TECHNOLOGY IDENTIFICATION IN RELATION TO EMBEDDED SYSTEMS

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ABSTRACT

Embedded Systems (ES) are information processing systems consisting of a hybrid combination of hardware and software components integrated into a technical environment. Their main purpose is to control, regulate and monitor a system to secure efficiency, reliability and specificity for a certain application under realtime requirements. Their importance manifests in a considerably increasing number of fields of technological applications, e.g. automotive, aviation and railway engineering, telecommunications as well as machinery and plant engineering. In this context, the identification of new technologies is an essential success factor in a highly competitive environment and therefore of high relevance for enterprises of ES. Hence, this paper analyses different types of methods, the importance of technology scouts, the process and relevant success factors related to the identification of new technologies in the field of ES.

Open-ended and guided interviews are chosen as research method consisting of a sample of 48 experts from several industries originating in the European Metropolitan Area of Nuremberg, Germany. These interviews have been analysed employing a qualitative content analysis, which is a suitable method to systematically extract relevant information from text material.

The results show that technology identification is of essential importance for companies of ES and beyond. Within the sample there exist 15 relevant methods for the identification of new technologies, e.g. subject related publications, exhibitions, internet, customer and supplier/producer. Roughly 73 % of the interviewed enterprises do not employ distinct technology scouts, instead technology identification is perceived as part of every employee's continuous duties. 36 companies use a formalised process which follows a predefined pattern. Regarding the factors influencing the success of identifying novelties in terms of ES, our study reveals six factors, namely networking, cost and profit optimisation, applicability, currency, corporate culture and competitive advantage.

Our findings are highly relevant for the evaluation of technology identification processes which are critical for the success of Technology Scouting (TS), managing innovation, planning technologies as well as foresight and forecasting related to emerging technologies. This study concerning technology identification and TS commends itself as a starting point for further investigations towards the closely related theoretical concepts of Technology Foresight and Technology Management.

Key words: Embedded Systems, Qualitative content analysis, Technology Foresight, Technology identification, Technology Management, Technology Scouting

INTRODUCTION

Problem outline

The globalisation and subsequent increase of competition, innovation in telecommunications, increasing and changing customer expectations as well as technological changes are revolutionising markets (Cespedes, 1994; Matthyssens and Vandenbempt, 1998; Røpke, 2001; Zähringer *et al.*, 2011). Among others, these factors trigger new technological developments in companies serving as a basis for competitiveness and competitive advantage (Edler *et al.*, 2002). Consequently, the identification of potential future developments and trends is crucial for technology-specific decision-making. In this context, companies face critical challenges concerning the recognition of technological change (Levinthal, 1992). To meet these challenges, firms have to monitor and reveal recent developments in order to be able to make strategic decisions in terms of technologies (Golovatchev *et al.*, 2010).

When it comes to technological change, Embedded Systems (ES) play an important role. The ES market experiences steady growth and is considered to be the most important application area of information and communication technology in the upcoming years. Its global volume is estimated at 60 billion euros, in other words about 100 times the desktop market (Beetz and Böhm, 2012; Eggermont, 2002; Marwedel, 2011).

ES are "information processing systems embedded into enclosing products" (Marwedel, 2003), i.e. microcontrollers to monitor, control or assist the operation of equipment, machinery or plant (Kemp, 1997). By this means, they interact either directly with their environment via communication devices or indirectly via sensors that capture data such as temperature or movement, as well as with actors that transform those data into action (Beetz and Böhm, 2012). The number of ES integrated in a product varies from at least one to ten in simple consumer products to several hundreds in complex professional systems so that an average household utilises easily 50 ES (Eggermont, 2002).

Their importance manifests in a considerably increasing number of fields of technological applications, e.g. automotive electronics, avionics, railways, telecommunications, health sector, security, consumer electronics, fabrication equipment, smart buildings, logistics, to robotics and military applications (Marwedel, 2011). To give an example, airbags, braking systems or power locks are nowadays inconceivable without ES (Beetz and Böhm, 2012).

In the following section, the theoretical basis concerning the definition, importance and process of Technology Scouting (TS) is provided as well as the research questions are derived. After that, the methodology applied, i.e. expert interviews and qualitative content analysis, is outlined. It is followed by the constitution of the (ES-specific) empirical findings in terms of technology identification methods, existence of technology scouts, technology identification process as well as success factors. Finally, the paper is topped off with concluding statements.

Theoretical foundations – Identification of technologies

Technology Scouting

In order to be able to continuously identify technological change, enterprises increasingly use methods to make distinct predictions about technologies (Rohrbeck, 2010). Such a method is TS.

It serves as a means to collect information about academic topics and technologies in a structured manner. Furthermore, it is used to facilitate and execute technology procurement (Rohrbeck, 2010). To a greater degree, the use of TS results in higher competitiveness and even in competitive advantages. Consequently, it is crucial to be able to recognise risks and threats being related to technologies in a very early phase due to the reason that then corrective actions can be carried out more successfully than in later stages (Rohrbeck, 2007). According to Spitsberg *et al.* (2013), TS contains several tasks, which are listed in table 1.

Table 1: The different tasks of Technology Scouting

	Task
Technology Scouting	Collection and enhancement of critical knowledge about critical technologies
	Identification and offering of technologies to satisfy certain demands and expectations
	Integration of suppliers and competitors to identify developments, trends and technologies that are part of the core business and therefore essential for the firm´s continuity
	Recognition of new and further developed technologies in an early stage of development
	Connection with a network that is oriented on technological developments

Both internal employees and external consultancies who thereby act as technology scouts can fulfill these tasks. They do not only perform a full-time job and are respected by decision makers and researchers, but also possess specific know-how about company-relevant science and technologies, a cross-departmental perspective and creativeness (Rohrbeck, 2010; Wolff, 1992). Methodological competence is another important characteristic. It ensures that the observer is able to apply correct methods to procure and process information. If there is a lack of competence, the R&D department will possibly be provided with redundant or even useless information (Rohrbeck, 2010; Wolff, 1992).

TS distinguishes between direct, i.e. Technology Monitoring, and indirect search, i.e. Technology Scanning, for technologies. The former aims at predefined technological areas or innovations in relation to a company´s own technologies whereas the latter is concerned with fields that are not covered by the existing portfolio or the strategic orientation of a company (Rohrbeck, 2007).

When it comes to the identification of technologies, the three concepts of TS, Technology Foresight (TF) and Technology Management (TM) are often confused. Hence, it is useful to explain their common features and differences within the context of this paper: TS is part of a system that addresses the identification and procurement of development-relevant technologies and information. In this regard, it fulfils on the one hand the identification and evaluation of technologies or new developments that provide the interface to TF. On the other hand, technology scouts facilitate technology procurement for TM. Then again, TF provides TM with relevant information about emerging technologies (Rohrbeck, 2010). Figure 1 visualises the connection between TS, TF and TM.

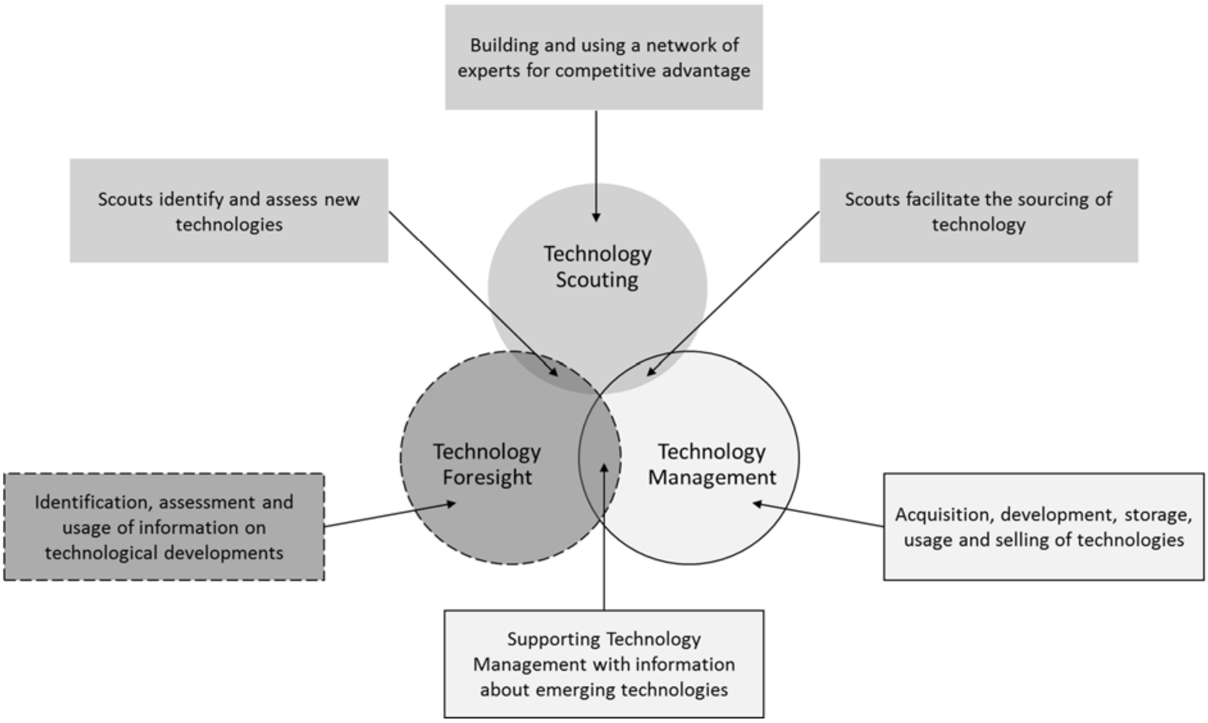

Figure 1: Demarcation of Technology Scouting from Technology Foresight and Technology Management, Source: own illustration based on Rohrbeck (2010)

Information sourcing

Obviously, information sourcing plays an important role and is part of TS. As a consequence, different methods of information sourcing are presented in the following.

In general, there are two different ways to obtain information in the context of technology identification. On the one hand, automatic search mechanisms (= formal information sources) rank among the most conventional methods to gather information. Here, the utilisation of databases contains analyses with regard to patents, publications as well as internet-based data generation (Porter, 2005). By way of example, the former are applied to competitive and technological trend studies. By this means, indications about technology or branch developments and new research fields can be deduced (Daim *et al.*, 2006; Hall *et al*., 2001; Park *et al.*, 2012).

In this context, the analysis of the technology lifecycle is helpful in order to understand to what extent information already exists internally and if further external information gathering is useful (Jones *et al.*, 2001). For this purpose, the S-curve can serve as a methodological tool (Modis, 2007; Phillips, 2007; Sood and Tellis, 2005). A combination of different methods allows the collection and evaluation of relevant information out of several databases (Porter and Cunningham, 2005). Nonetheless, automatic search mechanisms in the context of technology identification have weaknesses, too. These are mostly noticeable in early technology development stages when there is a greater number of concerned parties, which develop technologies simultaneously and use different names for in other respects identical technologies. In early stages, significant information is scarce. Thus, experience in assessing the technology´s potential serves as a success factor (Rohrbeck, 2010).

On the other hand, informal information sources, e.g. the Delphi-method, go beyond the borders of automatic search approaches. It is therefore another possibility to gather important information to deduce the future development of technologies (Karvonen *et al.*, 2009; Ronde, 2003). In general, it enables users to combine and study experts´ opinions (Ronde, 2003; Skulmoski *et al.*, 2007). Besides expert knowledge, further external sources and information play an essential role in TS as well. These are e.g. press reports, business news, electronic media, company or scout contacts and a cross-company information exchange (Porter and Cunningham, 2005). Furthermore, systematic literature reviews of academic publications in journals or reference books provide information exactly like competitors, suppliers and exhibitions (Arman and Foden, 2010).

In addition, customer experiences and insights facilitate the information exchange since technology development should be customer-oriented (Payne and Frow, 2005). Similarly, information exchange between firms and universities or research institutes contributes to the identification of technological trends. In the course of this, universities provide enterprises with technologies and associated information (Gomes and Kruglianskas, 2009; Gross, 2013; Woerter, 2012). Moreover, roadmapping is a tool to tailor technologies or products more effectively to demand requirements. Consequently, it is necessary to understand latter to be able to prepare the requirements specification. This serves as an information source for technology-oriented idea generation (Groenveld, 2007).

Apparently, the procurement and acquisition of information can be effected by means of several methods and tools. It has to be determined which patents, academic publications or research institutes are used for the identification process. The point is not to apply all of those methods and concepts but rather those being appropriate for and specifically tailored to the identification of predefined technological search areas (Spitsberg *et al.*, 2013).

The process of Technology Scouting

The process of technology and innovation scouting begins with the identification of recent developments, trends and ideas in R&D (Golovatchev *et al.*, 2010). According to Golovatchev *et al.* (2010) innovation radars are employed to give an overview of relevant internal and external technology trends rating them by their potential relevance to the company. Moreover, such radars are able to trigger suggestions for strategic innovation development projects. More precisely, Rohrbeck (2007) proposes a division of the TS process into six stages, as illustrated by figure 2.

Figure 2: The process of Technology Scouting, Source: own illustration based on Ashton and Stacey (1995), Reger (2001) and Rohrbeck (2007)

As a first step, (directed) Technology Monitoring or (undirected) Technology Scanning are used to *define the search areas* ***(1)***. Secondly, technology scouts are responsible for *the selection of information sources and methods* ***(2)*** to be employed. As previously mentioned, information sources can be classified into formal, i.e. automated database search algorithms covering journals, magazines, technology reports and trend studies, or informal, e.g. networks, exhibitions, workshops and conferences. The latter are especially important in highly dynamic technology environments (Reger, 2001). At the same time, the method selection strongly depends on the time horizon of the usage of information and the compatibility with other methods (Ashton and Stacey, 1995; Reger, 2001). In the subsequent third phase, the gathered *information is collected* ***(3)*** and electronically stored for later process stages. Here, technology scouting networks as well as highly experienced and knowledgeable scouts serve as a success factor (Ashton and Stacey, 1995; Reger, 2001). The fourth stage deals with the *filtering, analysis and interpretation of these data* ***(4)*** by interactive teams consisting of scouts and information recipients. This approach ensures effectiveness, recipient orientation and value creation (Reger, 2001; Rohrbeck *et al.*, 2006). The fifth stage in the technology scouting process is concerned with *the information evaluation and decision-making* ***(5)*** in terms of R&D investments or development actions to be taken (Ashton and Klavans, 1997). The process is finalised by the *usage of the previous information, data and findings* ***(6)***. At the same time, this operates the already mentioned interface to TF. Within this stage, based on a cost/benefit analysis of the TS methods and actions, factual value creation takes place.

In the aftermath, the complete process has to be revised to reveal weaknesses that are to be reduced or even removed (Ashton and Stacey, 1995). Likewise, the briefing of technology scouts at the very beginning of the TS process is crucial to tailor it in anticipation of the final stage and subsequent process of TF (Rohrbeck, 2007).

Research questions

The previously illustrated theoretical findings prove that academic literature definitely deals with technology and/or innovation identification. Nevertheless, almost none focus on companies being concerned with the development or integration of ES.

With reference to the identification of technologies, several methods have been revealed from literature (e.g. Porter, 2005). Thus, experts assigned or employed by a company are responsible for identifying technologies (Rohrbeck, 2010; Wolff, 1992). In this context, it is also possible that besides the mentioned identification methods, further methods, that are particularly important and therefore serve as success factors, exist. For instance, it is possible to apply identification methods that have been adapted to the company's environment or the respective industry.

According to scientific literature, the identification of new technologies follows a predefined process including technology scouts and other success factors (Rohrbeck, 2007). Contrary to that, a processindependent examination of recent technological trends and advancements with reference to ES could also be possible. As a consequence, the following four research questions (RQ) can be derived:

i. **RQ 1:** Which set of methods in terms of identifying technologies with regard to ES does exist?

ii. **RQ 2:** How important are technology scouts/divisions for identifying technologies with regard to ES?

iii. **RQ 3:** How important are predefined processes for identifying technologies with regard to ES?

iv. **RQ 4:** Which success factors in terms of identifying technologies with regard to ES do exist?

Hence, this paper analyses different types of methods, the existence of technology scouts, the process as well as relevant success factors related to the identification of new technologies in the field of ES.

METHODOLOGY

Method of data collection

Data collecting is based on expert interviews. This method is recommended as it fosters trust and cooperation that are needed to inquire sensitive data (Rosenthal and Rosnow, 1991). The requested information in this study can be considered as sensitive data as they contain e.g. information that might be useful for competitors. In total, 48 experts have been interviewed who occupy different positions and work in companies of all sizes from several industries like automotive, electronics, avionics, telecommunications and fabrication equipment that play a particular role regarding ES. As the research project, this paper is based on, was supported with funds from the Bavarian government, all respective companies are located in the European Metropolitan Area of Nuremberg (EMN). Additionally, this region represents one of the strongest economic regions in Germany. The sample size of 48 interviewees balances the intensive resources required for in-depth interviews against the little marginal benefit of additional interviews (Sheng *et al.*, 2009).

In contrast to a quantitative method that applies structured (or closed) interviews, qualitative approaches make use of interviews that apply open-ended questions. This type of question allows the respondents to expand their answers and go into detail regarding issues of high relevance for the respondents. Moreover, such an interview allows flexibility regarding the wording and sequence of the questions (Rosenthal and Rosnow, 1991). Consequently, the questions are not compulsory identical in the qualitative proceeding. Equally, no response options are provided as they could influence the respondent. This leads to a broader base of information and additionally allows answers that have been unexpected beforehand.

The 48 interviews discussed in this paper follow the concept of guided interviews. In the course of this, a coherent list of questions is applied that involves all questions the interviewee should answer. Thus, a consistent proceeding can be ensured by the given questionnaire. This approach should lead to an easier evaluation referring to comparability of results (Meuser and Nagel, 2009). The guideline used for the interviews in this study is divided into three sections and starts with the identification of technologies that constitute as innovations for a company or industry. This part should examine, what methods are applied to recognise trends and advancements. Furthermore, this section dwells on the importance of technology scouts or technology divisions specifically responsible for technology observation. The second part of the guideline is concerned particularly with the process of identifying new technologies. Here, the respondents are asked about the existence and standardisation of such a process as well as about potentials for improvement. The last section of the interview guideline covers factors that are crucial for a successful search for recent advancements in terms of ES technologies.

Evaluation method

The interviews have been evaluated by employing a qualitative content analysis as this method is recommended in literature (Holsti, 1968; Krippendorff, 1989; Mayring, 2000; Sonpar and Golden-Biddle, 2007). Each compiled research question deals with a superior issue that consists of several elements. Consequently, there exist various subordinated questions in the interview guideline referring to one research question. The research questions and the interview guideline serve as an orientation guide for the evaluation of the interviews. Individual categories are crucial for the evaluation (Berelson, 1952; Kassarjian, 1977). The categories should depict different opinions or approaches. These are derived deductively from theory or inductively from the interviews (Gläser-Zikuda, 2003; Mayring, 2000; Woodrum, 1984). As a result, categories that are the basis for the evaluation arise for each question in the interview guideline. On the one hand, these categories can consist of an ordinal scale, for instance with the manifestations “not at all – little – much”. On the other hand, the categories can be comprised of particular types of manifestations and proceedings. These categories do not refer to an ordinal scale, but to the existence of a specific procedure or method. An example would be categories referring to informing about new trends. Among others, here are categories like “exhibition” or “newsletter” included. In this context, the data is perused tentatively in the beginning to check if the already chosen categories can be applied to the data and to what extend further categories have to be added (Mayring, 2000).

In the next step, each interview is analysed based on the category system. Thus, nearly every question is particularised whereas some questions can be elaborated together. Particular parts of the interviews are selected and allocated to one category, for instance at the above already mentioned question “How do you inform about recent trends and advancements?” Besides the named categories “exhibition” and “newsletter”, additional categories are created according to the stated process. Afterwards, the answer of each interviewee is allocated to at least one of the derived categories.

In parts, the categories are consolidated in a meaningful way. This is e.g. the case, if it becomes apart that categories are very similar and therefore a separation is quite difficult or if certain categories coincide. Consequently, a superordinate category is introduced that involves previously similar categories. For instance, this is the case for the categories “company magazine”, “whiteboard” and “system” that are allocated to the superordinate category “internal communication systems” (ICS). The subordinate category “system” thereby refers to all statements about a general company-internal communication system and both categories “company magazine” and “whiteboard” represent two tools to spread knowledge. The ascertained results of these subordinated categories are then allocated to the superordinate category ICS.

The evaluation follows the frequency analysis (Holsti, 1968). This means that for each answer that is allocated to a category, a “1” is referred to that category in the respective interview. If a category does not pertain, it stays empty respectively is marked with a “0”. For example, if an interviewee says that the company receives information about recent developments through exhibitions and newsletters, both categories “exhibition” and “newsletter” receive a “1”. Respectively, all other categories receive a “0”. Thus, the statements are quantified and attributes that occur more or less often can be identified.

RESULTS

In the following, the results are presented in charts. In the respective bar charts, the horizontal axis shows the respective categories while the vertical axis states the number of respondents of each category. Subsequently, some utterances from the interviews are presented to illustrate the respective manifestations qualitatively. Moreover, this counteracts the potential loss of data through the reduction that comes along with the methodology applied. First of all, the methods of collecting information about recent technologies or trends elaborated from the interviews are presented. Afterwards, it will be referred to the availability of technology scouts, before the existence of a compulsory technology identification process will be analysed. Finally, this paper will dwell on success factors of the search for new technologies with regard to ES.

RQ 1: Technology identification methods

First, the amount of technology identification methods applied by the interview partners in practice is examined. As figure 3 illustrates, only three experts (~ 6 %) limit themselves to solely one method to identify new technologies. 12 of the total 48 respondents (~ 25 %) use exactly two methods. Eleven other experts (~ 23 %) employ three methods. The residual 22 experts (~ 46 %) utilise four to eight methods. Thus, most interviewees apply two or three methods to gather information about technologies. For instance, one expert applies the two approaches “professional publications” and “suppliers” to get information about technologies. Another expert explains, his/her company is present on exhibitions, checks competitors’ web pages and receives information from professional magazines. These methods are allocated to the three categories “exhibitions”, “watching competitors” and “subject related publications”.

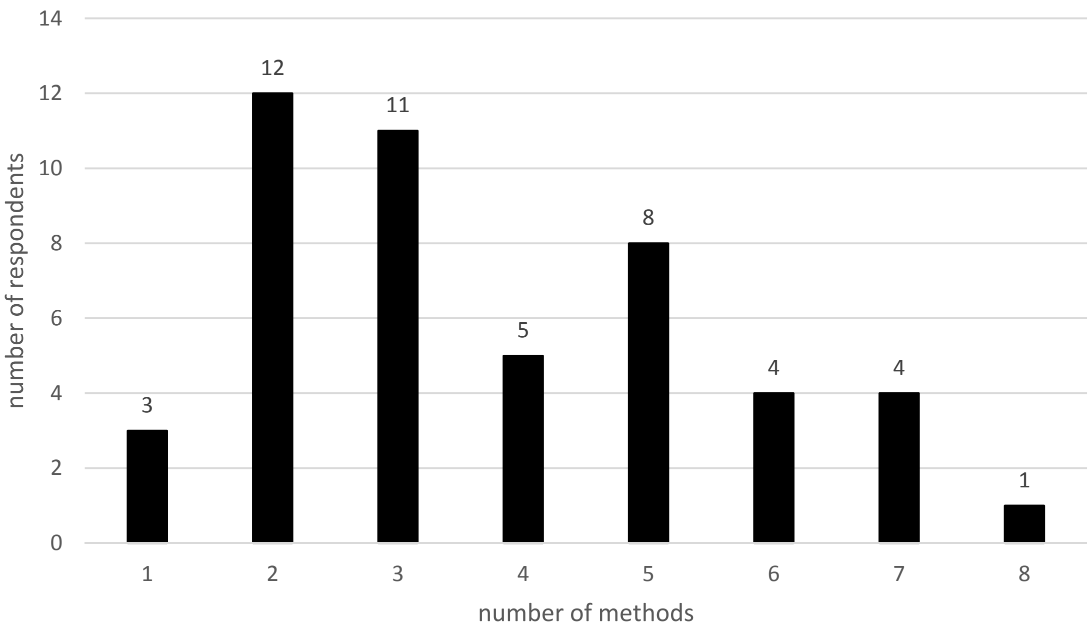

Figure 3: Number of applied technology identification methods, Source: own illustration

In total, 15 methods have been identified in the interviews. In this context, several methods have been grouped together reasonably. For instance, journals and publications have been allocated to the same category "subject related publications". These 15 procedures applied by the respondents to gather information about new developments are presented in figure 4. Thereby, in most cases more than one method is applied, as already described afore.

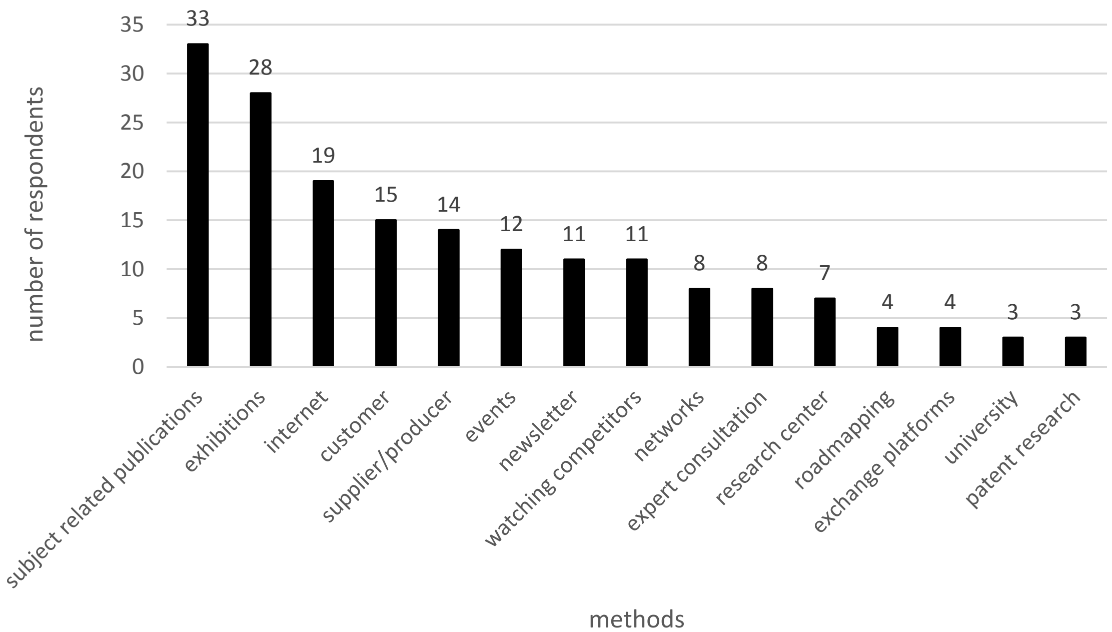

Figure 4: Types of applied technology identification methods, Source: own illustration

Subject related publications (= formal information source) as a tool of information retrieval is the method most often utilised by the respondents. The research in professional publications, professional magazines, journals as well as in magazines belongs to this category. In total, 33 out of

48 experts (~ 67 %) apply this method. The usage of it is exemplarily illustrated by one respondent who states that professional publications as well as professional press regularly serve as a source of information about market novelties that are potentially taken into consideration.

Exhibitions (= informal information source) are the second-most mentioned method. They are mentioned by 28 of 48 experts (~ 58 %) as a source of information about recent trends. For instance, one respondent excludes professional magazines due to a lack of actuality in his/her field and therefore states solely exhibitions as a source of information.

The third-most represented method is the **internet** (= formal information source). Here, 19 experts (~ 40 %) use the internet to search for information about recent developments. In this context, the interviewees either search in online databases or retrieve explicit information from the internet. One respondent explained that the internet is used as a source of information about recent trends if there is a particular interest. Another expert refers in this context to a database as an explicit source of information and mentions the IEEE Explorer as an example. This database allows to search in an easy and straightforward way for information.

Customers (= informal information source) are the first external source of information that is directly associated with the respective company and interacting with it. This category is comprised of 15 experts (~ 31 %). According to the expert statements, consultations with the customers are mainly affected. Moreover, potential trends in the customers' point of view can serve as a signal for future technology developments, as one expert states. Therefore, the respective company chooses customers who already have first information about such developments. Subsequently, these trends are tried to understand. As a result, the company and its customers establish a mutual information transfer about current trends.

In total, 14 experts (~ 29 %) make use of **suppliers or producers** (= informal information source) as input for information about novelties. In this case, suppliers offer information through presenting developments that are already available in form of a product. Furthermore, joint product development can result in an exchange of information.

Besides these five most frequently stated methods, ten further methods, that play a minor part, are mentioned (see figure 4). They include for instance competitors, networks, external experts or universities. In total, only between three and twelve interviewees (~ 6-25 %) state each of these methods.

RQ 2: Existence of technology scouts / divisions

After having shown the single methods that are applied to identify advancements in the previous section, the following will investigate the existence of technology scouts or divisions responsible for the technology observation in the respective companies of the respondents.

The existence of specifically appointed technology divisions or technology scouts is approved by 13 interviewees of the total 48 (~ 27 %). In this context, one expert mentions two types of scouts. The first, technology scouts, concentrate on technological opportunities and feasibility. This means, among others, research of technologies that still lack a concrete marketing approach. The second type are market-oriented technology scouts. They figure out markets to apply technologies or to identify which technologies will be demanded in future to derive technical developments. The majority, 35 out of 48 respondents (~ 73 %), has no technology scouts or divisions in their companies. One reason can be, as one expert states, that such institution is not necessary due to the respective company's size.

Among the 35 experts who denied the existence of specific technology scouts or divisions, 27 (~ 77 %) highlight technology identification as part of every employee's continuous duties. For instance, one interviewee argues that it is part of the daily business to look for new developments.

RQ 3: Existence of a process

In the following, the findings with regard to a process for the identification of developments will be depicted by dwelling on the existence of a process.

According to the interviews, 36 out of 48 experts (~ 75 %) have a process to observe technologies. Only three respondents (~ 6 %) state that there exists no process in the respective company while nine experts (~ 19 %) did not make a statement or do not know if their companies apply a process or not.

Ten respondents out of the 36 who know about a process to identify technologies (~ 28 %) can draw on a clearly defined process design. The residual 26 interviewees (~ 72 %) do not use a predefined process design. One respondent serves as an example for a not predefined process design. He/she argues that his/her company has no defined process due to its medium-sized character. The company sometimes employs an intern who collects newspaper articles about competitors who have introduced a new technology. As a result, this company maintains an Excel-list about current technical features of competitors. Thus, this company has a process, but lacks a strict procedure.

Contrary to not defined processes, one expert states an explicit process for the introduction of new products. This process provides a framework for the company`s strategic direction. The process additionally considers the probability of customers' projects to meet the overall goal of acquiring new business. Moreover, the expert emphasises the necessity of observing and developing technologies on the one hand and of being in the customer's mind who orders this solution on the other hand.

12 out of the 36 interviewees who have a process for identifying technologies, whether predefined or not (~ 33 %), identify scope for improvement in the processes. As an example can serve one respondent who suggests a more systematic designed process. Another respondent adduces public meetings and protocols as potential improvements. This means, general access to as well as the collection of information could improve the process.

RQ 4: Success factors

Being asked about the success factors of searching for new developments in the field of ES, the interviewees stated six different factors. Similar to the methods of identifying developments, several respondents named more than one success factor. Moreover, 10 out of 48 respondents (~ 21 %) did not make any statement about success factors at all.

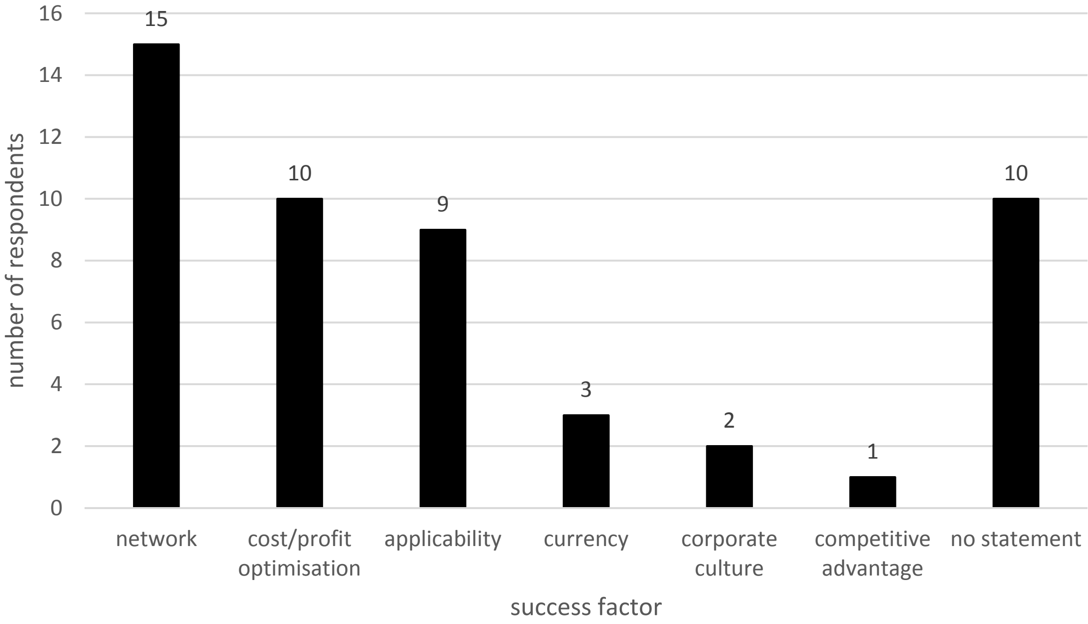

Figure 5: Success factors for technology identification, Source: own illustration

As figure 5 shows, the most often mentioned success factor is **network**, being mentioned 15 times (~ 31 %). In this context, networks are particularly understood as the connection to suppliers and customers. For instance, the respective person in a company can have contact to crucial partners that can help to identify technologies. One expert illustrates this by emphasising the importance of personal networks. According to him/her, a draughtsman working closely with a supplier is able to receive indications about preparations and innovations of components. Equally, a salesperson can gather information about customer needs by talking to them. The second-most mentioned category is **cost/profit optimisation** (~ 21 %) representing the only financially driven success factor. Another factor is the **applicability** that is stated by nine respondents (~ 19 %). That means for instance, that the technology proves functional after its development. One expert argues that the company has to be able to apply the technology in general, though it has to be compatible to old systems. In reference to **currency**, the point of time of research and identification is essential and therefore stated by three experts (~ 6 %). One interviewee who argues that a short development time is crucial illustrates this. **Corporate culture** as a success factor is named by two respondents (~ 4 %) who mention that the culture has to be shaped by openness, honesty and fearlessness. Thus, the corporate culture has to offer the possibility to try new ideas. Only one expert names **competitive advantage** (~ 2 %), referring to the divergence of own developments from competitors', as a source of strategic differentiation.

CONCLUSION

Our literature review serving as a basis for this study revealed that there is a lack of theoretical analyses regarding technology identification with reference to ES. Consequently, this paper focusses on the methods, existence of technology scouts, process and success factors when it comes to identifying new technological trends and advancements in the context of ES, which is superiorly referred to as TS (Rohrbeck, 2010).

The qualitative content analysis of the conducted 48 expert interviews resulted in the finding that there exists a set of 15 technology identification methods in total. The majority of the respondents employ at least two of these methods. The most important among these are subject related publications and the internet, representing formal information sources (e.g. Porter, 2005), as well as informal information sources (e.g. Arman and Foden, 2010), i.e. exhibitions, customers, suppliers and producers. Thus, companies that operate within the highly competitive environment of ES should preferably apply a combination of these instruments, which should be tailored to and suitable for the respective organisation, in order to ensure effective and successful TS.

Moreover, our study observes that specifically appointed technology scouts do not play a critical role in detecting developments of ES. In fact, respective responsibilities are delegated to each relevant employee as part of his/her daily business. Consequently, we argue that, depending on the organisational structure and culture, no separate technology scouts are stringently required. In this case, it has to be guaranteed that every employee concerned with technological aspects performs the tasks related to TS.

In addition, this paper clearly notices that three-quarters of the research sample do have a process to discover technological progresses in the field of ES, although it does not follow a predefined pattern. Based on both the theoretical findings (Ashton and Stacey, 1995; Golovatchev *et al.*, 2010; Reger, 2001; Rohrbeck, 2007) and the interviewees` experiences, we suggest implementing a clearly predefined, structured and standardised ES identification process. Thus, it is possible to continuously improve the process to leverage value creation and effectiveness as well as to operate the interface to TF more successfully.

Similarly to the diversity of ES identification tools, several success factors have been revealed. Companies concerned with detecting future technological developments in terms of ES benefit the most from utilising a close relationship to suppliers and customers. Thus, we recommend establishing, maintaining and expanding a preferably far-reaching network in order to gather information more effectively and ensure customer-orientation, which serves as a key for meeting market demand. Also, financial stability by cost/profit optimisation plays a central role. Moreover, applicability, i.e. functionality of ES and compatibility to old systems, is critical and consequently advised by this study.

These findings are highly relevant for the evaluation of ES identification processes that are critical for the success of managing innovation, planning technologies as well as foresight and forecasting related to emerging technologies. Nevertheless, due to the geographic limitation of our research, future studies have to prove that these results hold true beyond the region of the EMN. Furthermore, the focus on TS of ES and its corresponding outcome within the context of this paper serves as a starting point for further research elaborating on TF, i.e. the evaluation, assessment and usage of information, and TM, i.e. the acquisition, development, storage and exploitation of technologies, in the context of ES.

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