Tackling the Critical Hurdles: Revising Technology-Based Ideation Processes

Sarah Manthey, Christin Eckerle and Orestis Terzidis
Karlsruher Institut für Technologie, Germany
sarah.manthey@kit.edu
christin.eckerle@kit.edu
orestis.terzidis@kit.edu

Abstract. Technological innovations are crucial for a country's economic growth as they often have radical innovation potential. Although recognized as a key role in the innovation process, lots of technologies remain unexploited. University spin-offs (USOs) have the potential to transfer technologies into technological innovations. Often though, in universities there is a lack of consideration of potential implementation right from the start. The so-called fuzzyfront end (FFE) stage is crucial for successful innovation, as no commercialization can be achieved without the identification of a suitable application. This represents a critical hurdle, as of to date appropriate approaches for a successful systematic identification and validation of technology applications are missing. Furthermore, most investigating studies rely on data from spin-offs that are already operating successfully on the market and have therefore survived the critical initial stages of development, without highlighting the FFE of their process. This fact makes the pre-development activity of opportunity recognition appear to be a scientifically neglected topic. In this research a mixed-method approach is conducted to investigate the critical hurdles in the technology application selection (TAS) process of technologies, consisting of an extended literature review, completed by interviews with stakeholder involved in the USOs ecosystem. Striving to uncover the black box of the FFE, the study aims to specify and operationalize requirements for application identification of technologies. These findings are of relevance for researchers and practitioners which like to facilitate the exploration of potential technological innovation.

Keywords: technological innovation, technology application selection, entrepreneurship, technology-push

1. Introduction

Technology push (TP) represents an important innovation strategy to exploit new technology and technological knowledge to transform it into value (Maier et al. 2016). While they have the potential to lead to breakthrough innovations (Herstatt and Lettl, 2000), it also involves high uncertainty. Identifying and selecting applications for new technologies is challenging and risky since the appropriate market is often not clear and no guarantee of success can be estimated (Terzidis and Vogel, 2018). Furthermore, systematic and consistent approaches for identifying application fields are sparse (Henkel and Jung, 2009).

Despite the high demand for technological innovations in industry and research, few practical approaches supporting the TAS process are known (Terzidis and Vogel, 2018), while several exist for Market Pull Innovations, like Design Thinking (Leavy, 2012). Furthermore, there is hardly any specific investigation on the process of TAS for new technologies. Literature reviews focusing on the TAS process have been conducted by several authors, investigating different kinds of influential factors in the process (e.g., Abd Rahim et al. 2021), perceived meaning of opportunity and the underlying process (e.g., Ojala and Puhakka, 2013) and the whole TP process (e.g., Gbadegeshi, 2018). Additionally, studies explored the theoretical underpinnings in practical settings, testing the derived factors and contributions in the business environment (Wohlfeil and Terzidis, 2015; Okhli et al. 2019). Associated research topics, like methods to support the identification and selection process of applications for technology, have been covered by e.g., Hartelt et al. (2015) and Veilleux et al. (2018). Few authors address the development and testing of practical approaches to identify and select applications for new technologies, despite the continuous interest in tackling the challenge of TP innovations leading back to Roberson and Weijo (1988), being followed by various studies until today (Moncada-Peternò-Castello et al. 2003; Bianchi et al. 2010; Terzidis and Vogel, 2018).

The current state of research shows that most studies investigate mostly parts in the TAS process with theoretical and practical approaches, while few address the design and testing of practical approaches to support the discovery of new applications for technology. Whereas George et al. (2016) conducted a systematic literature review (SLR) on influential factors in the opportunity recognition process, no aggregated state of the art for application identification and selection in TP exists yet.

The purpose of this study is to explore how systematic approaches to conduct TAS for new technologies need to be designed to serve industry and research as a guiding approach to foster technological innovations. Considering theoretical contributions as well as the practical perspectives of experts in the field of TP by using a mixed-methods approach, this paper follows the main objective of answering the following research questions:

RQ1: Which influential factors exist for the TAS process and which kind of challenges arise within it?
RQ2: Which kind of approaches do already exist and for which target group are they tailored?
RQ3: What is the relevant content of an systematic TAS approach and how is it compiled?

Thereby, the paper contributes to the body of knowledge on the TP field, by exploring the fuzzy field of TAS. Based on the findings, challenges, influential factors, and key concepts are identified, which provides the fundament for designing a systematic approach for TAS. The paper is organized as follows: Section 2 will present the research methodology, and section 3 will present the results of the analysis. The paper concludes with a critical discussion and identification of limitations and future research directions.

2. Methodological approach

Two phases of data collection were executed. In phase one, a SLR on the topic of TAS was conducted. Phase two consisted of semi-structured interviews to investigate the area of ideation and evaluation processes for technologies from a practical perspective.

For the first phase, a SLR has been chosen as the appropriate method to explore the challenges, influential factors, as well as methods and processes of TAS, following the approach of Kitchenham and Charter (2007). Based on the focus of the study, search terms were derived from both aspects, the application identification and selection, and TP.

“opportunity discover*” OR "opportunity seek*" OR "opportunity develop*" OR "opportunity recognition" OR "opportunity identif*" OR "application scenario generation" OR "commercial potential" OR "techno-market insight" OR "business idea generat*" OR "prospecting" OR "application identification" OR "application recognition" OR "application ideation" OR "ideation at the fuzzy front end")

AND

("technology*push" OR "spin*off" OR start*up OR NBTF OR "technology commercial*" OR "New Technology based Firm" OR "academic entrepreneur*" OR "university entrepreneur*" OR "research entrepreneur*" OR "technology transfer")

The search was initiated on the search engines Web of Science, IEEE Xplore, Business Source Premier, EconLit, and Google scholar, which resulted in 1024 results. To complete the list of relevant literature, a backward and forward search was conducted. Not accessible or relevant literature for TAS was excluded, as well as too broad literature. Afterwards, 20 studies were considered in the citation analysis. After a forward and backward search, 54 publications remained to be considered for further analysis. In the final stage of SLR process, a hand search was used to identify more frameworks and methods regarding the ideation process in TP innovation, which resulted in 66 publications at last.

No limitation on a specific date range in the search was set to avoid too narrow results in the initial search and given the fact that one of the most important publications in this field was already in 1989 by Souder. Study selection criteria, based on the research questions and refined during the search process (Kitchenham and Charters, 2007) were defined as follows: Language: English; Full-text open access; Period: 1989 – 2021; Covering the relevant parts in the TAS process. Exclusion criteria precluded the results, which were only focusing on TP processes, just touching the surface of TAS, or fulfilling none of the inclusion criteria. The complete list of references can be obtained per request to the authors.

For extending and validating the gathered insights of the SLR, interviews were chosen as a suitable complementary data collection method. Using the advantages of flexibility while giving guidance and structure at the same time, semi-structured interviews were chosen to explore the area (Kallio et al. 2016). The interviews were conducted with 20 representatives in the field of technology transfer around the USO’ ecosystem, including entrepreneurs, professors, and executives in research institutions. During the interviews, the respective function of the interviewees, as well as their individual experiences with the technology application identification and selection process were discussed. A qualitative content analysis was conducted (Mayring, 2014), following a deductive approach based on the SLR. Still, additional categories were added during the analysis if necessary.

The findings from the SLR and the interviews were used to enable an in-depth understanding of the topic of TAS as well as the derivation of influential factors, emerging challenges in the process and commonly known processes and methods, to answer the outlined research questions.
Results

2.1 Influential factors and challenges in the TAS process

To answer the first research question, influential factors in the TAS process, as well as accompanying challenges were analysed. A total of 13 influencing factors were identified, seven of which were frequently mentioned, but six only mentioned by individual sources. All influencing factors were also mentioned in the expert interviews - conversely, no new factors were added.

Prior Knowledge describes information people already have and can be separated into three major dimensions in the technology context: prior knowledge of markets, prior knowledge of ways to serve markets, and prior knowledge of customer problems (Shane, 2000). Siegel and Renko (2012) extended this by the dimension of technology knowledge, as the ideation is influenced by the relationship between technology and market knowledge. The importance of the balance of domain-specific and general knowledge for identifying new applications for technology was stated by Frishammar et al. (2012).

A widely accepted key driver of opportunity recognition is *Experience*, which is closely related to *Prior Knowledge* and illustrates a more practical perspective (Shane, 2000; Park, 2005; Rahim et al. 2015). Especially technical experience assists in the application identification process by assessing the potential and trends of a new technology (Rahim et al. 2015). The amount of identified applications for a technology increases by the amount of experience of the involved actors (Gruber et al. 2008).

Professional and Social Environment of entrepreneurs have a strong impact on their ability of opportunity recognition (Cooper and Park, 2008), as it acts as a mediator between the personal characteristics and the opportunity recognition – a change in the environment can thereby lead to the identification of an application (George et al. 2016).

Particularly the *Social Network* can act as a suitable platform to exchange knowledge, increasing possibilities to identify opportunities (Lim and Lee, 2019). Hereby, the balance of weak and strong ties plays an important role (Elfring and Hulsink, 2003). Active utilization of the social network also fosters the selection of the most promising application by assessing its potential (Franzoni, 2007).

Empirical evidence exists for *Personality Traits* in the TAS process, as some are significantly correlated with entrepreneurial behaviour (Rauch and Frese, 2007). In the context of ideation, activeness (Veilleux et al. 2018), creativity, optimism, and self-efficacy (Ardichvili et al. 2003), self-regulated learning (Abd Rahim et al. 2021), and openness to experience (Dew, 2009), risk propensity (Neill et al. 2017), self-confidence (Abd Rahim et al. 2015) are of special importance. In addition, curiosity, imagination, and open-mindedness are crucial for the identification of applications for technology (George et al. 2016).

First introduced by Kirzner (1997), the term of *Entrepreneurial Alertness* gathered popularity in terms of application identification, enabling the entrepreneur to perceive opportunities without actively searching (Baron, 2006). It can be strengthened by personality traits like creativity and optimism (Ardichvili et al. 2003) and is seen as a key determinant of the ideation process (Garcia-Cabrera and Garcia-Soto, 2009; Lim and Lee, 2019).

Besides the number of applications found by spontaneous recognition (Shane, 2000), *Systematic Search* to discover opportunities is of much importance in the field of technological innovation (Baron, 2006). By creating a linkage between changes and trends with the market, customer, and technology, entrepreneurs are even able to achieve serendipity (Dew, 2009). Furthermore, active search strengthens the opportunity development competence and deepens alertness, knowledge and experience, which in turn contribute to application identification (Garcia-Cabrera and Garcia-Soto, 2009).

Further influential factors involve *Customer Inclusion* (Holzleitner, 2015), *Clear Advantage of Technology* and *Carefully Examined Alternatives* (Bishop, 2004), *Contact with Industry and Scientific Community* (Rasmussen and Wright, 2015), and *Information Transformation* (Corbett, 2007).

The interviews confirm the influencing factors identified, although it is noticeable that these are not mentioned in equal measure - the focus in the interviews is on *Experience* and *Alertness*.

Besides the influencing factors, challenges in the TAS process are also evident, which is identified by 14 articles and extended by the interviews by six. Due to thematic overlaps, a list of eleven challenges in total was drawn up.

Grégoire and Shepherd (2012) detected a *Cognitive Challenge,* to make the connection between technology and potential target market because of superficial dissimilarities, which was also identified by Terzidis and Vogel (2018). Hence, a *Lack of related Market Knowledge* (Shane, 2000; Vohora et al. 2004) is often recognized in the ideation process. Although this challenge can be solved by combining experts with different knowledge (Shane, 2000), a *Lack of Resources*, due to missing time, energy, or financial capital impedes the process (Gruber et al. 2008; Strøm, 2018). A *Lack of Human Capital* (Vohora et al. 2004) is another challenge in the ideation process, as it is vital to discover and create entrepreneurial opportunities (Alvarez and Barney, 2007; Marvel, 2013).

Strong investigation of *Underlying Technologies* is suggested by experts, as some unexploited opportunities could be avoided due to a deeper comprehension of the technology. Furthermore, besides the fact that involving customers in TP processes is difficult, the *customer needs to be considered* when thinking about possible applications, also suggested by Henkel and Jung (2009) in their lead-user integration approach. Overall, *missing technological and entrepreneurial Alertness* hinders a promising opportunity recognition while obtaining S*ufficient Alertness* itself is also a challenge, as it is based on personality traits, knowledge, experience, environment, search process, and social network (García-Cabrera and García-Soto, 2009).

Although successful ideation is sometimes based on spontaneous recognition, enabled by alertness and prior experiences (Kuo, 2011) *Systematic Approaches* aiding at matching a technology and a market are still missing (Felkl, 2013). Furthermore, especially in the case of research-emerged technologies or technology knowledge, systematic search processes are needed to estimate potential applications of the technology. In most cases, technologies are bought from existing companies that already have concrete use cases of the technology in mind, which makes inventors quick to dismiss the possibility of their own spin-off or further development. On the one hand, there is a high demand for systematic processes that can facilitate application identification, while on the other hand, the potential impact of systematic exploration is not well understood.

The *Selection of the Appropriate Application* is also a difficult process that is rarely addressed, especially in a practical context, and is usually approached with rather random methods, such as gut feeling or decisions by hierarchical levels. Furthermore, in ideation processes that are carried out, few *Alternative or Multiple Applications* are identified, which is sometimes related to other challenges, such as *cognitive challenges* (Strøm, 2018). Although identifying different applications can mitigate risk in TP processes (Bianchi et al. 2010), as the likelihood of developing valid applications is higher, the challenge is still very significant, and supporting methods are poorly known.

2.2 Building blocks of a TAS process

Although a high need for systematic TAS processes was identified (Kuo et al. 2011; Platzek et al. 2012), isolated or no systematic approaches are known in practice. Especially actors in the USO's area expressed high interest in a structured approach to transform the technology developed in research institutions into a consumable product or service (Djokovic and Souitaris, 2008; Rothaermel et al. 2008), while the interviewed entrepreneurs that had already gone through the process showed less interest but were still open to such a process. The SLR resulted in 17 TAS approaches (Table 1), published between 1986 and 2018, and represent the existing approaches for TAS processes.

Table 1: TAS approaches in literature

Authors	Publication year	Titles
Conway and McGuinness	1986	Idea Generation in Technology-Based Firms
Roberson and Weijo	1988	Using Market Research To Convert Federal Technology Into Marketable Products
Souder	1989	Improving productivity through technology push
Lynn and Heintz	1992	From experience: where does your new technology fit into the marketplace?
Moncada-Paternò-Castello et al.	2003	Early identification and marketing of innovative technologies: a case study of RTD result valorisation at the European Commission's Joint Research Centre
Bishop	2004	A Comprehensive Model for Technology Push Product Development
Nelson	2005	A Detailed Approach for Concept Generation and Evaluation in a Technology Push Product Development Environment
Danneels	2007	The process of technological competence leveraging.
Henkel and Jung	2009	The Technology-Push Lead User Concept: A New Tool for Application Identification
Bianchi et al.	2010	Enabling open innovation in small and medium-sized enterprises: how to find alternative applications for your technologies
Evans et al.	2010	Seeding and Harvesting the Innovation Gap: Linking Technology to Social and Market Needs
Kuo et al.	2011	Reconsidering the role of brainstorming in the marketing of technology-driven innovation
Maarse and Bogers	2012	An Integrative Model for Technology-Driven Innovation and External Technology Commercialization
Felkl	2013	Advanced Technology Innovation Mapping Tool to Support Technology Commercialization
Holzleitner	2015	A comprehensive framework for successful commercialization of technology push innovations
Strøm	2018	Identification of Applications to Technology in the CERN Knowledge Transfer Group
Terzidis and Vogel	2018	A Unified Model of the Technology Push Process and Its Application in a Workshop Setting

The publication by Terzidis and Vogel (2018) was also known to some of the interviewees through their own use. Other approaches to systematic ideation were not mentioned except for *"keeping and constantly expanding and evaluating an excel list"*. The startup founders tended to develop their ideas based on identified market opportunities, to which they then identified the appropriate technology. Consequently, a strict TP process did not take place here.

The target groups of the identified approaches varied from "technology managers" (Terzidis and Vogel, 2018) to "various large companies" (Bianchi et al. 2010) to "everyone interested in technology-based product innovation" (Henkel and Jung, 2009). In summary, the approaches were designed for actors who want to turn a technology into value by identifying and selecting a suitable application to build on to trigger further development.

However, 17 concrete approaches could be identified, while all of them were found in the literature and tailored for technology manager, different-sized companies, and individuals, which answers the second research question. To tackle the third research question, the relevant content of a TAS process was examined by investigating the 17 identified approaches in more detail. Thereby six clusters were identified: *Technology characterization* (Examining the basic functional and situational characteristics), *trend assessment* (Exploration of related trends and changes), *market assessment* (Exploring related market and industry), *customer integration* (Exploring needs of customer), *value analysis* (Value assessment of market and customer) and *evaluation* (Evaluating the application with defined criteria). A clear differentiation was not possible for each approach; moreover, the approaches go into varying degrees of detail in the execution of their process.

The identified approaches contain on average about 3-5 of the clusters, while none of the approaches contain all. *Technology characterization* was mentioned in more detail in five approaches, where partly detailed information for a suitable method were given, however, all the processes started with the technology. Terzidis and Vogel (2018) suggested a Technology Canvas, which is inspired by the description of a patent. Technology Description was mentioned by Linton and Walsh (2008) and Moncada-Paterno-Castello et al. (2003). Felkl (2013) and Bianchi et al. (2010) put their focus on the functionalities of the technology.

Trend and market assessment were mentioned each four times in the processes (e.g., by Henkel and Jung, 2009), but the underlying methods were not specified, yet it was stated that it shall be close to the functions of the technology. The customer integration was just mentioned in two approaches, one focusing on the lead user (Henkel and Jung, 2009) and one analysing the customer buy decision (Felkl, 2013). Mostly, the value analysis was based on the assessment of customer benefit and technology functions (Felkl, 2013; Terzidis and Vogel, 2018). The evaluation was mentioned in three processes and based on given criteria, which support the selection of the final application (Bianchi et al. 2010; Maarse et al. 2012, Terzidis and Vogel, 2018).

2.3 Requirements for a systematic TAS process

The research has shown that processes developed so far contain the most important building blocks of a TAS process. However, the influencing factors and challenges that can affect and arise in such a process should also be considered here. Although there is already some overlap, blocks to be added are the use and expansion of human capital, the consideration of limited resources, the identification of alternative and multiple application fields, and the structured evaluation of identified applications, as the literature shows, that those can highly influence the process and are not found or specified in the existing processes yet.

The outline of identified challenges, influencing factors, and clusters of existing processes provide a comprehensive picture of the requirements that a process should address to support a systematic TAS process. To make these findings tangible, they are transformed into concrete requirements. These should be considered in future processes to ensure that the TAS process becomes more impactful. The requirements for a systematic and effective TAS process are listed below.

1. The process needs to enhance the user's knowledge of markets, trends, and technology
2. The process must enable users to understand the underlying function of the technology and to connect this to potential markets and industries
3. The process must support users to make use of and extend their human capital
4. The process must provide guidance on how to explore multiple and alternative applications
5. The process must enhance users to consider potential customer and their needs
6. The process must enable users to do the technology application selection within limited resources
7. The process must enable users to evaluate their ideas in a structured manner

The requirements presented function as guiding recommendations for designing TAS processes more systematically in the future, as previously developed processes didn't specify, how they were developed nor presented a detailed evaluation approach. Hence, they combine the current theoretical and practical findings in this field, which in turn may lead to encouragement to seek to transform more frequent technologies into value.

3. Discussion

Technology push and market pull innovation strategies have an important function in the management of innovative ideas, technologies, and trends (Maier et al. 2016). The coexistence of these two approaches has led to numerous debates over the last decades, and the focus has been shifted several times from paying more attention to technology push approaches to promoting market pull approaches (Guo et al. 2020). As market pull is a rapid and simple methodology that is expected to be successful in the short term, it has increasingly become the focus of entrepreneurial activities in recent years (Maier et al. 2016). In this context, the human-centred methodology "Design Thinking" has become progressively prominent and has become an integral part of almost every organisation Thinking (Leavy, 2012). However, the major difficulty in this case is that disruptive or radical innovations rarely emerge. This contrasts with technology push innovations - however, here the high risk due to high uncertainty and high costs is a deterrent (Herstatt and Lettl, 2000).

Studies show that authors have been working on the topic of TAS and the corresponding processes for more than 20 years to make technology push innovations more acceptable. Despite the comparatively long period of investigation, research is still in the early stages of finding the answer to the question of how to design a systematic process to make a systematic TAS process more tangible and thus reduce the barrier to entry.

The last few years have been characterized primarily by market-pull approaches and have brought corresponding innovations to the market (El Abjani and Ghafs, 2020). Still, the need for systematic approaches to transform technology into value is present, especially among technology-driven companies, but also among research institutions which come up with new technologies or new technological knowledge, seeking for applications (Geum et al. 2015). While further research has been undertaken in this area, due to the prominence of the design thinking methodology and the according shaping of entrepreneurial activities in the sense of the market pull approach, the focus on technology push innovations has faded into the background (El Abjani and Ghafs, 2020).

To transform this status, a detailed examination of technology push innovations, in particular the fuzzy front end, is necessary to make them tangible and thus relevant for entrepreneurs and researchers (Stevens, 2014). The approaches identified during the systematic literature research show a solid basis for the discussion of technology application selection processes, which can be seen as drivers for technology push innovations.

However, none of the approaches has yet been able to establish itself or achieve popularity, such as it is the case for the design thinking approach whereby here no declaration is known. Although many approaches are already trying to close this deficit, at least the practical perspective suggests that there is still room for improvement. In addition, the development of an applicable TAS approach can lower the inhibition to technology-push innovation, which could result in more technology-based ideas and companies, as well as the aggregation of existing knowledge through increased awareness of the topic to further develop the processes.

4. Conclusion, limitations, and further research

This research enables a wider understanding of the underlying factors and challenges, occurring in the TAS process. A total of 13 influencing factors were identified, out of which six were only included through individual references. The results of the interviews confirmed the most frequently mentioned factors in this context, but in particular experience and alertness. Furthermore, a total of eleven challenges in the TAS process were identified, of which fourteen were identified through paper and six through interviews - with the elimination of thematic duplication yielding the final eleven.

Altogether, 17 approaches towards a TAS process were identified in the systematic literature review. The results of the interviews demonstrated that the only systematic approach known was the TAS approach by Terzidis and Vogel (2018), which were used by the interviewees themselves.

Furthermore, by reviewing the identified approaches, the research provides the building blocks of existing systematic approaches, transforming them into requirements for a systematic TAS process. By reviewing the status quo and summarizing the previous research in this field, a clear picture of the TAS process is provided, which can be used as a basis for further investigations.

Nevertheless, this study faces its limitations. Although the small number of experts provides an initial estimate of the overall situation, it is not indicative of the population. Besides that, the fuzzy nature of the TAS environment might exclude experts, which are more experienced in this field, but not identified as those yet. Another limitation is the wording of the Technology Application Selection process, as some stakeholders are more familiar with other terms.

Moreover, the search string and the quality criteria narrow the search radius accordingly, which could have excluded potential promising and relevant research. Furthermore, the identified processes are equally analysed, besides their narrow and unspecific target groups, which may lead to inconsistencies in the association.

In further research, a specific target group could thus be identified, and interviews tailored accordingly, with a wider field of experts and stakeholders. Additionally, cases could be investigated where technologies have already been transformed into value. In these settings, similarities to identified processes and building steps in the processes could be identified and influencing factors and challenges could be aligned. Furthermore, the requirements that have been worked out should be reflected on to check the projectability of these requirements for various scenarios as well as test them with the given approaches.

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