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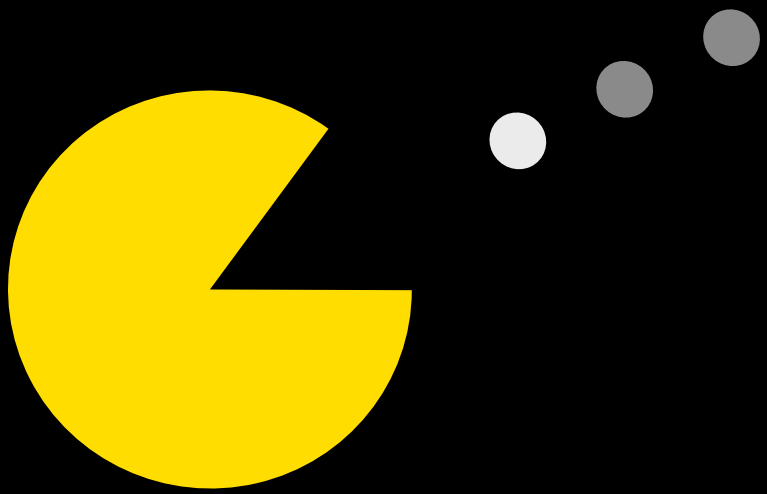
FRAUNHOFER GROUP FOR INNOVATION RESEARCH

SVEN SCHIMPF

DISRUPTION FIELD STUDY

How companies identify, evaluate, develop and implement potentially disruptive technologies



DISRUPTION YOUR COMPANY?

Imprint

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INHALT

1 THE MYTH OF DISRUPTIVE INNOVATION

How do companies identify potentially disruptive technologies?

How are they evaluated?

How are potentially disruptive technologies developed and implemented?

The disruption field study is dedicated to these questions with the aim of providing insights into the actual handling of potentially disruptive technologies by companies. The more attention a term receives, the broader and more extensive its semantic scope becomes. Time and again it can be observed that the inflationary use of terms in business, politics, society and science leads to a dilution in which, ultimately, no one knows exactly what the other is talking about. In a kind of Babylonian confusion of language, it is often no longer possible, in such cases, to tell whether the words are a conceptual air bubble or a well-founded description of real challenges or systems. The phenomenon of disruption seems like a myth that no one should ignore or leave uncommented.

Since attention to the notion of disruptive innovation has increased in recent years, the conceptual classification, and discussion of the understanding of the term, is the starting point of this study

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We would like to honor the excellent work of Clayton M. Christensen, who made a significant contribution to the field of technology and innovation management by shaping the theory of disruptive technology and innovation. Clayton M. Christensen died on January 27, 2020, at the age of 67.

2 THE DESTRUCTION OF INVESTMENTS MADE BY ESTABLISHED COMPANIES

2.1 CONCEPTUAL UNDERSTANDING

What is disruptive innovation?
Let's start with the legitimation of the broad use of a term: The term "disruption" has its origin in the Latin word "disruptio". According to popular encyclopedias, this is synonymous with the terms break, breakthrough, destruction, or interruption. Imagine the possibilities this definition opens up: The scope of potential disruptions seems limitless, even in view of media coverage today. Therefore, the focus of this study is not so much on the wide-ranging definition, as on an understanding of the concept of disruption in the discipline of innovation research.

Clayton M. Christensen's works, such as his doctoral thesis and subsequent publications The Innovator's Dilemma (Christensen 1997), The Innovator's Solution (Christensen and Raynor 2003), Seeing What's Next (Christensen et al. 2004), and The Innovator's DNA (Dyer et al. 2011), are key to the use of the concept of disruption in innovation research. Here the phenomenon of disruption, or more precisely disruptive technology, and later disruptive innovation, is presented and described in detail, with case studies and models. In order to understand a disruptive innovation, the following two central questions are considered:

At what level does a disruptive innovation take place?
To define an innovation, one question is essential: For whom is something new? Here we are talking about the subjective dimension (Hauschildt et al. 2016, pp. 17-19). Accordingly, the level at which disruptive innovation takes place is central to disruptive innovation. This study focuses on the implementation level both with regard to the definition of an innovation and with regard to the differentiation of disruptive innovation from other forms of innovation. The implementation level is the field where an innovation is implemented which is usually a market environment (see Fraunhofer Group for Innovation Research (ed.) 2018, p. 6).

Who is affected by the impacts of a disruptive innovation?
Besides clarifying the level of the system in which a disruption takes place, the second question to be asked is which object is centrally affected by a disruptive innovation. Within the framework of this study, the traditionally dominant organizations in the implementation field, also referred to as incumbents, are regarded as those that are centrally affected by the impacts of a disruptive innovation. In most cases, these are companies that have been able to dominate a market for long periods of time.

Within the framework of this study, a disruptive innovation is understood as an innovation that substitutes existing reference solutions in the field of implementation, hence making the investments of dominant market participants (incumbents) obsolete. A disruptive innovation is therefore associated with a change in the power balance in the market (see Danneels 2004, p. 248).

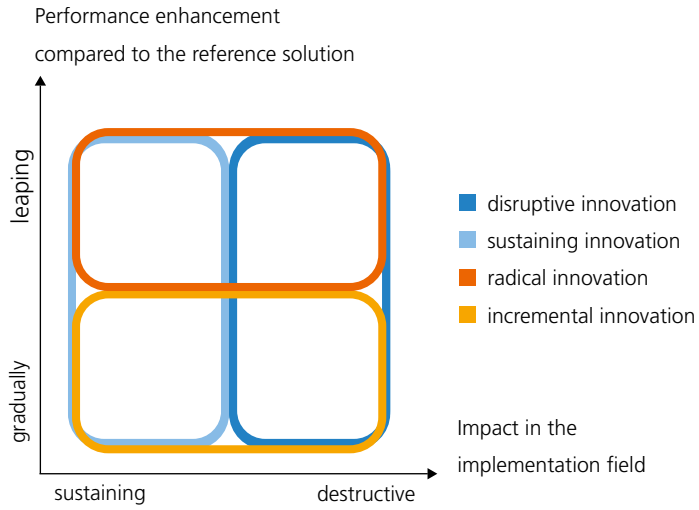
Definition of a disruptive innovation in a managerial context
Innovation that substitutes reference solutions in the market and makes investments of dominant market participants obsolete and, based on this, fundamentally changes the balance of power in the market.

The counterpart to a disruptive innovation is the sustaining innovation, which strengthens or preserves existing power relations in the field of implementation.

A pragmatic warning sign for disruptive innovations, as described by several company representatives in a workshop in January 2017, is "...when established market participants do not take a solution seriously or even make fun of its implementation plans".

A differentiation between low-end and new-market disruptions, as suggested by Clayton M. Christensen, building on the initial concept (Christensen and Raynor 2003, pp. 43-55), is not considered in the context of this study. This is because, in practice, new-market disruptions are often closely related to low-end disruptions. In this intersection, reduced performance is combined with lower costs, thus opening up a new customer group with lower disposable income or willingness to pay. According to the focus of this study, the common denominator of both dimensions is that they can lead to a fundamental change in the balance of power in the market. However, based on Clayton M. Christensen's differentiation, it must be added that low costs do not have to be a necessary prerequisite for this effect, and potentially disruptive innovations can also be introduced in higher price segments (Utterback and Acee 2005; Gans 2016). Thus, a disruptive innovation can be triggered both by the character of the innovation itself, and by special framework conditions in the market or in the dominant companies. The paradoxical character of a disruptive innovation is also fascinating: If a potentially disruptive innovation is recognised as such by the dominant market participants in time, the appropriate measures often lead to this innovation losing its disruptive character (see Gans 2016, Chapter 3).

Disruptive innovations are often mentioned in the same breath as radical innovations. In contrast to the definition of a disruptive innovation by the effect in the implementation field, radical innovations are commonly defined by their content dimension and thus by the significant increase in performance of the innovation compared to a reference solution. In this respect, for example, a completely new combination of services, a performance increase of at least five times or a cost reduction of more than 30 percent compared to the reference solution is proposed (Leifer et al. 2000, p. 5). It goes without saying that these assessment criteria must be adapted to the respective industry or field of implementation. The counterparts to radical innovation are step-by-step, sequential development, referred to as incremental innovation.



1 *Differentiation of the terms "sustaining" versus "disruptive" and "radical" versus "incremental" based on the performance and impact of an innovation.*

This intersection can be explained by placing the definitions of radical and disruptive innovation side by side. A disruptive innovation can be classified as radical or incremental in terms of performance improvement, just as a radical innovation can have a disruptive or sustaining character (see Fig. 1). In past examples, however, it can be observed that disruptive innovations, with a few exceptions, are often closely related to a radical increase in performance.

Technological developments are often essential drivers or enablers for disruptive innovations. This can affect new or further developed system architectures as well as new functions or the improved fulfillment of existing functions. Using the example of the replacement of analog photography by digital photography, the technological development of digital image processing was driven by further developments in process and storage technologies for home computers as well as new possibilities for data transfer. For companies such as Kodak, Agfa or Leica, the resulting success of digital photography made previous investments in analog photography obsolete. The role of these companies in the market, and their raison d'être, were also called into question. Similar patterns supported by technological change can be found in many of the disruptive innovations mentioned in literature (a list can be found under Christensen 2013, Chapter 17.7). This is also the case in current examples, which are discussed as potentially disruptive innovations, for example in the taxi market exemplified by the companies Uber or Lyft. Here, a substitution of conventional taxi services can be observed in many places. The new services were enabled by the technological development of the Internet, combined with mobile data services and positioning via mobile phones. These developments have led to many of the paradigms of the taxi industry being called into question and in some cases losing their validity. (Does a taxi have to be recognizable by a taxi sign? Does the driver have to know the streets of the city? Is a taximeter necessary in the vehicle? Must a taxi service own cars?).

The criteria that point to potentially disruptive innovations include (Schimpf 2016, pp. 3f; Vorbach et al. 2017, p. 383):

- **the fulfillment of the basic functions required by the user through a potentially disruptive innovation,**
- **the potential for further development of a potentially disruptive innovation,**
- **the cost advantages of a potentially disruptive innovation compared to the reference solution in the market, and**
- **the surpassing of user requirements by the reference solution in the market or a mismatch between both.**

The focus of the study is on technology planning, and thus on the planning of the future use of technologies. Technologies that could potentially lead to a disruptive innovation are considered in this context as potentially disruptive technologies.

2.2 MANAGEMENT OF DISRUPTIVE INNOVATIONS IN COMPANIES

A question that is often raised is whether disruptions in companies can be "managed" at all. Scientific studies also underline that luck or gut feeling, as well as clever timing, can play an important role in the management of disruptive innovations (see Barney 1997). In the concept of innovation roulette, luck is methodically integrated into innovation management, and referred to by the term serendipity (see Pillkahn 2013). It can hardly be denied that luck plays an inestimable role in innovation processes. However, a company that is informed about all relevant developments in the corporate environment can anticipate a potentially disruptive innovation at an early stage, and can actively shape it.

Since numerous starting points are given in the literature this study examines how companies approach the issue in practice.

Identification	Evaluation	Development and implementation
Who is responsible for the identification?	Who is responsible for the evaluation?	Who makes the decision?
How is the search field defined?	Do formalized evaluation processes exist?	Who is responsible for development and implementation?
Do formalized processes exist?	Which methods are used for the evaluation?	In what forms do development and implementation take place?
Which information sources are used?	Which criteria are used?	

2 *Questions concerning the handling of potentially disruptive technologies in the early phases of the innovation process from identification to implementation of potentially disruptive technologies in disruptive innovations.*

The focus of this study is on the early phases of the innovation process, from the identification of potentially disruptive technologies to the decisions about the forms of implementation in disruptive innovations. The questions assigned to each of these phases are shown in Fig. 2.

The trajectory mapping proposed by Clayton M. Christensen is probably the most common approach in literature for the management of disruptive technologies and innovations (Christensen 1997). Here we propose to continuously analyze the curve of performance improvement demanded by the market combined with the curve of performance improvement expected from technological developments or innovations. As a result, substitution of reference solutions can be predicted and planned at an early stage.

Provided that the underlying data is available or predictable, the method provides insight into what market participants are focusing on today and in the future. Regardless of the availability of complete information, which in practice is hardly imaginable in any area, trajectory mapping is a valid method to unite the technology perspective with the market perspective. In addition, functions that are not yet in the focus of user requirements can be taken into account at an early stage in the technology selection process.

In addition to trajectory mapping, various other methods of strategic planning and strategic foresight are suitable for the early identification, evaluation and implementation of potentially disruptive technologies. This includes, for example, the analysis of customer needs according to the principle of solution-independent customer benefit or the "job to be done principle" (Christensen and Raynor 2003, Chapter 3), the theory of the evolution of the value chain, the theory of emergent strategy, the motivation/ability frame work as well as checklists and evaluation models for identifying potentially disruptive innovations (Christensen et al. 2004, p. 281f.; Hüsig et al. 2005; Rafii and Kampas 2002; Goose 2016).

However, the question of whether the methods and procedures typically used in an industry are suitable for successfully dealing with potentially disruptive technologies must be raised in all phases.

3 DISRUPTION FIELD STUDY

3.1 CONTEXT AND METHODOLOGY

The disruption field study was conducted as an online survey from September 2016 to February 2017 and disseminated through various social media channels and corporate networks during this period. Due to survey completeness, 86 out of a total of 161 responses could be considered for the final evaluation. A special feature of the results is certainly the high participation of small and medium-sized enterprises with fewer than 250 employees, which make up almost 40 percent of the participating companies. Correspondingly, the evaluation of the results takes into account the special features of these companies.

The core questions of the study are how companies can identify potentially disruptive technologies, evaluate them in an entrepreneurial context, develop and implement them in products, processes, services, or solutions. Prior to this study, these questions had been exploratively investigated in a qualitative survey with five selected innovative companies in order to create the basis for a broader and empirical investigation (Schimpf 2015). In our preliminary study, we observed that there are relatively few activities in companies that are explicitly designed to deal with potentially disruptive technologies. On the basis of the findings from the preliminary study for this paper, combined with a broad literature analysis, eight hypotheses were derived enabling a comparison of the handling of potentially disruptive technologies with the handling of other technologies.

3.2 RESULTS OF THE DISRUPTION FIELD STUDY

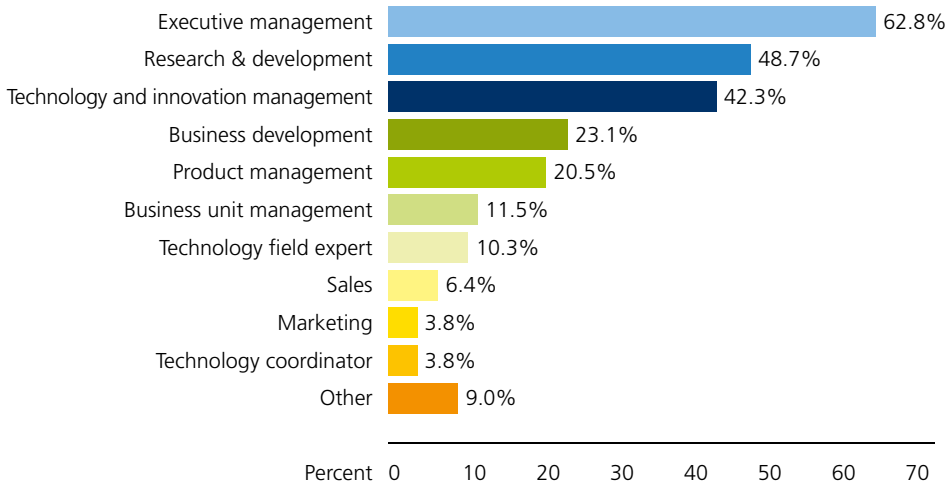
First and foremost, a big thank-you goes to the participants in the study who made this study possible by investing their time and providing information on how potentially distruptive technologies are dealt with in their companies. According to the phases shown in Fig. 2, the study is divided into the (1) identification, (2) evaluation and (3) development & implementation of technologies. Each phase investigated the handling of potentially disruptive technologies and other technologies. In addition to these phases, the communication of information on potentially disruptive technologies in companies, and their integration into internal company roadmaps, was examined. The findings are critically reflected in this study.

3.2.1 Results of the disruption field study

The first step of the process is the identification of potentially disruptive technologies. The study focuses on whether responsibilities and formalized processes exist in the participating companies and which sources of information are used for identification.

Responsibility for identification

As shown in Figure 3, in nearly two-thirds of participating companies, executive management is responsible for identifying potentially disruptive technologies (62.8 percent). This is followed by research and development (48.7 percent), and technology and innovation management (42.3 percent). It is important to bear in mind that distributed responsibilities within the company were also taken into account in the question due to the possibility of multiple responses.



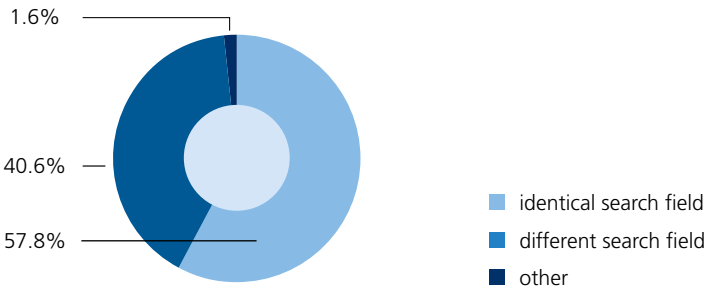
3 *Responsibility for the identification of potentially disruptive technologies (n=78, multiple responses)*

In addition to the proposed business areas, representatives in the field of information technologies or related services were also named. Executive management plays an important role in both large and small companies, which can be explained in particular by the potentially far-reaching effects of potentially disruptive innovations (see also Leifer et al. 2000, p. 41).

Prominent in the results is that market-oriented business areas such as sales and marketing, play a rather modest role in identifying potentially disruptive technologies. This runs counter to the theoretical approach that user value can, and should, play a decisive role as an a point of orientation for disruptive innovations and also for potentially disruptive technologies (Christensen et al. 2016; Christensen and Raynor 2003, Chapter 3).

Search fields for identification

In innovation research, it seems omnipresent that in contrast to sustaining innovations, the source of potentially disruptive innovations often originates from other industries or areas that are not directly related to the core business. In contrast, the search fields are identical in a majority of the companies surveyed (57.8 percent) for potentially disruptive technologies and for the other technologies (see Fig. 4).



4 *Differences in search fields between potentially disruptive technologies and other technologies (n=64)*

For those companies in which the search fields for potentially disruptive technologies differ from the search fields for other technologies, the criteria used are shown in Table 1.

	Potentially disruptive technologies	**Other technologies**
Technology field	Non-industry technology fields	Technology fields of technologies already in use
Market environment	Outside of current market environment	Inside of current market environment
Maturity	Low technological maturity (starting at TRL 0 or 1)	High technological maturity (starting at TRL 2 or 3)
Organizational responsibility	Central responsibility	Decentral responsibility of business units
Degree of connectivity	High degree of interconnected development	Decentral responsibility of business units
Utility gain	High utility gain	Incremental utility gain
Business model	New business models	Traditional business models

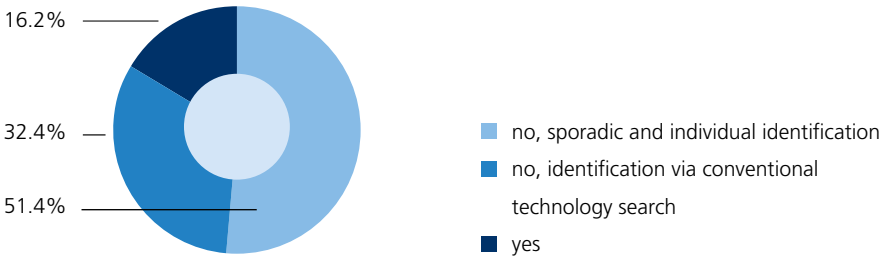
Tab. 1 *Differentiation criteria for search fields to identify potentially disruptive technologies compared to search fields used for other technologies.*

Possibilities for the identification of potentially disruptive technologies seem to lie in the selection of markets, which are susceptible to potentially disruptive innovations due to overfulfilment of current customer needs. It is alarming to note that the differentiation criteria for the identification of potential disruptions do not include reduced and focused performance features (compared to reference solutions) and the potential for further development (Schimpf 2016, p. 16).

Formalization of identification

As shown in Fig. 5, the identification of potentially disruptive technologies is rather sporadic and does not involve formalized processes (51.4 percent) in the majority of the companies surveyed. Among the group of companies in which formalized processes exist, a large part covers the identification of potentially disruptive technologies within the scope of conventional technology searches. Only a small proportion has formalized processes specifically for the identification of potentially disruptive technologies.

In this context, the question arises as to whether sporadic and individual identification, or the identification of potentially disruptive technologies via conventional technology search, is able to support the identification of technologies that can lead to major changes in an industry or a market.



5 *Existence of formalized processes for the identification of potentially disruptive technologies (n=74)*

Information sources for identification

Among the top 20 information sources used (see Table 2), start-ups (43.1 percent) followed by trade fairs and conferences (41.7 percent each) are the most frequently used sources of information for identifying potentially disruptive technologies. That 34.7 percent of participating companies refer to the term serendipity as an information source is both surprising and exciting. Serendipity can also be described as the accidental discovery of something not searched for or in a broader sense as coincidence, and has its origin in the saga of the Princes of Serendip[1].

Trade fairs (63.1 percent), conferences (46.2 percent) and market analyses (33.8 percent) are at the top of the list of information sources for the identification of other technologies. Trade fairs can be seen as a kind of superordinate source of information, which in turn unites the competition as well as suppliers and customers. Due to the great importance of trade fairs in the feedback of study participants, it would be interesting to find out to what extent they are also formally and explicitly used for the identification of technologies, and if they prove effective for the identification of potentially disruptive technologies.

1 Serendip: old Persian name for Sri Lanka.

Taking into account the current substitution of exhibitions by other communication channels and the decline in participation in trade fairs in different sectors, it would also be interesting to examine which communication and information channels could be their replacements in the future.

The Saga of the Princes of Serendip[1] :
Three royal children are sent on a journey by their father. On their journey they follow rather inconspicuous clues to a camel that has come before them. By combining these randomly observed clues, they gain various insights about the camel and its cargo. They conclude, for example, that the camel is lame, blind in one eye and missing a tooth.

When they meet the camel's trader, they tell him about their findings. The trader then accuses them of having stolen the camel. He demands a punishment from the emperor, because according to him only the thief of the camel can have the knowledge mentioned.

The royal children report to the emperor about the clues they observed which led them to their knowledge about the camel: The tracks showed that the camel was lame. The grass had been eaten from the side of the road where it is less green, so the princes had concluded that the camel must be blind on the other side. On the way, chewed grass was found, which allowed the princes to conclude that the camel had a gap in its teeth.

At the end of the story, the camel is found in the desert and the emperor appoints the king's children as his advisors because of their powers of observation.

According to the saga of the Princes of Serendip, the term "serendipity" stands for insights that arise from the seemingly random observation and combination of rather inconspicuous clues.

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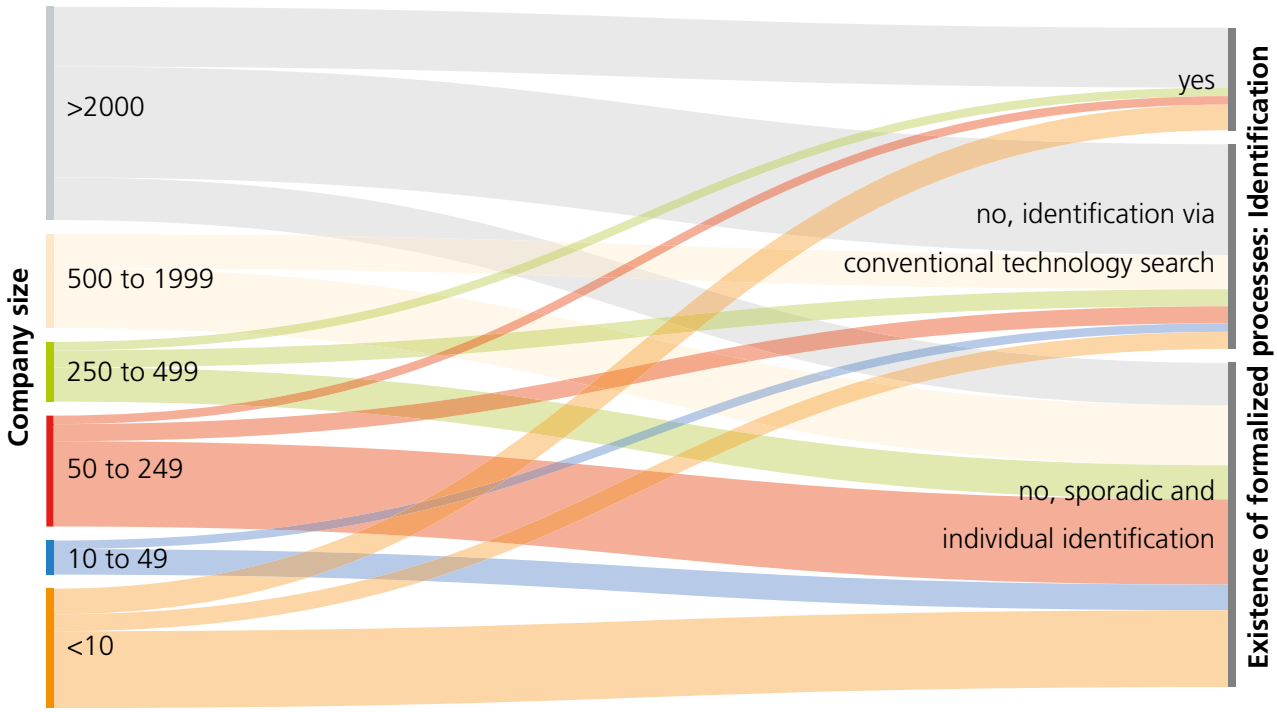
1 Jamison Hodges 1964, Colman 2006, summarized at https://en.wikipedia.org/wiki/The_Three_Princes_of_Serendip, accessed March 2019

Rank	The 20 most frequently cited sources of information for identifying potentially disruptive technologies		The 20 most frequently cited sources of information for identifying other technologies	
01	Start-ups	43.1%	Trade fairs	63.1%
02	Trade fairs	41.7%	Conferences	46.2%
03	Conferences	41.7%	Market analyses	33.8%
04	Market analyses	38.9%	Customer / user analysis	32.3%
05	Chance (serendipity)	34.7%	Competitors	32.3%
06	Technical research institutes	31.9%	Universities and colleges	30.8%
07	Studies	31.9%	Expert network	30.8%
08	Expert network	29.2%	Suppliers	30.8%
09	Universities and colleges	26.4%	Product research	29.2%
10	Product research	25.0%	Technical research institutes	29.2%
11	Journals	25.0%	Journals	26.2%
12	Customer / user analysis	22.2%	Patent analysis	20.0%
13	Competitors	22.2%	Seminars	18.5%
14	(New) employees	19.4%	Federations	18.5%
15	Market / technology scouts	18.1%	(New) employees	18.5%
16	Context analyses	16.7%	Chance (serendipity)	18.5%
17	Patent analysis	15.3%	Context analyses	16.9%
18	Companies from other sectors	15.3%	Studies	16.9%
19	Social media	13.9%	Market / technology scouts	16.9%
20	Inventors	13.9%	Start-ups	13.8%
	n=72, multiple responses		n=65, multiple responses	

Tab. 2 *Information sources prioritized according to citation frequency for the identification of potentially disruptive technologies and other technologies.*

As serendipity is mentioned as a source of information for potentially disruptive technologies as well as sustaining technologies by a not inconsiderable proportion of the companies involved, it would be interesting to see to what extent serendipity is actually promoted in companies, which field is covered by close monitoring, and how serendipity is anchored in the innovation culture (see, for example, Pillkahn 2013).

As shown in Fig. 6, formalized processes are used to identify potentially disruptive technologies, especially in large companies with more than 2000 employees. It is interesting to note that these are directly followed by micro-enterprises with less than 10 employees.



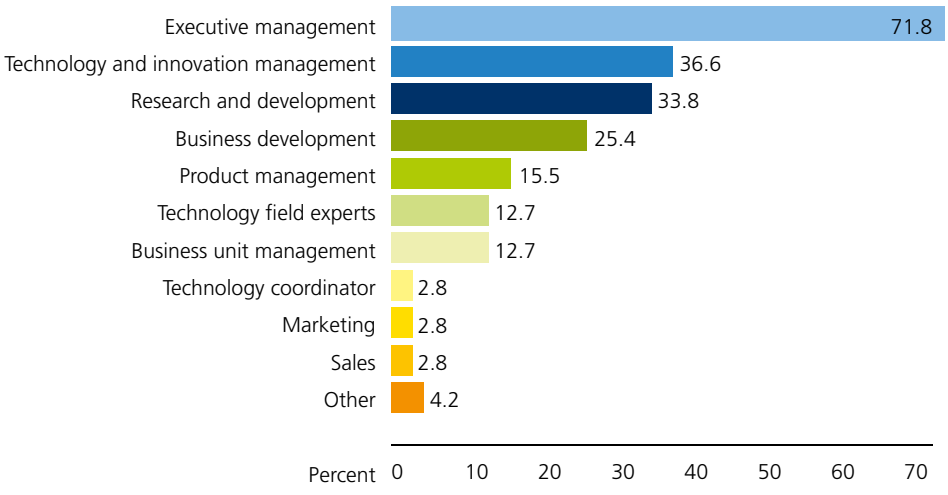
6 *Interrelation between company size by number of employees and the existence of formalized processes for the identification of potentially disruptive technologies (n=74)*

3.2.2 Evaluation of potentially disruptive technologies

When evaluating technologies, both the technologies themselves, and their effects, have to be evaluated in order to support decisions in technology planning. In the evaluation phase, our study focuses on the responsibility for the evaluation, the formalization of underlying processes as well as the methods, and evaluation criteria used for the evaluation.

Responsibility for the evaluation

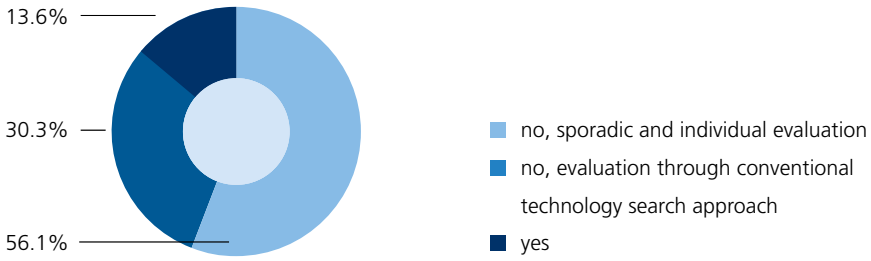
As shown in Fig. 7, the responsibility for evaluating potentially disruptive technologies lies with executive management (71.8 percent) in the majority of the companies participating in the study. This is followed by innovation and technology management (36.6 percent), with research and development in third place (33.8%). The important role of executive management can be explained by the fact that potentially disruptive technologies are often new fields for companies with a correspondingly high level of uncertainty. This also explains the examples in which management is regarded as a key success factor for managing disruptive and radical innovations (Leifer et al. 2000; Christensen 1997); O'Connor 2008).



7 *Responsibility for the evaluation of potentially disruptive technologies (n=71)*

Formalization of evaluation

More than half (56.1 percent) of the companies involved in the study are evaluate potentially disruptive technologies sporadically and individually without formalized processes, while one third (30.3 percent) use their conventional technology search approach (see Fig. 8). Only a small proportion of the companies participating in the study (13.6 percent) have established formalized processes for evaluating potentially disruptive technologies. It is noticeable that this question remained unanswered by a relatively high number of participating companies.



8 *Existence of formalized processes for the evaluation of potentially disruptive technologies (n=66)*

Evaluation methods applied

As shown in Tab. 3, intuition of employees or experts for the evaluation of both potentially disruptive and other technologies is the most frequently cited method, with 79.4 percent and 71.2 percent of the responses respectively. In addition, it can be observed that strategic instruments such as scenario analysis (35.3 percent) or SWOT analysis (29.4 percent) are the most frequently cited methods for evaluating potentially disruptive technologies, whereas classic techniques such as cost-benefit analysis (39.4 percent) or customer surveys (37.9 percent) are most frequently cited for other technologies. Technology maturity levels, which are cited as an indication of the special nature of potentially disruptive technologies, are only applied by one fifth (22.1 percent) of the participants.

Rank	The 10 most frequently cited methods for evaluating potentially disruptive technologies		The 10 most frequently cited methods for evaluating other technologies	
01	Intuition of employees / experts	79.4%	Intuition of employees / experts	71.2%
02	Scenario analysis	35.3%	Cost benefit analysis	39.4%
03	SWOT analysis	29.4%	Customer survey	37.9%
04	Risk analysis	27.9%	Profitability calculation	37.9%
05	Technology radar	26.5%	SWOT analysis	30.3%
06	Cost benefit analysis	26.5%	Technology lifecycle analysis	25.8%
07	Profitability calculation	25.0%	Technology maturity	25.8%
08	Customer survey	22.1%	Utility analysis	24.2%
09	Technology maturity	22.1%	Technology analysis	22.7%
10	Publication analysis	22.1%	Scenario analysis	22.7%
	n=68, multiple responses		n=66, multiple responses	

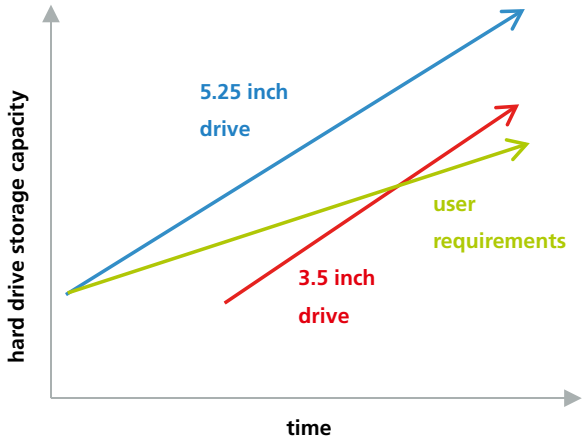
Tab. 3 *Methods prioritized according to frequency of citation, which are used to evaluate potentially disruptive technologies and other technologies.*

Use of trajectory mapping for evaluation

Trajectory mapping, which Clayton M. Christensen believes to be the most suitable method for evaluating potentially disruptive technologies and innovations, is only used by just under 5 percent (4.8 percent) and is not known as a method under this term in more than half of the participating companies (see Fig. 10).

The trajectory mapping method

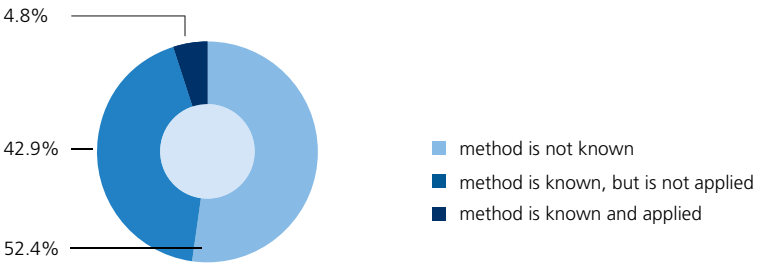
A trajectory map is a graphical representation of the development paths of technologies on the basis of critical performance characteristics along the time axis. This allows the development paths in an industry to be displayed and projected into the future in order to estimate possible future competitive dynamics.



9 *Trajectory map based on the hard drive capacity performance feature of different drive sizes and user requirements in the desktop PC market (Christensen 1997, Chapter 9)*

In the example of the development of hard drives, Clayton M. Christensen uses, for example, storage capacity in megabytes as a critical performance characteristic in order to compare the development paths of different hard drive sizes in the period between 1975 and 1990 with the respective performance characteristics required in the market (Christensen 1997, Chapter 1). This approach enables us to identify the point in time at which a currently less powerful technology becomes an established reference technology (see Fig. 9).

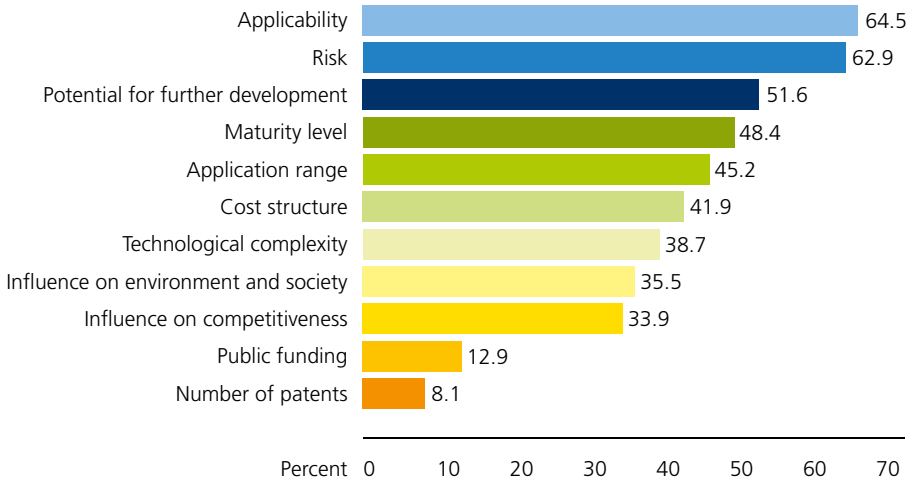
Since trajectory mapping allows an estimation of the point in time from which a technology on the development path fulfills the performance characteristics necessary for the application, we believe an important next research step will be to find out why this method is only used by such a small number of participating companies.



10 *Familiarity and use of the Trajectory Mapping method (n=63)*

Evaluation criteria

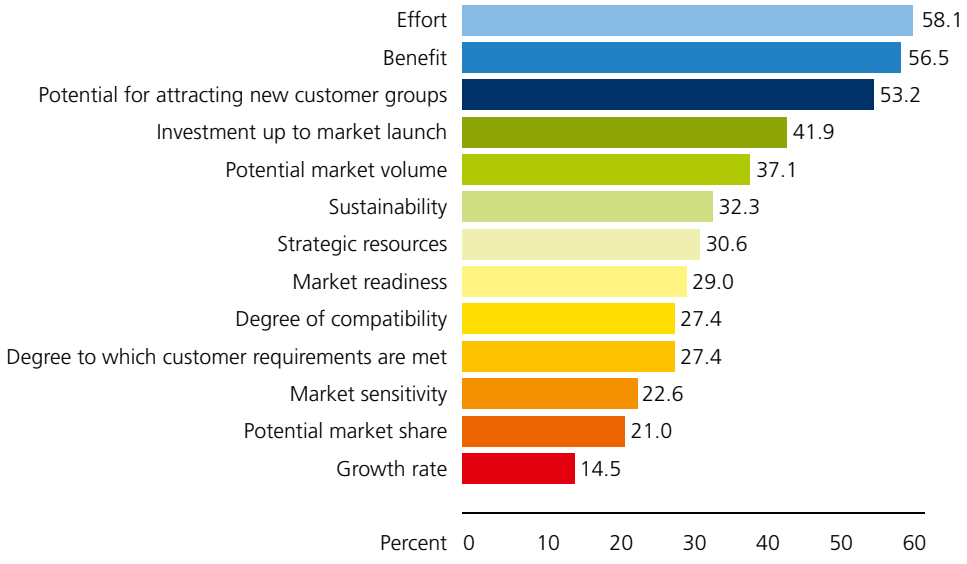
For the evaluation of potentially disruptive technologies, a distinction was made between the evaluation areas of the singular technology characteristics, the target markets, and the reference technology established in the market. These three assessment areas are based on the model that the success of a potentially disruptive technology lies both in the fulfilment of performance characteristics of the technology itself, and in characteristics of the target markets and the reference technologies established in the target markets.



11 *Criteria with focus on singular technology characteristics for evaluating potentially disruptive technologies (n=62, multiple responses)*

Looking at the singular technology characteristics of potentially disruptive technologies, a majority of participants use the applicability of a technology (64.5 percent) and the related risk (62.9 percent) as evaluation criteria. These are followed by the potential for further development (51.6 percent), the maturity level (48.4 percent), and the application range of a technology (45.2 percent). It should be noted here that potentially disruptive technologies differ from sustaining technologies in terms of their lower applicability, higher risk and often lower maturity level, and therefore have to be evaluated separately.

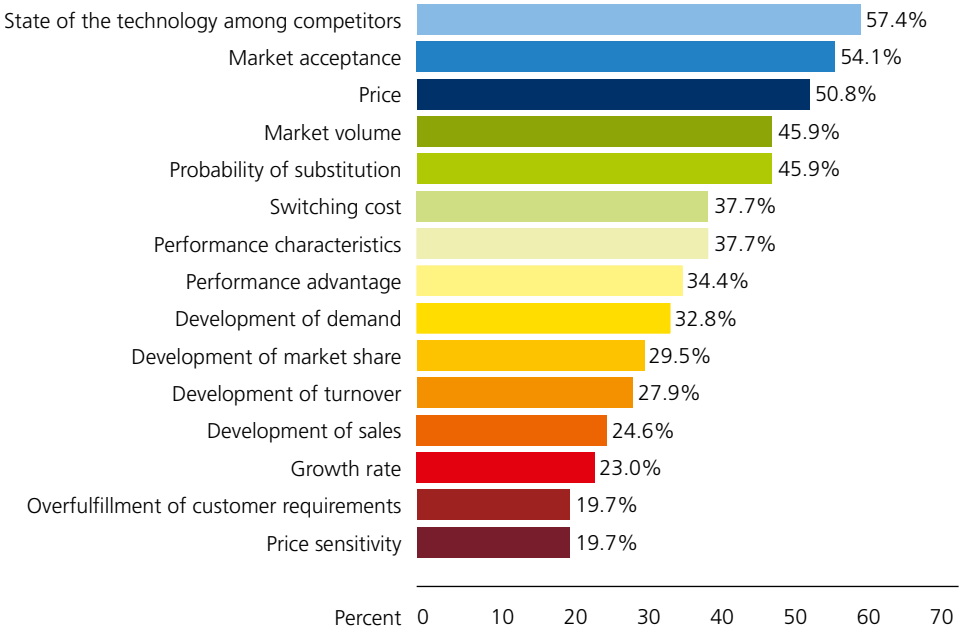
With regard to target markets, the most frequently cited criteria for evaluating potentially disruptive technologies include effort (58.1 percent), benefit (56.5 percent), and potential for attracting new customer groups (53.2 percent). The degree to which customer requirements are met, which is often a key feature of potentially disruptive technologies, is cited as a criterion by only slightly more than a quarter (27.4 percent) of the participating companies (see Fig. 12).



12 *Criteria with focus on target markets for the evaluation of potentially disruptive technologies (n=62, multiple responses)*

These criteria address the basic framework for the use of a technology in a defined target market regardless of the available competing technologies.

The focus on reference technologies is particularly relevant for the evaluation, as these can be substituted by potentially disruptive technologies if successfully implemented in products and solutions. However, as shown in Fig. 13, the main criteria in this assessment area are the state of the technology among competitors (57.4 percent), market acceptance (54.1 percent), and price (50.8 percent). One of the most important criteria, the overfulfilment of customer requirements by reference technologies, as a signal for market receptiveness to potentially disruptive technologies, was mentioned by barely 20 percent of the participating companies.



13 *Criteria with focus on reference technologies for the evaluation of potentially disruptive technologies (n=61, multiple responses)*

The feedback for a quite high number of criteria from all three focus areas should, however, be critically questioned and, if necessary, be assigned to the specification of the evaluation criteria for selection in the questionnaire. It would be interesting to know which of the given criteria have actually been formalized by companies in the evaluation of potentially disruptive technologies in the corresponding processes, and which of the criteria mentioned are only being used implicitly in the decision-making process.

Knowledge management

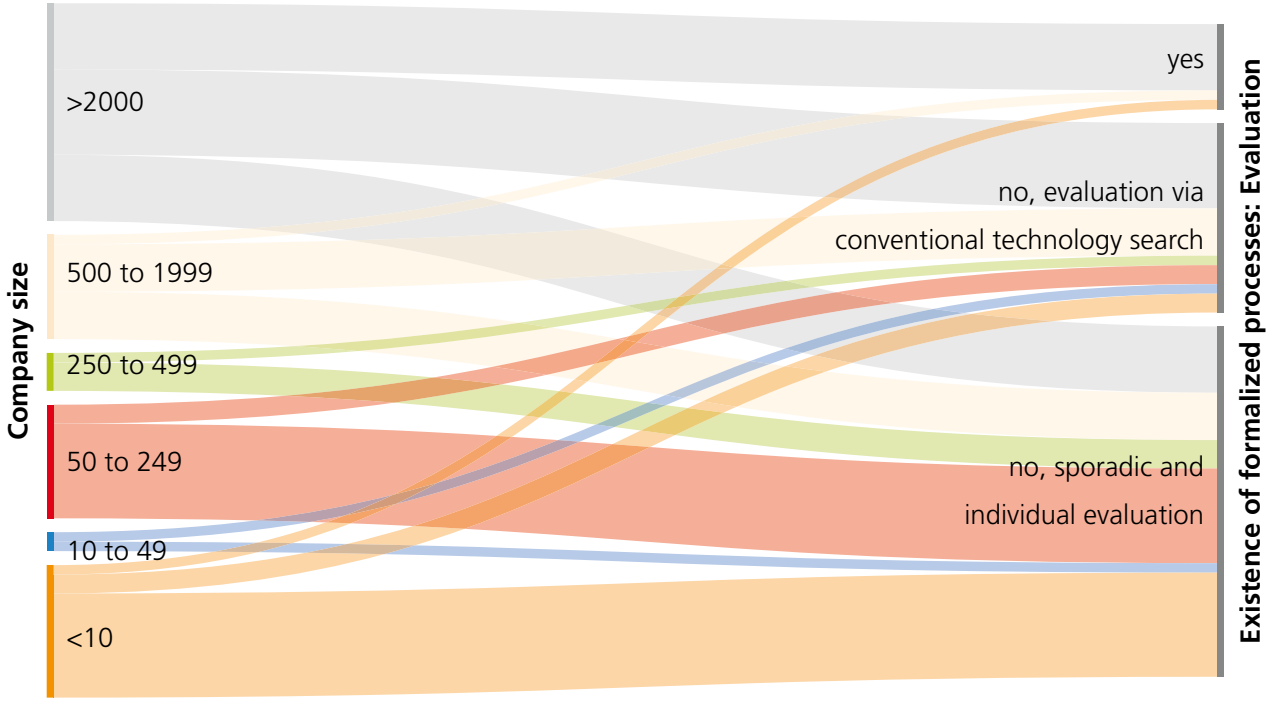
In the communication and storage of information, potentially disruptive technologies are treated equally by the vast majority of the companies involved (92.0 percent, n=29). According to the results presented in Tab. 4, technology data sheets (57.4 and 46.0 percent), technology roadmaps (34.0 and 32.0 percent), and product roadmaps (29.8 and 28.0 percent) are among the most common methods for the storage and communication of information about potentially disruptive technologies.

Rank	The 10 most frequently cited methods for storing information on potentially disruptive technologies		The 10 most frequently cited methods for storing information on other technologies	
01	Technology profiles / data sheets	57,4%	Technology profiles / data sheets	46,0%
02	Technology roadmap	34,0%	Technology roadmap	32,0%
03	Product roadmap	29,8%	Product roadmap	28,0%
04	Technology radar	25,5%	Innovation roadmap	28,0%
05	Innovation roadmap	25,5%	Technology radar	20,0%
06	Technology portfolio	21,3%	Process roadmap	18,0%
07	Process roadmap	19,1%	Technology portfolio	14,0%
08	Technology wiki	14,9%	Technology wiki	14,0%
09	Technology readiness level	10,6%	Technology trees	8,0%
10	Technology trees	8,5%	Technology readiness level	6,0%
	n=47, multiple responses		n=50, multiple responses	

Tab. 4 *Methods, prioritized according to citation frequency, used to store and communicate information about potentially disruptive technologies and other technologies*

Companies that responded have incorporated potentially distruptive technologies into their internal roadmaps, either after successful evaluation with respect to company relevance (56.0 percent) or after evaluation and concretization for implementation into an innovation (44.0 percent). However, we must note that this question was only answered by a very small proportion of the companies involved (n=25).

As shown in Fig. 14, formalized processes for evaluating potentially disruptive technologies are more likely to be used in large companies than in small ones. In companies with fewer than 500 employees, use of evaluation processes is mostly sporadic and individual.



14 *Relationship between company size by number of employees and the existence of formalized processes for evaluating potentially disruptive technologies (n=66)*

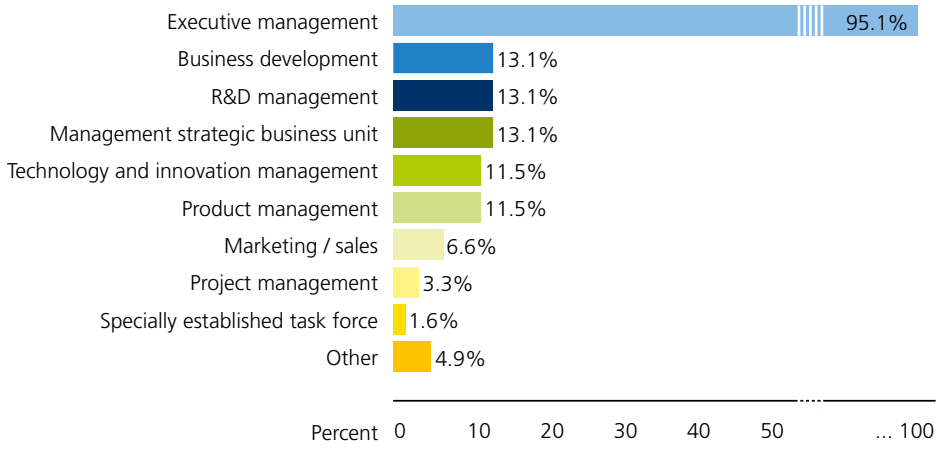
3.2.3 Development and implementation of potentially disruptive technologies

The third step in the process is the development and implementation of potentially disruptive technologies. In addition to the responsibility for decision-making and for the development and implementation itself, the organization within or outside the participating companies plays an important role in this phase.

Decision and responsibility for development and implementation

The decision to develop and implement potentially disruptive technologies is made by executive managers in almost all participating companies (95.1 percent). Only a few companies have responsibility for decisions in other areas of the company (see Fig. 15). The strong involvement of executive management can be observed throughout all company sizes.

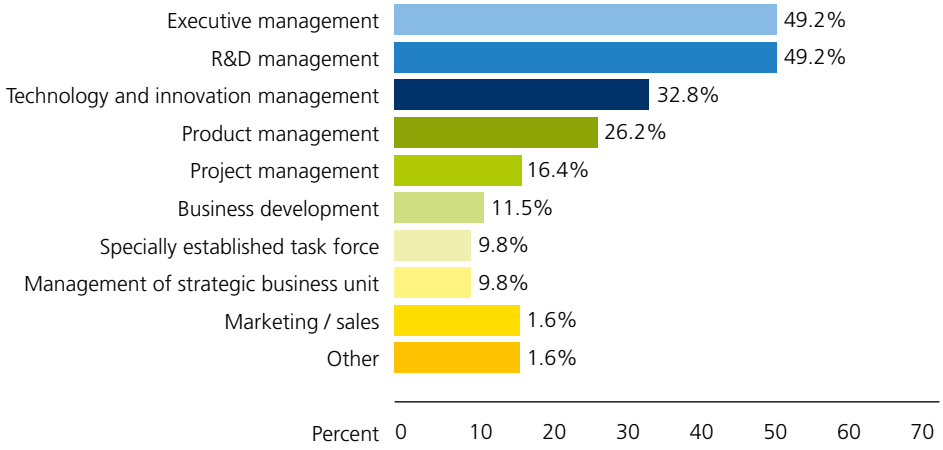
As a matter of principle, it can be assumed that the divisions involved in the valuation will be integrated into the decision-making process.



15 *Decision-makers on the development and implementation of potentially disruptive technologies (n=61, multiple responses)*

It is interesting to note that in terms of responsibility for development and implementation, almost half (49.2 percent) of the companies involved have cited executive management and at the same level R&D management (49.2 percent) (see Fig. 16). In approximately one tenth of the responses, the option to use a specially established task force (9.8 percent), or business development (11.5 percent), play a rather subordinate role.

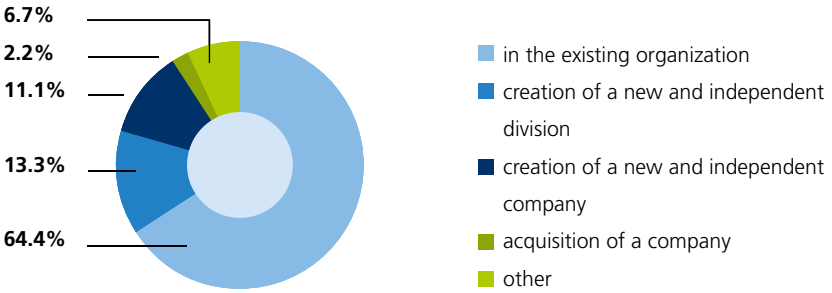
Especially in small companies, the responsibility for the development and implementation of potentially disruptive technologies lies with the executive management, whereas in larger companies the responsibility lies within the functional areas.



16 *Responsibility for the development and implementation of potentially disruptive technologies (n=61, multiple responses)*

Organization of development and implementation

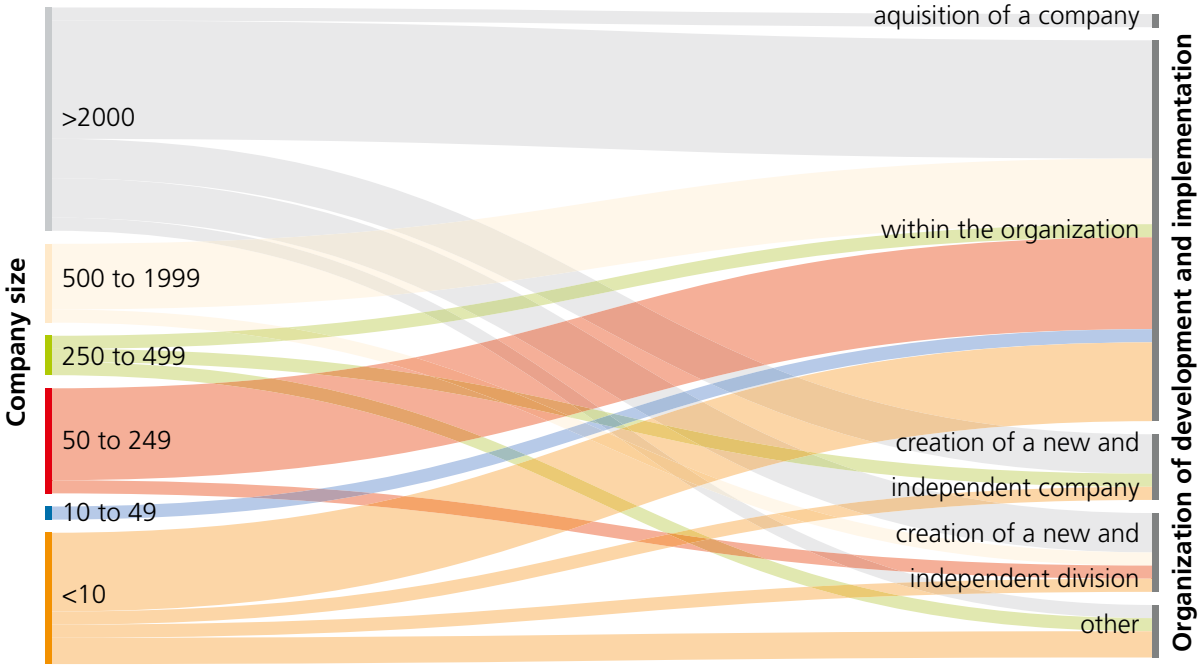
Among the participating companies working on the development and implementation of a potentially disruptive technology, a large proportion (64.4 percent) of the companies surveyed report operating within their established organizations. 13.3 percent of the reporting companies state that they have chosen to create new and independent departments for this purpose. Few choose the path outside their own company for the development and implementation of potentially disruptive technologies (see Fig. 17). This also includes the use of platforms or cooperation with other companies (mentioned under "other").



17 *Where does the development and implementation of a potentially disruptive technology take place? (n=45, after excluding companies that are not working on the development and implementation of a potentially disruptive technology)*

When considering the development and implementation of potentially disruptive technologies, the high proportion of companies in which the development and implementation takes place within the existing organization should be regarded as critical, as potentially disruptive technologies often require different development capabilities than sustaining technologies.

The character of potentially disruptive technologies as enablers for disruptive innovations, and thus as potentially destructive influencing factors for existing investments of established players, implies that existing organizations view this type of innovation more critically. In literature, the establishment of independent organizational structures or units is reported to be a common model for dealing with potentially disruptive technologies and innovations (see, for example, Anthony 2015; Assink 2006).



18 *Relationship between company size by number of employees and organization of development and implementation of potentially disruptive technologies (n=45, after excluding companies not working on the development and implementation of potentially disruptive technologies)*

As shown in Fig. 18, the size of companies by number of employees does not seem to have a significant impact on how companies develop and implement potentially disruptive technologies.

Challenges and success factors for managing potentially disruptive technologies

Knowledge of the scientific state of the art aside, explicit investigation of the challenges and success factors, from the business perspective, is one of the most important factors in ensuring successful transfer of methods and procedures. The feedback from the companies replying to our survey covers a wide range of different areas, with relatively few overlaps and identifiable priorities. The concepts of identification, cooperation, stakeholders, and market launch are mentioned remarkably frequently in the responses (see Fig. 19).

19 *Word cloud generated from challenges and success factors mentioned by participants (adjusted, size based on frequency of citation, n=21)*

The challenges and success factors mentioned were clustered in order to present the more-prominent topics from the replies of the participating companies.

The most important challenges

Strategic orientation and initiation of development activities

Search spaces beyond the established business areas in technology search and foresight are necessary for the identification of potentially disruptive technologies. Findings from these search areas must be continuously synchronized with strategic orientation. A further challenge, in this context, is the timely initiation of development projects on potentially disruptive technologies.

Resources for the development of potentially disruptive technologies

The provision of sufficient resources was identified as a major challenge. In this context, the financing of start-ups was highlighted by participating companies.

Implementation and market introduction of potentially disruptive technologies

Achieving the necessary flexibility and speed to adapt to new technologies and business processes was also identified as an important challenge, particularly for larger, established market participants. Market size is a major driver of investment decisions in technology development, so the initially small size of existing markets where potentially disruptive technology could be deployed are aggravating the situation. Investments for development and marketing are often not made available in sufficient amounts.

Integration into existing structures and resistances

Potentially disruptive technologies are often related to new demands on all parties involved. In this context, the early sensitization and participation of the organization was mentioned as an important point, for example, through appropriate preparation, and personnel development measures. Resistance from existing structures and customers who are opposed to changes associated with potentially disruptive technologies was mentioned as a particular challenge.

The synchronisation of strategic orientation and potentially disruptive technologies is a particularly interesting point, as this is given relatively little weight in classical approaches for developing R&D and innovation strategies. Resistance to change from within existing structures and from customers stands in contrast to the large proportion of participating companies that are using existing structures to deal with potentially disruptive technologies.

The most important success factors

Conscious management of potentially disruptive technologies

Success factors cited included the identification of the potentially disruptive technologies, the need to take technologies seriously once they have been identified, and, most importantly, identification of the potential threats to the current business model from new technologies. An additional success factor mentioned was the perception of potentially disruptive technologies as an opportunity rather than a threat.

Strategic planning and risk taking

Consideration of potentially disruptive technologies in target-setting and strategic planning. In particular, the conscious renunciation of low-risk, timely transactions in favor of riskier and more long-term transactions, was highlighted. This included the courage to fail, as well as budgets especially dedicated for potentially disruptive technologies.

Early adoption of potentially disruptive technologies

Another family of success factors mentioned was the early adoption of potentially disruptive technologies to secure a technological lead, to develop skills, and to secure these through patents.

Organization and cooperation

In addition to the fundamental creation of structural and organizational prerequisites, ambidexterity was mentioned, referring to the ability of an organiaztion to be efficient in their day-to-day business combined with a high degree of novelty in development projects. Cooperation in partner networks along the value chain was another success factor that was cited for dealing with potentially disruptive technologies.

The success factors for dealing with potentially disruptive technologies may vary from case to case. A lump-sum approach to early entry into potentially disruptive technologies, for example, should certainly be viewed with caution.

3.3 SUMMARY

This study focuses on the analysis of how companies deal with potentially disruptive technologies, from identification through to development and implementation. It is based on the understanding that disruptive innovation is characterized by substituting reference solutions in the market, and making the investments of incumbents obsolete. Potentially disruptive technologies are referred to as those technologies that can potentially lead to a disruptive innovation.

The identification of potentially disruptive technologies takes place sporadically and individually in the majority of participating companies via conventional technology search, and with identical search spaces as used for the identification of sustaining technologies. The most important information sources mentioned include start-ups, trade fairs, conferences, and market analyses. Likewise, potentially disruptive technologies are evaluated by a majority of the participating companies either sporadically and individually or via conventional technology search. As with other technologies, employee intuition is by far the most frequently cited evaluation method. The applicability and the risk of technologies are the evaluation criteria most frequently mentioned for the evaluation of potentially disruptive technologies with regard to singular technology characteristics. With regard to target markets, the focus is on costs and benefits. The development and implementation with regard to potentially disruptive technologies takes place in a considerable majority of the participating companies within their existing organizations. Throughout the entire process, executive management is the most important decision-making group on potentially disruptive technologies. The question arises whether a sporadic and individual identification and evaluation, combined with more classical evaluation criteria and a largely internal development and implementation, can do justice to the characteristics of potentially disruptive technologies? Often potentially disruptive technologies do not appear in the search field of the core business. It is also questionable whether the competencies and resources of established market participants are suitable for the successful development and implementation of potentially disruptive technologies.

These questions are also reflected in the challenges mentioned by the participants. In summary, these include the strategic orientation and initiation of development activities, the availability of development resources for potentially disruptive technologies, implementation and market launch, as well as the integration of potentially disruptive technologies into existing structures, including associated resistance. The success factors reported, such as a conscious handling of potentially disruptive technologies, strategic planning, and the willingness to take risks, seem to be slightly inconsistent with the responses to survey questions along the process from identification through to development and implementation of potentially disruptive technologies.

The results indicate that there is a serious gap between the state of science and its implementation in companies. The challenge to close this gap should be addressed by companies and scientists in order to successfully deal with the phenomenon of disruptive innovations, not only in language use, but also in practice. This results in the following recommendations:

Recommendations from identification to implementation

| Identification of potentially disruptive technologies
Search spaces for potentially disruptive technologies should be explicitly defined and regularly updated. This includes both markets, and technology fields that show characteristics for a potential disruption.

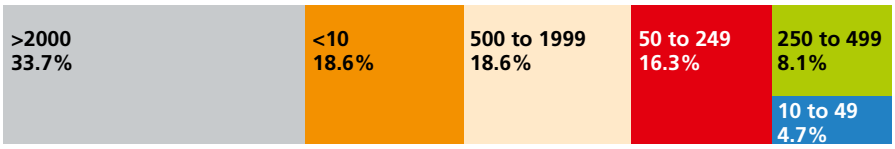
| Evaluation of potentially disruptive technologies
The range of methods available should be used in combination with a balanced set of evaluation criteria. The evaluation criteria must go beyond the evaluation criteria commonly used in the industry. For instance, trajectory mapping is part of the methodical standard equipment in order to continuously compare the performance characteristics demanded by the market with technological progress or the progress of non-technological solutions.

| Development and implementation of potentially disruptive technologies
Your own company is not necessarily aligned to the development and implementation of a potentially disruptive technology! The appropriate organization within and outside your company should be identified and selected for each individual case.

The basis for successful management of disruptive innovations is a deep understanding of user requirements, independent of existing solutions as well as the competence to assume the perspective of other, current, and potential market participants.

3.4 STUDY PARTICIPANTS

The context of the types of companies represented and their activities are essential to understanding the results of this study. A wide range of companies are represented, both in terms of number of employees and annual turnover. As shown in Fig. 20, the two most frequently represented company sizes are large companies, with more than 2000 employees representing a third of the participants (33.7 percent), and micro-enterprises, with fewer than 10 employees (18.6 percent).

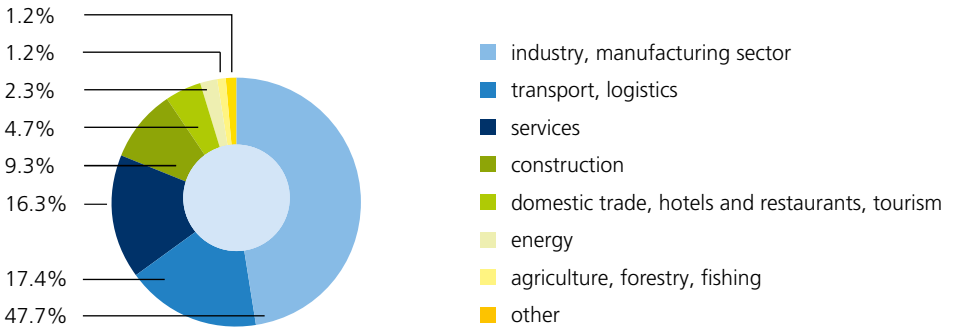


20 *Size of the participating companies based on the number of employees (n=86)*

Companies with an annual turnover of more than 50 million euros (54.7 percent), and those with an annual turnover of less than 2 million euros (22.1 percent), are the most strongly represented corporate groups (see Fig. 21).

21 *Size of participating companies based on annual turnover in million euros (n=83)*

With respect to the sectoral affiliation shown in Fig. 22, industry, and the manufacturing sector in particular, are represented with almost half of the companies involved (47.7 percent). These are followed by transport and logistics (17.4 percent), and the service sector (16.3 percent).



22 *Industry affiliation of the participating companies (n=86)*

Despite the execution of this study as an international and multilingual online survey, German-speaking companies represent the vast majority (81.4 percent), followed by companies from the United States (5.8 percent).

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