, Rothaermel, 2003). On the contrary, continuous changes describe incremental technological improvements which often will not be noticed or appreciated by customers (Christensen, 1997). There is a multitude of terms or word combinations trying to describe discontinuous technologies. These are for instance “revolutionary innovation”, “technological shifts”, “technological breakthrough”, “identity-challenging technology” etc. (Abernathy, Clark, 1985; Anderson, Tushman, 1990; Tripsas, 2009). Bowman, Ambrosini (2000) point out that the difference between discontinuous technologies, i.e. innovations and established technologies is the perceived value of the product and how the value is being captured (Bowman, Ambrosini, 2000). Christensen & Bower (1996) and Hulin & Roznowski (1985) state that the aspect of the underlying processes for value creation is also different than that of established technologies (Christensen, Bower, 1996; Hulin, Roznowski, 1985). Disruptive technologies have the potential to change the existing market structure completely. In some cases incumbent companies fail to sustain their leading position and new market leaders dominate with their new technologies (Kammerlander, 2013). After examining the works by Abernathy & Clark (1985), Christensen (1997), Charitou & Markides (2003) as well as Gilbert (2003), 5 common characteristics of disruptive technologies can be summarized. First, disruptive technologies are initially inferior in their performances in comparison to established technologies. Second, the technologies’ new features are initially valued by niche customers and not by mainstream customers and third, the technology is usually less complex and cheaper than existing ones. Fourth, disruptive technologies first appeal to low-end, price-sensitive customers at the time of its introduction. And a last characteristic describes that after improving the technologies’ performance it is possible that mainstream customers also value these new features leading to a broader customer base (Abernathy, Clark, 1985, Christensen, 1997, Charitou, Markides, 2003, Gilbert, 2003). In this paper the above mentioned common definition of disruptive technology will be used.
Radical technologies have less potential to change existing market structures. But radical technologies have the potential to substitute established products. This is because radical technologies involve e.g. production, product or material technologies, which are novel to incumbent companies (Hill, Rothaermel, 2003; Benner, 2007).

Until today, there is little understanding of the clear distinction between radical and disruptive technologies. One possible differentiation will be described in the section “Module 2: Technology model”. The heterogeneous understanding of discontinuous technology change results in a gap in understanding the influence of these technologies´ characteristics on a company’s both internal and external environment. Without a profound understanding of these characteristics and their impact on companies, it is a big challenge for companies to design their technology planning in consideration of their context. The framework presented in this paper aims at introducing a solution for technology managers in order to design their technology planning approach corresponding to their context.

**Existing planning approaches**

A planning approach describes the overall basic setting, i.e. guidelines for conducting (technology) planning. The synoptical (Ansoff, 1990; Albach, 1969) and incremental general planning approach (Learned, 1965; Katz, 1970) is well-established both in practice and in science and is suitable for being transferred to the field of technology planning. In addition to these extreme approach types there are variants or hybrids such as the synoptical-analytical approach, incremental-entrepreneurial etc. (Paine, Anderson, 1977; Wohlgemut, Hess, 2000).

The synoptical planning is characterized by its holistic, comprehensive style of managing the complexity of a planning problem without dividing it into sub-problems. Further, the synoptical approach tries to capture and process as many relevant information as possible (Picot, Lange, 1979). Initially, one or more than one objectives are being defined. Later these objectives are being used for assessing different strategies and selecting strategies by the management (top-down). During this process the corporate strategy will be checked in certain intervals, revised and forwarded to a lower hierarchy level for realization (Wohlgemut, Hess, 2000).

In contrast to the synoptical approach the incremental planning approach divides a complex problem into one or more sub-problems and focuses on the most urgent or actual sub-problem. The solution and the corresponding objectives are being developed successively and not necessarily in a logical sequence. The author Lindblom notes, that process steps are possible and manageable without common goals and without the existence of a coordination mechanism (Lindblom, 1959).

The synoptical and incremental approach can differentiated based on the dimensions “goals” and “data” (cf. figure 2). These two dimensions define a planning problem´s scope of solution (Wheelwright, 1970). The synoptical approach´s objective is to find solutions in order to fulfil the more long-term target. The feasibility of the corresponding solutions is secondary. Whereas the incremental approach first aims at finding solutions which are feasible and against this background the actions are being concretized (Picot, Lange, 1979).
In the literature, more planning approaches are known which basically comprise of hybrid forms of the two previously mentioned main approaches. Other approaches are the incremental-entrepreneurial as well as synoptical-analytical approaches. The incremental-entrepreneurial approach’s process is less adaptive but more integrated than the incremental approach. The synoptical-analytical can be described as more flexible in its structure and process than the pure synoptical approach, but is still more limited in its flexibility than the incremental or logic-incremental approach (Paine, Anderson, 1977).

**Research studies on design dimensions and contextual factors for planning systems**

Many studies have been accomplished in the field of planning in order to define the relevant design dimensions, with which firms can design their planning approach. Design dimensions can be structured into functional, organizational and instrumental dimensions (Horvath, 1998). Figure 2 illustrates this classification and corresponding attributes such as philosophy, structure and planning input. It is being assumed that the philosophy aspect is of central relevance for planning systems since it describes a company’s attitude towards its planning system and affects other dimensions such as personnel, process etc. (Szymerski, Müller-Böling, 1980). Unfortunately, these authors never analysed the aspect of philosophy more in detail.

With respect to the synoptical and incremental planning approach Mintzberg has developed the relevant design dimensions (cf. figure 3). The synoptical planning approach can be described by a more anticipating and goal oriented decision-making and planning behavior, a more analytical, comprehensive evaluation process of many alternatives. Also, the synoptical planning has a long-term planning horizon, more formalized planning process in order to achieve concrete goals via integrated and continuous process steps.

The incremental approach can be characterized by a more reactively behaviour and primarily solves urgent, actual problems and does not plan in alternatives. The incremental planning approach tries to achieve more unspecified, short-term goals based on serial process steps and adapts its planning according to the actual situation.
Legend: 0 = not processed, 1 = partly processed, 2 = processed

### Figure 2: Overview of the scholarly contribution to the discipline of planning (extract)

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Figure 3: Characterization of the synoptical and incremental approach (Mintzberg, 1995)

These planning approach design dimensions depict an excerpt of possible parameters. It is to be analyzed which dimensions are relevant for the technology planning approach and which additional dimensions need to be identified in order to create a holistic view of the technology planning approach.
Influencing or contextual factors describe a company’s internal and external situation, which can hardly be changed. These factors affect a company’s planning system. It is being assumed that different contexts induce different solutions for the design problem (Buchner, 2002). Figure 4 illustrates the relationships between a firm’s environment, strategy and its organizational structure. Here, the organizational structure contains the planning system. The environment strongly influences the organizational structure (arrow 1) (Lawrence, Lorsch, 1967; Burns, Stalker, 1961). Various characteristics of the organizational structure also affect the management’s perception of its environment’s development, so that both influencing factors are strongly interdependent (arrow 2) (Anderson, Paine, 1975; Downey, Hellriegel, Slocum, 1977). It is being assumed that a fit between environmental and organizational structure benefits the value creation (arrow 3). On the other side, a positive success affects structural changes via the management (arrow 4) (Child, 1972).

“Structure follows strategy” is a widespread quotation by Chandler (Chandler, 1962), which implies that strategy affects the organizational structure (arrow 5). Then again, Bower (Bower, 1970) points out that the organizational structure has influence on the strategy formulation in form of a information filter ("structure follows structure") (arrow 6). Rumelt has proven that a strategic and structural fit results in success (arrow 3). Since companies define their environmental domain via strategic decisions, it can be stated that strategy affects the environment (arrow 7). Technological, legal and competition-related environmental variables limit the strategic freedom of action (arrow 8) (Hofer, 1975). It is being assumed that a fit between the environment and strategy is a main success factor (arrow 9) (Porter, 1983). Some enhanced scientific works have demonstrated the success itself is a prerequisite for strategic changes (arrow 10) and that success changes the industry structure (arrow 11). It can be noted, that an organization’s planning system, which is embedded in the organizational structure is strongly related to other both internal and external factors, i.e. strategy, success and environment.

Figure 4: Interdependencies between environment, strategy and organizational structure in a Neo-Contingency-Modell (Bourgois, Astley, 1979)

In summary, there is a great amount of work available in the literature dealing with planning in general and its different approaches. Both design dimensions and contextual factors have been studied, which need to be considered when designing a planning system.
Technology planning can be understood as a sub-process of corporate planning. The difference between these planning systems is the different object of observation. Technology planning strongly focuses on technologies and how they shall be managed. But until now, there is little knowledge regarding the different design dimensions and contextual factors of a technology planning approach. Since, general planning and technology planning are similar to each other respective their functions and goals, the more studied and established general planning approach can be an adequate basis for developing a technology planning approach.

Gaps in literature

First, as described in the previous sections a common understanding must be created in terms of the characteristics of disruptive and radical technologies. The influence of these technologies on a company’s both internal and external system must be analyzed in order to generate concrete recommendations for actions for designing a context-based technology planning approach. Second, a technology planning approach needs to be defined in order to have a profound base for aligning a company’s technology planning to its environment which comprises of the characteristics of the technologies being considered, the (technology) strategy and external environment. In a next step, the influence of the different contextual factors on the technology planning’s design dimensions need to be studied. The results are different technology planning approaches which are suitable for specific contexts.

Until now, there are little scholarly works available which has elaborated various technology planning approaches and the factors influencing it such as technology, strategy, organizational structure etc. The aspect of technology influencing a company’s planning system has been neglected and more research is required in order to give practitioners more guidance regarding the design of their planning approach.

OBJECTIVES AND STRUCTURE OF THE PROPOSED APPROACH

Objectives and solution hypothesis

The general objective of this paper is to present a framework for developing technology planning approaches. These approaches shall support incumbent organizations to manage discontinuous technology changes more specifically considering influencing factors such as the corresponding technology strategy and the effect of the technologies on an organization’s system.

In an initial step a morphology of the technology planning approach needs to be developed in order to depict all relevant design dimensions, i.e. decision fields (see module 1). In another step a technology model needs to be developed for characterizing discontinuous technology change and the constituent characteristics of the sub-dimensions “disruptive technologies” and “radical technologies” (see module 2). More knowledge is required with respect to understanding the impact of the different characteristics on an organization’s internal and external system (see module 3). The internal context refers to aspects such as a company’s product portfolio, its production process, strategy etc. The external context describes the market structure, customer requirements etc. Therefore an environment model is to be developed. In order to find the most suitable combination of different elements of the morphology, these environmental aspects as well as technology strategy
aspects (see module 4) need to be considered. In module 5 different technology planning approach models will be defined.

**Module 1: Morphology of the technology planning approach**

The aim of module 1 is the systematic development of a morphology, i.e. morphological box of the technology planning approach. Morphologies allow the structuring and creative development of complex problems and depict an adequate tool for this research objective. The methods involved are central analytical research methods and can be differentiated between a descriptive (description objective), theoretical (explanation objective) and a practical (design target) knowledge objective (Zelewski, 1999, p. 27 ff.; Welter, 2006). Based on the identified solutions within the morphology interdependencies can be explained and design recommendations can be formulated. In contrast to a typology the overall goal of a morphology is not the development of results which are factually true. The main benefit of a morphology is the creation of a holistic overview including new, not yet identified solutions. The "design and evaluation of the morphological box" is one of the most important methods within the morphological research. Module 1 applies this method. Zwicky defines the basic procedure and stresses aspects which need to be considered within the development of a morphology (Zwicky, 1989, p. 114). These are as follows:

- The morphological research is an absolute research discipline and derives all dimensions of a solution without previous assessment.
- The methodology of the morphology development applies the morphological box as visualization tool.
- The application of the morphological research ensures the consideration of all relevant solutions.

For the development of a morphology both contentual and formal requirements need to be derived. These requirements result from the problem and the objectives of each topic. Contentual requirements relate to special conditions of e.g. technological change, practitioners of the technology planning approach etc. Formal requirements include the reliability, validity and utility of the research results (Sprung, 1984; Friedrichs, 1990; Nachreiner, 1997).

Within this paper, the focus of the morphology development is set on the formal design possibilities of a technology planning approach. Contentual design possibilities, e.g. the activities of technology planning such as the development of a technology strategy and technology roadmap are not within the scope of consideration. Based on a detailed analysis of available studies and literature the relevant characteristics of a technology planning approach can be identified (Mintzberg, 1995; Zahn, 1979; Szyperski, 1980; Ansoff, 1990; Wild, 1982; Gomeringer, 2007; Bullinger, 1994; Tschirky, 1998; Frauenfelder, 2000). In the following, the characteristics of the morphology are also referred to as a design dimensions. Their characteristics are called attributes.

There are many scholarly works within the field of technology planning. These works deal with technology planning’s process, its tasks, its organization etc. (Gomeringer, 2007; Schuh, 2011; Orlitski, 2013; Bullinger, 1994; Tschirky, 1989; Frauenfelder, 2000). So far, the existing studies mainly focus on specific elements of technology planning. There is little knowledge about an overall technology planning approach which includes the basic settings of a company regarding its technology planning. The content of technology planning can be aligned to the specific technology
planning approach. Thus, a systematic investigation of the relevant design elements of a technology planning approach must be conducted.

Module 2: Technology model

The aim of this model is to provide a possibility to describe discontinuous technological change, i.e. disruptive and radical technologies and to identify their constituent characteristics as well as the corresponding attributes. A common understanding needs to be created since scientific work has not found a common denominator. For this purpose, a collection, analysis and synthesis of existing work regarding technological leap, disruptive technologies etc. need to be conducted.

In the literature a great number of approaches exist in order to describe technological advances, disruptive technologies technologies, "breakthrough" technologies, "revolutionary innovation" etc. (Anderson, Tushman, 1990; Tushman, Anderson, 1986; Chesbrough, 2001; Brenner, 2007; Gilbert, 2005; Kaplan, Tripsas, 2008; Foster, 1985). Currently, these terms are often used synonymously without a clear differentiation from each other (Suarez, Rogelio, 2005). Often the terms technology and innovation are also being used synonymously (Christensen, 2003). In Christensen's work "The innovator's dilemma" the term "disruptive technology" is a central aspect. In his consecutively work "The innovator's solution" he has replaced it with "disruptive innovation". Christensen has explained this substitution as disruptive innovation does not only include technological aspects or products, but also services and business model innovations (Christensen, 2003). Figure 5 gives an overview of different definitions and shall stress the need for a systematic analysis and definition of especially the terms radical and disruptive technologies. These terms are mostly used both in science and in practice.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Foster</td>
<td>1980</td>
<td>Technological discontinuity</td>
<td>Technological opportunities with „superior performance improvement potential“, i.e. more remote „technical limits“, lying on a different „S-curve“ as compared to the old technology</td>
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<tr>
<td>Chesbrough</td>
<td>2001</td>
<td>Technological change</td>
<td>Technological change is characterized by 3 dimensions: technical complexity, external linkages, institutional environment</td>
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| Christensen| 1997 | Disruptive technology     | Disruptive technologies have „worse product performance, at least in the near-term“, offering „very different value proposition“, are often „cheaper, simpler, smaller […] more conveniently to use, thus being attractive for „few fringe (and generally new) customers."
| Hill and Rathaemel | 2003 | Radical technological innovation | „Involves methods and materials that are novel to incumbents [in order to achieve a commercial or industrial objective] and can be based either on an „entirely different knowledge base or [stem] from the recombination of parts of the incumbents established knowledge.“ |
| Benner     | 2007 | Radical technological change | A change that „shifts the underlying base of technological knowledge in an industry’s products and promises dramatic improvement in price and performance, possibly resulting in product substitution“ |

Figure 5: Overview of different definitions of discontinuous technological change
Figure 6 depicts possible constituent characteristics of radical and disruptive technologies which help to characterize and distinguish these terms from each other. The main difference between disruptive and radical technologies refers to their application. Disruptive technologies can be characterized by “non-standard” features, whereas radical technologies include standard, improved features. Niche customers who value disruptive technologies develop new or other evaluation criteria which convince them to buy or use these technologies. Radical technologies primarily address mainstream customers who use existing criteria for assessing the standard or improved technology features. These different constituent characteristics influence a company’s system differently, since disruptive technologies go together with a certain degree of uncertainty since the evaluation criteria are different from the mainstream technologies. A company’s planning behaviour needs to be much more adaptive than that of a company which is planning the introduction of a radical technology addressing mainstream customers with known assessment criteria.

<table>
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<tr>
<th>Characteristic</th>
<th>Radical</th>
<th>Disruptive</th>
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<tr>
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<td>New / improved technology / features</td>
<td>„Non-standard“ Features</td>
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<tr>
<td>Performance (initially)</td>
<td>Better</td>
<td>Worse</td>
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<tr>
<td>Time of impact</td>
<td>Mid-term</td>
<td>Long-term / unspecific</td>
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<tr>
<td>Price (initially)</td>
<td>More expensive</td>
<td>Cheaper</td>
</tr>
<tr>
<td>Target market (initially)</td>
<td>Established market</td>
<td>New market / niche</td>
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*Figure 6: Characterization of possibilities for radical and disruptive technologies (Christensen, 1997; Adner, 2002)*

**Module 3: Environment model**

The objective of this module is to identify the impact of disruptive and radical technologies on an organization’s internal and external environment. Additionally, the difference between the impact of the two technologies needs to be clarified. In this paper it is being assumed that 4 different impact types can be identified, thus providing a framework for the different planning approach models. The method of the “relative fixation” will be applied (Buchner, 2002), which includes the fixation of two types via defining two extreme forms of impact combinations (type 1: both high external and internal impact, type 2: both low external and internal impact). Then two hybrid forms will be developed using a mixture of the extreme forms (type 3: high external and low internal impact, type 4: low external and high internal impact). Figure 7 visualizes these impact types. Once companies have evaluated the impact and assigned to an impact type, the underlying technology strategy needs to be considered in order to define the right technology planning approach.

Different technological characteristics have a different impact on various system parameters. A worse performance of a disruptive technology in comparison to a radical technology may influence the customers’ perception in a negative way. But usually, its cheaper price has a positive effect on the addressed customers. So the different impact levels need to be analyzed by weighting them e.g. analogue to the Likert-scale concept (1-5 points).
Various studies have already examined the impact of introducing new technology into established organizations. Qian has conducted a survey involving the US and Chinese market and the results have shown that the introduction of new technologies mostly have a positive effect on an organization’s competitiveness, productivity, production flexibility and product quality. Other effect parameters are the product costs, customer benefits, economic efficiency, customer loyalty, and the introduction of new products (Qian, 2002). Woodward, Perrow, Thompson and Argyris investigate the active relationship between technology and organizational structure (Woodward, 1965; Perrow, 1971; Thompson, 1967; Argyris, 1972). Woodward and Perrow stated that technologies exert a direct influence on the design of an effective organizational structure. Argyris on the other side comes to the conclusion that technologies influence the organization structure only to a smaller extent. He further points out that companies will not change their organizational structure with any new technology (Argyris, 1972). In addition, there are numerous studies which deal with other effect parameters. Silverman and Donaldson examine for example the link between technology and the human factor (Silverman, 1970; Donaldson, 1996).

![Figure 7: Possible features and characteristic attributes for describing a system environment](image)

In this paper it is being assumed that disruptive technologies tend to have a stronger external impact than radical technologies. This hypothesis is based on disruptive technologies’ characteristic of having the potential to change existing market structures. Radical technologies on the other hand are characterized primarily by their “technological newness”. As mentioned before in section 2 radical technologies involve “methods and materials that are novel to incumbents” and can require an “entirely different knowledge base or [stem] from the recombination of parts of the incumbent’s established knowledge” (Hill, Rothaermel, 2003). Thus the new or different technologies have a massive impact on the internal system of an organization.
Module 4: Technology strategy model

The strategy model involves all relevant strategic characteristics, which need to be considered in a technology planning approach. A technology strategy is characterized by different decision fields such as technology-timing, technological performance, technology source, technology exploitation (Schuh, 2011; Schulte-Gehrmann, 2014). Figure 8 gives an overview of the relevant strategic decision fields. Based on the technology strategy model, practitioners shall be able to describe their strategic context.

Many authors have already studied the discipline of strategy (Bea, 2005; Ansoff, 1965; Chandler, 1962; Miles, Snow, 1978) and technology strategy intensively (Schuh, 2011; Gomeringer, 2007; Porter, 1985; Wolf, 1994). Strategies can be distinguished into such as corporate strategy, competitive strategy, sustainability strategy, geographical strategy, technology strategy etc. (Bea, 2005; David, 2011). Strategy is understood as a contextual factor which influences an organization’s operation. Many authors have investigated the impact of strategy on e.g. an organization’s structure, resource planning or overall success as well as the impact on an organization’s environment. Most studies on the topic of "strategy" stress that the "fit" between the strategy and the business-related context factors is crucial for a company’s success (Bain, 1956; Chandler, 1962; Gupta, 1982). The distinctive characteristic of a technology strategy is its focus on strategic decisions for technologies. Since technology chains become more complex and technology changes are being observed more frequently than decades ago, technology strategies is of central relevance for technology-oriented companies.

The technological performance level influences the technology planning approach. If a company aims at a high performance level for particular radical technologies, the company needs apply a high planning intensity and frequency, since radical technologies are characterized by low customer requirement uncertainty (Wolf, 1994). If a company plans to integrate a disruptive technology and aims at a high performance level, its planning intensity and frequency can be high too, but needs to be flexible for adaption. This is because radical technologies are characterized by a higher customer requirements uncertainty, which results in a demand for a more flexible technology planning approach.

The technology strategy model shall illustrate those strategic decision fields, which constitute a key input for the development of a technology planning approach.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological performance</td>
<td>Technological leader</td>
</tr>
<tr>
<td>Technology timing</td>
<td>Pioneer</td>
</tr>
<tr>
<td>Technology source</td>
<td>Internal development</td>
</tr>
<tr>
<td>Technology exploitation</td>
<td>Internal use</td>
</tr>
</tbody>
</table>

*Figure 8: Possible features and feature expressions to describe a strategy model (Schuh, 2011)*
Module 5: Reference planning approach model

In this module, the results of the modules 1 - 4 are being combined. The aim of this module is the identification of reference planning approaches for different impact types. These planning approaches shall offer companies concrete recommendations for how to manage discontinuous technological changes. Therefore, the interdependencies between the relevant contextual factors and design dimensions need to be studied in order to derive implications for the different technology planning approaches. Figure 9 depicts an excerpt of a planning approach morphology. In dependency with a company’s context different combinations of attributes are possible (cf. figure 9).

In order to investigate these complex interdependencies, approaches of network thinking and systems engineering are applied. This involves the study of the relationships between the various contextual factors to each other and the identification of active (strong influence on other variables, without itself being affected), critical (influence others and be influenced by other variables), reactive (be largely of other variables influenced) and languid (hardly be influenced by others and influence others only small) variables (Doerner, 1997; Gomez, 1991). Alternatively, an influence- and pareto- analysis will be carried out, which helps to highlight the strongest dependencies (Pfeifer, 1993). As an example, a desired quality leadership and pioneer in market entry (technology timing) affect the planning approach characteristic "speed of adaptation", because the technological knowledge and associated skills need to be built up quickly in order fulfil the goals of the technology strategy. The basic compatibility of the contextual factors and design dimensions can be mathematically modelled by using a bipartite graph (Nitzsche, 2009). This mathematical model can also be implemented in a tool which depicts the relationships and makes the model more applicable. Based on this tool more detailed planning approaches can be analyzed. The interdependencies can be weighted.

"Figure 9: Possible design dimensions and their attributes of a planning approach morphology"
CONCLUSION

This paper contains the current version of a framework which shall support companies with designing a technology planning approach for managing disruptive and radical technologies in accordance to their context. In this paper the word “context” describes the technological and strategic boundary conditions of a company as well as its external environment.

In a first step, the relevant design dimensions of a technology planning approach need to be identified and characterized. In a next step, a distinction must be developed regarding disruptive and radical technologies. In literature and in practice these terms are being widely used, but there is little systematic understanding of these terms ‘characteristics’ and their distinctive attributes. A technology model shall support companies with characterizing the kind of technology which shall be integrated into the organization. Thus, a good understanding is required regarding the impact of the technology on a company’s e.g. corresponding product, production process, customer base. Additionally, the underlying technology strategy also affects an organization’s way of planning these specific technologies. It is being assumed that a technology strategy reflects the corporate strategy of an organization. Based on the characteristics of the technology being transferred and a company’s context an adequate technology planning approach can be identified. By linking all these models or aspects the framework is being created.

More scientific work is required in order to enhance and concretize this framework with special emphasis on the development of the morphology for a technology planning approach and the planning approach model which includes causal relationships between the context factors and design dimensions. Also, in a further step the applicability of this framework needs to be validated based on case studies.

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