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Technology Application Selection – the TAS Framework

Finding promising applications for new and emerging technologies

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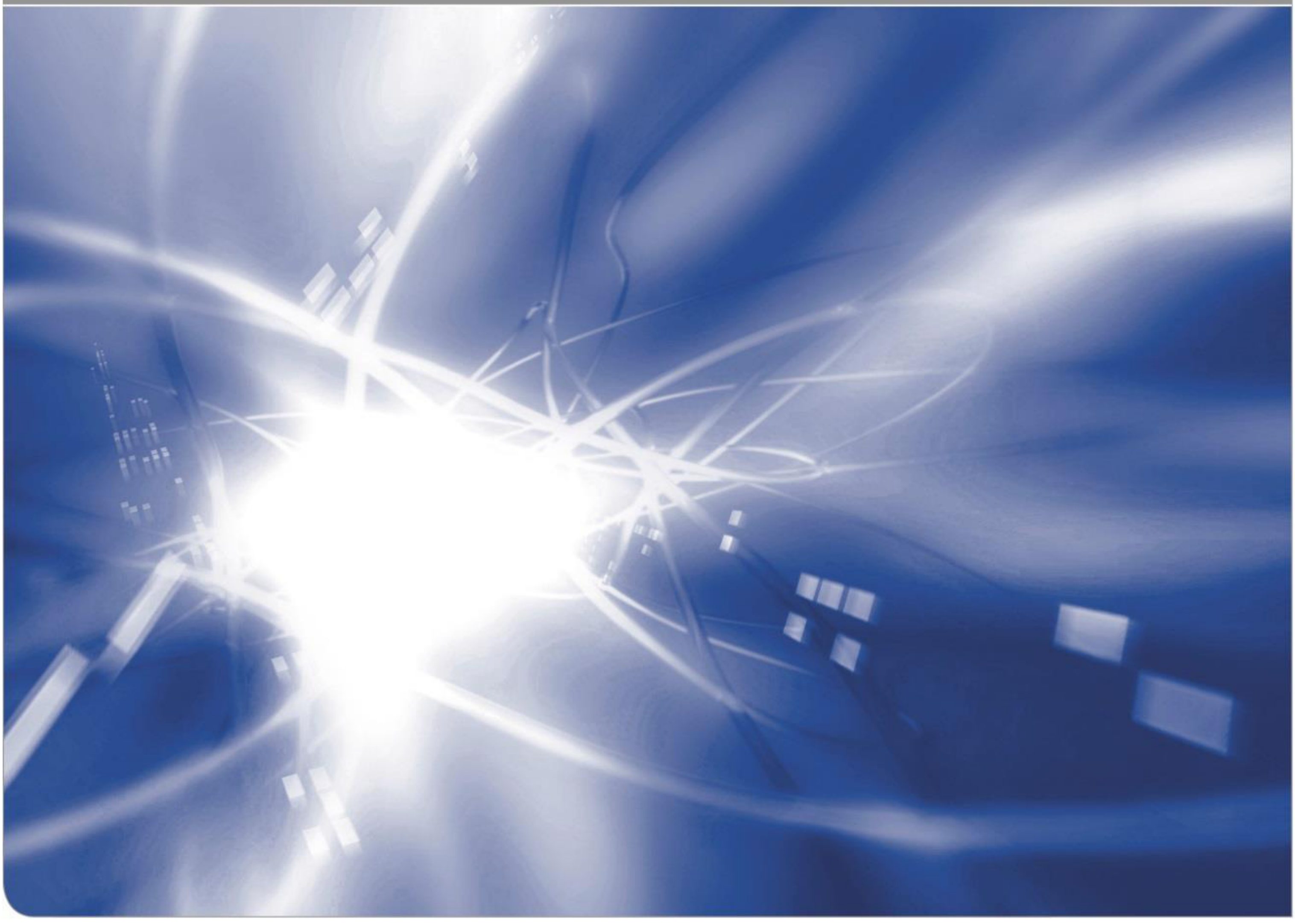

Abstract

Technological innovation has always been an important factor for economic success. Several ways to explore technological innovation exist, whilst it mostly arises from research. Due to the complexity and the accompanying uncertainty of its successful commercialization and the long duration of its research and development, technological opportunities mostly endeavor unexplored. One of the main challenges of technological innovation is the identification of application fields for the respective technologies. To tackle this challenge, various research has investigated this and developed conceptual and practical frameworks for a guided application identification process. Still, detailed guidance for a technology application identification is missing. Here, the TAS – the Technology application selection framework comes into play, which will be presented in this paper.

Abstrakt

Technologische Innovation ist seit jeher ein wichtiger Faktor für den wirtschaftlichen Erfolg. Es gibt verschiedene Möglichkeiten, technologische Innovationen zu erforschen, wobei diese meist aus der Forschung hervorgehen. Aufgrund der Komplexität und der damit einhergehenden Ungewissheit ihrer erfolgreichen Kommerzialisierung und der langen Dauer ihrer Forschung und Entwicklung bleiben die technologischen Möglichkeiten meist ungenutzt. Eine der größten Herausforderungen der technologischen Innovation ist die Identifizierung von Anwendungsbereichen für die jeweiligen Technologien. Um diese Herausforderung zu bewältigen, haben sich verschiedene Forschungsarbeiten damit befasst und konzeptionelle und praktische Rahmen für einen geführten Prozess der Anwendungsidentifizierung entwickelt. Dennoch fehlt es an einer detaillierten Anleitung für die Identifizierung von Technologieanwendungen. Hier kommt das TAS - das Technology Application Selection Framework - ins Spiel, das in diesem Beitrag vorgestellt wird.

Introduction

Technological knowledge generated at universities has gained a high priority in recent years. Both researchers and practitioners agree that universities and other public research organisations are some of the main sources of innovation (Tidd & Bessant, 2011). Especially technological innovations are crucial for a country's economic growth (Kirchberger & Pohl, 2016) and play a vital role in the innovation policy to support the creation of university spin-offs (Wright et al., 2007). According to Kirby (2011), universities need to contribute to society by creating research that can be commercialized into new products or services.

University spin-offs can be narrowly defined as firms that exploit intellectual property or patented inventions generated from university research (Di Gregorio & Shane, 2003). They represent one of the commercialization methods and are considered an important mechanism for transferring new technologies to industry (Kivimaa et al., 2017; Gbadegeshin, 2017). Besides that, unexploited technological breakthroughs can be transformed by them (van Burg et al., 2008). However, to generate value, it is important to introduce these technological innovations successfully to the market (Kirchberger & Pohl, 2016), as good technologies usually do not sell themselves (Gibson & Smilor, 1991).

To achieve success from the exploitation of technological innovation, an appropriate commercialization mechanism for the new technology needs to be selected and deployed (Aslani et al., 2015). Besides the creation of a new venture or spin-off further methods exist, yet few studies have addressed the commercialization process of spin-offs (Segui-Mas et al., 2016) and how the new technology is transformed into a consumable product or service (Djokovic & Souitaris, 2008; Rothaermel et al., 2008).

Even though the importance of the creation and dissemination of knowledge at universities as an important driving force for technological innovation and economic growth is highlighted by scholars and commercialization is desired (Muller et al., 2004), many newly developed technologies remain untouched. By having a heavy focus on research, universities, institutes, and R&D departments lack thinking about implementation from the start (Caetano & Amaral, 2011) and scientific approaches for identifying suitable applications (Lynn & Heintz, 1992). In conclusion, the lack of suitable applications is one of the key factors why the commercialization of a new technology does not occur.

Since the application and commercialization of new technologies are crucial for technological innovation, it is important to find ways to explore the potential of new technologies (Henkel & Jung, 2009). This early stage in the innovation process, also known as Fuzzy-Front-end (FFE), involves the so-called pre-phase zero of the development phase (preliminary opportunity identification, market and technology analysis) (Khurana & Rosenthal, 1997). Several studies highlight the importance of the fuzzy front end (Atuahene-Gima, 1995; Booz, Allen & Hamilton, 1982; Dwyer & Mellor, 1991; Shenhar et al., 2002). According to Cooper and Kleinschmidt (1994), the quality of pre-development activities determines the success of the product development, as the FFE decides which projects will be executed (Verworn et al., 2006).

Technology Push vs. Market Pull

In the Fuzzy Front End of innovation, mainly two concepts are located: Technology Push and Market Pull (Koen et al., 2001). Market Pull (MP) innovations usually start with unsatisfied customer needs or identified problems in the market, while Technology Push (TP) is mainly triggered by internal or external research with the objective to commercialize the application of knowledge or a specific new technology (Maier et al., 2016). In contrast to MP, potential market opportunities and areas of application are yet unknown (Henkel & Jung, 2009). Studies have indicated that the TP strategy is the least common approach (Kostoff & Schaller, 2001). One reason for its sporadic use is that TP is seen as more difficult and time-consuming, as market opportunities and use cases need to be drafted in advance (Herstatt & Lettl, 2004). Nevertheless, both TP and MP innovation strategies are important factors for the effective management of ideas, technologies, and trends (Maier et al., 2016). Table 1 outlines the differentiation between the innovation approaches.

	Technology Push	**Market Pull**
Trigger	Company Supplier	Market Customer
Focus	R&D Activities	Customer insights Market research
Market uncertainty	High	Low
Time horizon	Long-term	Short to medium-term
Degree of innovation	High	Low/ medium
Objectives	Generating new application fields	Improvement of existing products/ applications

Table 1: Comparison of the innovation approaches technology push and market pull, inspired by Maier et al., 2016

As technological change can be the most powerful engine of growth, by fueling the growth of new brands, creating new markets, or transforming small outsiders into market leaders, TP innovations have radical innovation potential (Chandy & Tellis 1998; Christensen, 1997; Foster, 1986; Souder, 1989). Furthermore, it can have a positive impact on international trade, industry structure, growth, and development of new and existing firms and industries (Utterback, 1971, p. 76). However, before a technological innovation can bring about change, its application must be uncovered (Shane, 2000). As the risk of identifying wrong or no applications is quite high, an appropriate process of application identification is of great importance (Kuo et al., 2011; Platzek et al., 2012). Stated by several authors, the systematic identification of market opportunities for new technologies are rarely addressed by researchers and thereby scarce in literature, which also results in a lack of adequate tools (Henkel & Jung, 2009; Platzek et al., 2012; Felkl, 2013). However, methods are crucial to cope with the high ambiguity and uncertainty in the fuzzy front end of technology innovation (Felkl, 2013, p. 27-28).

A unified model of the technology push process

Numerous models exist for technology push innovations that depict different phases to support the fuzzy front end in the innovation process: To understand the whole development process of Technology Push, to communicate with stakeholders, or to better plan the different work steps (Klocke & Gemünde, 2010; Lane, 2000). Terzidis and Vogel (2018) have therefore focused in their work on creating a consolidated model, aiming to include all necessary and outlined process steps. Based on their extensive systematic literature review, a consolidated and unified model of the technology push process has been developed, which provides an overview of the different activities and steps in the technology push process (Fig. 1). The unified process model divides the different phases in foundation, technology application selection, explorative development, and product introduction, all accompanied by specific activities, which are distinguished in the technology advancement and the supporting management activities. According to Terzidis and Vogel (2018) the main phases of the process were derived from the technology advancement activities. The illustration of the activities is also complemented by the Technology-Readiness-Level, whereby no more specific distinction is made.

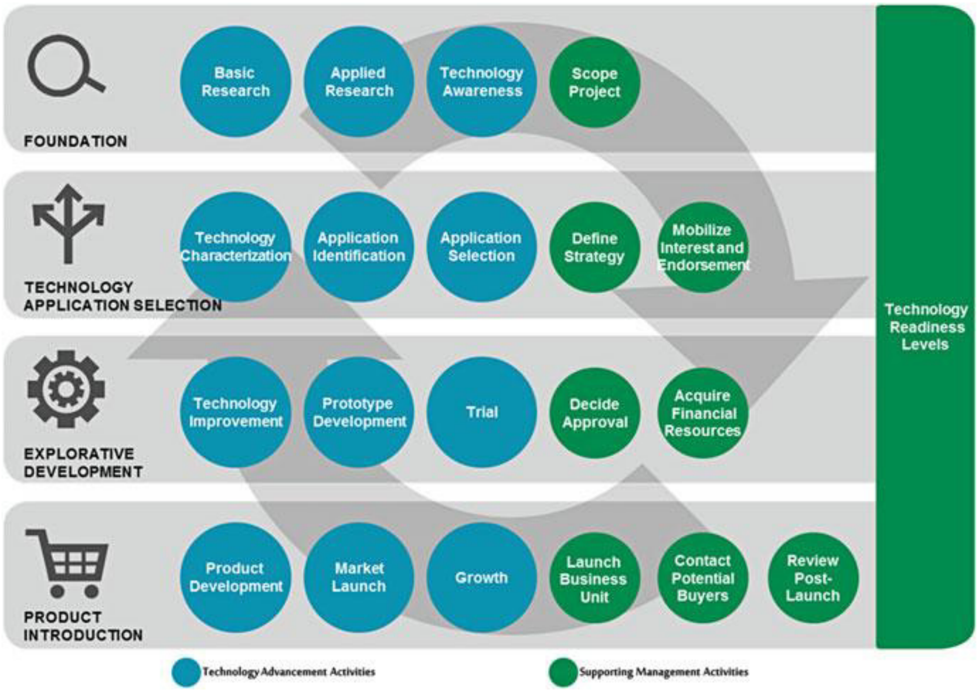

Figure 1: The unified model of the technology push process (Terzidis & Vogel, 2018)

The first phase, foundation, covers the base of the development process and focuses on the technological side on detection, planning, and finding, whereas the management side sets the project scope. In the Technology Application Selection phase, a technology must be understood in detail, several applications identified, and the most promising ideas evaluated and selected, so the strategy-idea fit can be verified and a strategy for the following process can be set. The third phase, explorative development, aims to improve and test the technology in iterative steps, to achieve approval of the management side, and to get financial resources. The product introduction covers the last phase of the unified process model, concerning the development of a market-ready product, with close market relationships and market penetration.

Besides introducing the unified process model, the authors also investigated the critical stages in the process, defined by (1) necessity for the success of technology push innovations, (2) underrepresented in practical settings, and (3) easy to support with standardized methods that can be applied to a diversity of cases. The second phase in the unified process model, the technology application selection phase, meets the criteria and was therefore chosen for further processing by the authors, which set the first version of the TAS framework.

Introducing the TAS Framework

The Technology Application Selection (TAS) Framework was developed by Terzidis and Vogel (2018) as a result of their investigation of the technology push process. It was developed for the execution in workshops and is substantiated with selected methods and tools from literature. The TAS framework belongs to the second phase of the technology push process and serves the technology advancement activities. According to Felkl (2013), this stage is improperly treated in literature. Furthermore, it's a critical key element for the success of technology push innovations (Jolly, 1997), as many technology commercialisations fail due to a mismatch of technological functions and customer needs. Furthermore, several authors already stated the high demand for an appropriate, yet easy to understand, process (Henkel & Jung, 2009; Kuo et al., 2011; Platzek et al., 2012).

The objective of the workshop aims to characterize a technology, stimulate creative idea generation about a technology application, and systematically evaluate and select the most promising ideas. It is tailored for several target groups, as the authors aimed to keep projectability across different domains. Hence, the workshop can be used by research institutions, technology transfer offices, and educators, as well as by innovators of different-sized companies.

The process constitutes of three phases: Technology characterization, opportunity identification, and application selection. The results, precisely the evaluated ideas, can be used to further develop the technology itself and the planned application to create prototypes and products. Those can then be subsequently launched onto a market.

The three phases comprise different activities to work through the technology application selection frameworks, which ensures a structured and guided technology push ideation. Figure 2 displays the different phases of the TAS Framework and outlines both, the tasks within the phases, and the expected outcome.

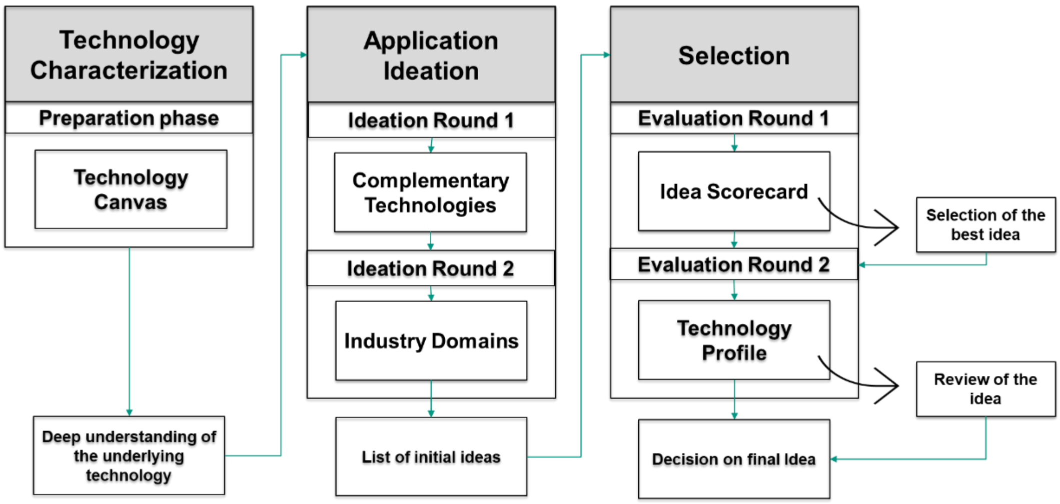

Figure 2: Phases of the Technology Application Selection Framework, own representation based on Terzidis and Vogel (2018)

The first phase sets the base for the further process and serves as a structured preparation. Therefore, the technology, on which the ideation process should be based, needs to be analysed to gather a deep understanding. Consequently, the Technology Canvas (Table 1) is used, which resembles the elements of a patent and describes the most important information to characterize a new technological invention. After this phase, it is crucial that all participants have the same level of knowledge about the chosen technology in order to be able to develop a wide variety of ideas.

Name	What is the technology called?
Problem	What problem is solved by the technology?
Technology description	What is the main idea and how does it solve the problem?
Technology benefits	What are the expected benefits of the technology?
State of the art	What are current solutions for the problem? What are alternatives?
Drawing	How can the functionality of the technology be depicted?
Technical Novelty	What makes the technology unique? How is it different from the state of the art?

Table 2: The elements of the Technology Canvas (Terzidis & Vogel, 2018)

The second phase tackles the application identification for the underlying technology. For gathering a broad number of possible applications, ideation techniques, and methods to foster divergent thinking and creativity, are chosen. Ideation methods as brainstorming or brainwriting are commonly known and thereby easily applicable. To support a result-oriented and successful technology-based ideation process, the focus lies on ideation stimuli, which form a fundamental part of several techniques (Emma, 2008). The TAS approach uses emerging technologies and industry sectors as idea stimuli to provide explicit anchors and a structured guidance for the process. Hence, the Gardner hype Cycle and the International Standard Industrial Classification (ISIC) are used. As a result, the participants should come up with several ideas out of different areas, which need to be clustered at the end of the phase. The outcome of the phase is illustrated by a clustered list of initial ideas.

The third and final phase covers the Application Selection. The participants need to shift from divergent thinking to convergent thinking and to sharpen their frame. To ensure a thoughtful selection, a two-step evaluation approach is chosen. For this purpose, the first evaluation step covers traditional market research, supported by the operationalization of the idea scorecard, which includes the most prominent evaluation factors (see Table 2). Those criteria need to be ranked from least to highly promising in the range of -2;-1;0;+1;+2. Consequently, the sum of the factors for each idea enables the ranking of the idea list. Hence, the best and most promising ideas can be selected and used for further evaluation.

Evaluation factor	**Guiding question**
Technical Feasibility	Is it technical possible to realize a product?
Market potential	Is there a market of sufficient size to create a business?
Profitability	Estimate whether the product has a chance to be profitable.
Team Values Fit	Do we have the right attitudes, resources, competencies, and commitment?
Market Entry	Are there any crucial market entry barriers to overcome?

Table 3: Evaluation Factors used in the Idea Scorecard

In the second evaluation step, the chosen idea needs to be assessed against alternatives, which are already existing in the market. To ensure the quality of the assessment, the relevant criteria to determine the final idea need to be analysed and selected, as they set the base for the comparison. Hence, the technology profile is used, which enables a visual assessment of the final idea against several competitors. Several competitors with different key factors need to be evaluated in order to estimate, if the idea is still evaluated promisingly or if another idea from the previous step should be selected for further evaluation.

Exemplary procedure of a TAS workshop in a research unit

For illustrating a typical TAS Workshop structure, an exemplary procedure of the TAS Workshop is outlined. In order to be able to map a successful process, a two-day workshop is presented.

The underlying didactic concept is twofold: One part is the introduction of terms and concepts, as well as background information on methods and tools. The complementing part involves the participation in practical workshops, where the participants work on the chosen technology and perform and carry out all three steps of the TAS process. After selecting the most promising idea, they continue with the business model development, which is not displayed in this work.

General conditions

For a successful If feasible, interdisciplinary participants with expertise in the respective areas should be involved. In addition, a group size of at least three, at most five persons is recommended. Several teams can be set for one technology, to maximize the amount of generated ideas in the second phase, but they should work independently within their teams and share their findings sequently at specific points in the process. In addition, sufficient time should be planned for the moderation of the framework, as well as for the independent elaboration of the various actions by the team.

As the initial workshop framework was planned in presence[1], specific materials need to be prepared. Those include specifically:

- Adhesive notes and appropriate pens
- Brown paper
- Pen and paper for note taking
- Glue points

Before the workshop begins, the participants receive information about the aim of the workshop as well as information about the technology to be studied in advance. This ensures a smoother process, as a deep comprehension of the technology can be a time-consuming task.

Process of the exemplary TAS Workshop

The timeline of the two-day workshop is illustrated in

Time	**Topic**	**Outcome**
10:00	Introduction and Agenda	Filled in Technology Canvas List of clustered initial ideas
10:30	Technology Characterization	
12:00	*Lunch Break*	
13:00	1st Ideation	
14:00	*Break*	
14:15	2nd Ideation	
15:15	*Break*	
15:30	Consolidation and Clustering of Ideas	
17:15	Reflection and feedback	

Table 4: Agenda Day 1 of 2

[1] To perform the workshop in a digital format, tools as MURAL or MIRO are suggested, which represent digital whiteboards.

Time	Topic	Outcome
10:00	Preselection	Reduced list of initial ideas Filled out Idea scorecard Technology Profile for top ideas Decision on the final idea
11:00	Idea sheet creation and presentation	
12:30	*Lunch Break*	
13:30	Idea selection	
14:30	Creation of Technology profiles	
16:00	*Break*	
16:15	Presentation of the technology profile	
17:00	Feedback and outlook	

Table 5: Agenda Day 2 of 2

The first day covers the first and the second phase of the TAS Framework. The first session aims at introducing the participants to the topic of the workshop and to clarify the objectives. The participants also introduce themselves (i.e. their current position, their prior knowledge of the technology). Moreover, the presentation lays out the agenda of the complete workshop to provide an overview.

This is followed by the technology characterization, which consists of three parts: Firstly, the technology is presented by an expert. Secondly, every participant defines the most important features using the Technology Canvas. Lastly, the filled in Technology Canvases are discussed and a common understanding about the technology is derived. Subsequently, the Application Identification gets initiated by two ideation sequences, which are jointly conducted. The first round focuses on the ideation stimuli “Complementary Technologies”, while the second is about “Industry domains”. Each Team brainstorms to generate a wide range of ideas, which is consequently collected and clustered into the list of initial ideas. Here, all teams contribute their ideas into one big chart. The day ends with a reflection and short feedback.

The Technology Characterization phase and the Application Identification phase will be described in more detail, to give a better overview of the respective steps.

Technology Characterization

> The presentation of the technology briefly summarizes the important features of the technology. It explains how the technology works and what it differentiates from similar technologies. The presenter is optimally the inventor him- or herself. At least, it is an expert who knows the technology very well. During the presentation, the participants engage in intensive notetaking. They note down questions and characteristics of the technology in a free format.

Subsequently, every team fills out a Technology Canvas which helps to structure the discussion and ensures that no important piece of information is missing. This is followed by a presentation of the results without discussion. Afterward, differences in the results are discussed to derive a common understanding of the technology and its characteristics. Depending on the degree of difference between the presented results, the discussion can be conducted through the different aspects of the Canvas or along common fundamentally different interpretations.

Application Identification/ Ideation

The participants are subdivided into tandems to improve the chance to individually contribute to the ideation process. In order to stimulate creativity, each group is assigned to a specific station that features a stimulus. After 10 minutes, the groups rotate, which is repeated every 10 minutes so that after 50 minutes, every group has received each stimulus. During the 10 minutes, the participants produce as many ideas as possible without judgement or any selection process. Each team receives its own color to define the authorship of the idea.

Which stimuli are used depends largely on the technology at hand. Useful search areas are technological trends (e.g. Gartner Hype Cycle) and relevant industries that might benefit from the technology. The stimuli are headlines with a short description and some pictures to give a general idea about the topic. Depending on the available time, the ideation process can be repeated to create more ideas based on other stimuli.

All ideas are presented station-wise. For each station, every group presents their ideas to the other groups before moving on to the next station. The ideas are moved to a central location (e.g. large brown paper on the wall). After each idea, the moderator asks whether the idea fits other ideas which are already on the wall. Moreover, duplicates from other stations can be immediately added to the wall by the respective group. In order to reduce the number of ideas to a maximum of 20, glue points are used. Each participant receives three to five glue points, to support the idea (maximum two points per idea). The top 15-20 ideas are chosen for further investigation. After all the ideas have been presented and the top ideas have been chosen, more clusters of ideas are formed by asking how the ideas can be rearranged and grouped. Names of the idea clusters are found through a group discussion, which the participants write down to trigger more thought processes after the session is over.

The second day covers the application selection and results in the decision on a final application selection for the technology. For the re-connection to the previous day, the workshop starts with a recall of all the different ideas generated on Day 1. Therefore, the ideas are equally assigned to all participants, who present them in front of the whole group. The further process includes just those ideas, which are supported at least by two participants, who base their assumptions on the general potential of the ideas.

To evaluate the ideas in the first place, the idea scorecard is used. Based on the previous selection of 15 to 20 ideas, the evaluation is conducted in the whole group. Therefore, the respective ideas are analysed individually on the given evaluation criteria. The participants decide collectively on the number of points they want to assign to each factor for the underlying idea. After all ideas have been evaluated in this way, the sum of each idea is calculated and ranked, with the most promising idea having the most points. The final outcome is the list of the top ideas – the number of those depend on the number of groups (e.g. five top ideas are chosen, if the workshop consists of five groups).

Each of the top ideas is transferred to the next evaluation step and subjected to the next analysis. Each team is working on one of the top ideas independently and then present the results they have worked out to each other.

Building upon this, the technology profile is used. This tool supports the evaluation of the chosen idea against the competition on the market. It analyses the most promising factors of the chosen idea and compares those to direct and indirect competition. Depending on the outlined promising factors, the selection might differ, as one competitor might be focused on one factor mostly, while the other satisfies the relevant factors in another way. Overall, the results need to be put on the technology profile (several ones can be used, depending on the selection) and presented to the other groups. In the following discussion the most promising idea based on the given evaluation is used for the further business model development.

The Application Selection phase will be described in more detail, to give a better overview about the respective steps.

Application Selection

1st Evaluation

The first evaluation is a simple scoring evaluation based on five equally weighted criteria: Technical feasibility, Profitability, Market potential, Team Values Fit and Market Entry. The participants discuss the several factors for each of the remaining ideas jointly, to figure out the final rating. Here, the discussion represents an important step, as the participants share their point of view on the respective factors and a commonly understanding is carried out. Furthermore, it is more likely to reach consensus in the group regarding the final ranking of the ideas, as this is an important factor, influencing the intrinsic motivation of the individuals in the further process. The outcome of this step is the ranked idea scorecard, starting with the idea with the highest amount and representing the most promising idea so far.

2nd Evaluation

The second evaluation is represented in the technology profile, which is used to evaluate a technology regarding its capability to satisfy the most relevant factors of the final product/service. Therefore, the first step is the research of potential competing technologies. The participants should find the currently used technology as well as other prospective entrants. Afterwards, both the technology at hand and the alternatives are scored on a 0-100% scale for each of the identified relevant factors, depending on how likely they are addressed. Lastly, the results are put on a technology profile poster with adhesive notes and then presented to the other groups. Based on these findings, the most promising idea out of the evaluated top ideas is chosen for further working with.

Optional the idea sheet can be used as a supporting tool in this step, as it is designed to briefly describe an application idea. By that, a specification of the idea and the integration in practice is outlined and can support the final decision on one idea at the end of the TAS Workshop.

Name	**Description**
Title	Name of the application idea
Team	Team that works on the idea
Problem/Area of application	Description of the application area and the problem to be solved
Solution/Drawing	Description of how the solution works and what it looks like
Advantages/Disadvantages	Description of the aspects that are advantages and disadvantages over alternatives

Table 6: Elements of the idea sheet

To evaluate the specific steps and the TAS workshop an evaluation is suggested at the end of the second day. Optionally it can be used after every phase, to improve in a formative way. In the evaluation process every participant is given the opportunity to name positive and negative aspects in a constructive manner and to comment on the workshop process and the content.

Conclusion

Based on the existing literature and strong expertise in the field of technology entrepreneurship, this paper presents a structured, science-based, and practice-oriented tool for educators, innovation managers, researchers, and entrepreneurs. The workshop design allows the TAS framework to be applied in several context, while the structured design helps the facilitators and the participants to elaborate each step with appropriate depth and systematically work out the application identification and selection process.

Literature

Aslani, A., Eftekhari, H., Hamidi, M., & Nabavi, B. (2015). Commercialization methods of a new product/service in ICT industry: case of a science and technology park. *Organizacija*, *48*(2).

Atuahene-Gima, K. (1995). An exploratory analysis of the impact of market orientation on new product performance: a contingency approach. *Journal of Product Innovation Management: an international publication of the product development & management association*, *12*(4), 275-293.

Booz, Allen & Hamilton. (1982). New Product Management for the 1980's. *Inc., New York*.

Caetano, M., & Amaral, D. C. (2011). Roadmapping for technology push and partnership: A contribution for open innovation environments. *Technovation*, *31*(7), 320-335.

Chandy, R. K., & Tellis, G. J. (1998). *Organizing for radical product innovation* (pp. 0225-0225). Marketing Science Institute.

Christensen, C. M. (1997). The Innovator's Dilemma: When New Technology Causes Great. *Firms to Fail (Harvard Business School Press, Boston)*.

Cooper, R. G., & Kleinschmidt, E. J. (1994). Determinants of timeliness in product development. *Journal of Product Innovation Management: An international publication of the product development & management association*, *11*(5), 381-396.

Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others?. *Research policy*, *32*(2), 209-227.

Djokovic, D., & Souitaris, V. (2008). Spinouts from academic institutions: a literature review with suggestions for further research. *The journal of technology transfer*, *33*(3), 225-247.

Dwyer, L., & Mellor, R. (1991). Organizational environment, new product process activities, and project outcomes. *Journal of Product Innovation Management*, *8*(1), 39-48.

Emma, Philip. 2008. “A Collaborative IP-Development Session.” IEEE Micro 1 (28): 112–111.

Felkl, J. (2013). Advanced technology innovation mapping tool to support technology commercialization.

Foster, W. K., & Pryor, A. K. (1986). The strategic management of innovation. *Journal of Business Strategy*.

Gbadegeshin, S. A. (2017). Commercialization process of high technology: A study of Finnish University Spin-off. *Academy of Entrepreneurship Journal*, *23*(2), 1-22.

Gibson, D. V., & Smilor, R. W. (1991). Key variables in technology transfer: A field-study based empirical analysis. *Journal of engineering and Technology Management*, *8*(3-4), 287-312.

Henkel, J., & Jung, S. (2009). The technology-push lead user concept: a new tool for application identification. *Unter Mitarbeit von Stefan Jung*.

Herstatt, C., & Lettl, C. (2004). Management of" technology push" development projects. *International Journal of Technology Management*, *27*(2-3), 155-175

Jolly, V. K. (1997). Commercializing new technologies: getting from mind to market. *Harvard Business Press.*

Khurana, A., & Rosenthal, S. R. (1997). Integrating the fuzzy front end of new product development. *IEEE Engineering Management Review*, *25*(4), 35-49.

Kirby, D. A., Guerrero, M., & Urbano, D. (2011). Making universities more entrepreneurial: Development of a model. *Canadian Journal of Administrative Sciences/Revue Canadienne des Sciences de l'Administration, 28(3)*, 302-316.

Kirchberger, M. A., & Pohl, L. (2016). Technology commercialization: a literature review of success factors and antecedents across different contexts. *The Journal of Technology Transfer*, *41*(5), 1077-1112.

Kivimaa, P., Boon, W., & Antikainen, R. (2017). Commercialising university inventions for sustainability—a case study of (non-) intermediating 'cleantech'at Aalto University. *Science and Public Policy, 44(5)*, 631-644.

Klocke, B., & Gemünden, H. G. (2010). Exploration and exploitation in high-technology start-ups: a process model for new fi rm development. *Handbook of research on high-technology entrepreneurs, Malach-Pines Text*, 57-83.

Koen, P., Ajamian, G., Burkart, R., Clamen, A., Davidson, J., D'Amore, R., & Wagner, K. (2001). Providing clarity and a common language to the "fuzzy front end". *Research-Technology Management*, *44*(2), 46-55.

Kostoff, R. N., & Schaller, R. R. (2001). Science and technology roadmaps. *IEEE Transactions on engineering management*, *48*(2), 132-143.

Kuo, D. C. L., Lin, C. C., & Yang, J. L. (2011). Reconsidering the role of brainstorming in the marketing of technology-driven innovation. *International Journal of Technology Marketing, 6(1),* 4-16.

Lane, J. P. (2000). Applications for a technology transfer model. In Proceedings of the RESNA 2000 Annual Conference, Arlington, RESNAPRESS (pp 282–284). ERIC.

Lynn, F., & Heintz, S. (1992). From experience: where does your new technology fit into the marketplace?. *Journal of Product Innovation Management*, *9*(1), 19-25.

Maier, M. A., Hofmann, M., & Brem, A. (2016). Technology and trend management at the interface of technology push and market pull. *International Journal of Technology Management, 72(4),* 310-332.

Müller, C., Fujiwara, T., & Herstatt, C. (2004). Sources of bioentrepreneurship: the cases of Germany and Japan. *Journal of Small Business Management, 42(1),* 93-101.

Platzek BP, Pretorius L, Winzker DH (2012) Sustainability in technology driven business environments: a company-level approach. In: *Proceeding of the 2012 PICMET'12: technology management for emerging technologies, IEEE, Vancouver,* pp 1195–1208.

Rothaermel, F. T., & Boeker, W. (2008). Old technology meets new technology: Complementarities, similarities, and alliance formation. *Strategic management journal*, *29*(1), 47-77.

Seguí-Mas, E., Sarrión-Viñes, F., Tormo-Carbó, G., & Oltra, V. (2016). Scientific production in the field of academic spin-off: A bibliometric analysis. *Intangible Capital*, *12*(1), 246-267.

Shane, S. (2000). Prior knowledge and the discovery of entrepreneurial opportunities. *Organization science*, *11*(4), 448-469.

Shenhar, A. J., Tishler, A., Dvir, D., Lipovetsky, S., & Lechler, T. (2002). Refining the search for project success factors: a multivariate, typological approach. *R&d Management*, *32*(2), 111-126.

Souder, W. E. (1989). Managing new product innovations.

Terzidis, O., & Vogel, L. (2018). A unified model of the technology push process and its application in a workshop setting. In *Technology Entrepreneurship* (pp. 111-135). Springer, Cham.

Tidd, J., Bessant, J. (2011). Managing Innovation: Integrating Technological, Market and Organisational Change (4th ed.). *Wiley: Chichester.* Utterback, 1971, p. 76

Van Burg, E., Romme, A. G. L., Gilsing, V. A., & Reymen, I. M. (2008). Creating university spin-offs: a science-based design perspective. *Journal of Product Innovation Management*, *25*(2), 114-128.

Verworn, B., Herstatt, C., Stockstrom, C., & Nagahira, A. (2006). " Fuzzy Front End" Practices In Innovating Japanese Companies. *International Journal of Innovation and Technology Management*, *3*(01), 43-60.

Wright, M., Clarysse, B., Lockett, A., Mustar, P., & Knockaert, M. (2007). Academic spin-offs, formal technology transfer and capital raising. *Industrial and Corporate Change*, *16*(4), 609-640.

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