

# A Technology Push Approach To Application Identification

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# Abstract

Detecting potential applications to technology is widely regarded as an important activity of technology based organizations; either to increase returns on previous research, or to identify potential market opportunities for new inventions. Indeed, as a technology may be combined with applications in multiple ways, the majority of new technologies are likely to have commercial potential as distinct applications in different markets. However, technology push application identification (TPAI), is highlighted as theoretically underdeveloped.

Therefore, this thesis investigates the field of TPAI. To provide a systematic and comprehensive overview of the subject, a literature review was conducted. Literature was acquired by including (1) relevant work found through structural searches, (2) relevant references cited in the selected articles, and (3) relevant articles citing already acquired articles.

The procedure resulted in 33 articles investigating TPAI. The oldest paper dates back to 1989, whilst half of the reviewed papers were published after 2010. The reviewed literature is spread over four different research schools; respectively technology transfer, open innovation, product development and business innovation. Very few of these studies build upon each other, or use the same vocabulary to describe TPAI. The studies propose different strategic tools for TPAI in practice. These are either tools for customer involvement, creative tools or analytical tools, or a mix of the three.

Analyzing the literature, the authors found two major approaches to TPAI; exploitation and exaptation. The exploitation perspective is characterized by studies in which the objective for TPAI is to discover existing applications for technology. The relating tools are analytical or customer involving. Regarding the exaptation perspective, this is characterized by studies striving to detect radical or new-to-the-world applications for technology. Tools associated with this perspective are creative or customer involving. In addition, the authors uncovered two major challenges for TPAI, market ambiguity and application bias. Both of these challenges are apparent for exploitation and exaptation alike.

To reaffirm TPAI as a prominent research field, further research is suggested to approach the daunting task of unifying the theories of TPAI, as well as building further on the exaptation and exploitation findings from this study. Furthermore, the authors suggest to add to the technology transfer school of research regarding TPAI.

# Acknowledgments

This thesis was written to contribute the pre-master work of Victoria Isern and Ranveig Strøm, fall 2016. Both authors are students at the Norwegian University of Science and Technology School of Entrepreneurship (NSE). The project objective is to explore a technology push approach to application identification.

Besides immersing themselves in the pre-master project, the authors have participated in the course TIØ4535 - Classical Entrepreneurship, at NTNU. In combination with the deliverables of the latter, this thesis will serve as the foundation for the coming master project.

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# 1. Introduction

## 1.1 Importance of Topic

Research from technology push environments are a main source of technological innovation (Hindle, 2004). If exploited, technological innovations can potentially lead to a profusion of commercial opportunities (ibid.). However, the process of commercializing technology is complex (Dorf and Worthington, 1987), and a key element for technology commercialization is the identification and evaluation of the technology's market potential (ibid.). Hence, the degree to which a technology push organization is able to successfully commercialize technological innovations, depends on its ability to identify suitable markets (Roberson and Weijo 1988; Slater and Mohr 2006) and the associated application areas.

Technologies in need of an application, for commercialization, is a common situation for technology push organizations (Lynn and Heintz, 1992). Technology push and market pull are integration strategies for commercializing technology (Porter, 1985; Dodgson, 2000; Schumpeter, 1982). The predominating integration strategy of organizations devoted to research or technology development, or both, is technology push (Kostoff & Schaller, 2001; Lee et al., 2007; Spithoven et al., 2011). A technology push organization focus on inventing a technology without regard for market attractiveness (Caetano and Amaral, 2011). In particular, public research centres, universities and research departments often are technology push organizations. Technology push innovations, when they succeed, often perform better than market pull innovations (Walsh et al., 2002; Kirchhoff et al., 2007). However, it is argued that technology push inventions fail more often than market pull innovations (Herstatt and Lettl, 2004).

The importance and impact of facilitating for the exploitation of developed technologies is more relevant than ever with the rise of open innovation (Caetano and Amaral, 2011). The increasing complexity of products combined with the rapid pace of technological change, has led to growing research and development (R&D) and commercialization cooperation between organizations (Chesbrough, 2003; Petroni et al., 2012). Both organizations and society benefit from this change as more technology

is utilized to its full potential, and might contribute to both increased wealth as well as industrial development (Autant-Bernard, 2001; Beise and Stahl, 1999; Di Gregorio and Etzkowitz and Leydesdorff, 2000; Feller et al., 2002; Roberts, 1991; Shane, 2001, 2003). Moreover, there are increasing calls from stakeholders of technology push environments to optimize innovation capabilities (Razak et al., 2014).

The strategy of gaining competitive advantage through searching for alternate market opportunities for developed technologies is not novel. In fact, Schumpeter's (1939) defined a third type of innovation, where a new domain of use and new market, is revealed through a new application of an existing technology. Moreover, detecting potential applications to technologies is widely regarded as an important activity of organizations, either to increase returns on previous research (Hayek, 1945; Stigler, 1961; Fiet, 1996), or to identify potential market opportunities for new inventions (Gruber et al., 2008). However, application identification in a technology push context, is highlighted as theoretically underdeveloped (Gregor and Hevner, 2015).

For a technology push organization the capability of detecting application areas for technology is key for technological commercialization. Indeed, as a technology may be combined with applications in multiple ways (Henkel and Jung, 2010), the majority of new technologies are likely to have commercial potential as distinct applications in different markets (Teece, 1982, 1986; Mahoney & Pandian, 1992; Trott & Cordey-Hayes, 1996; Danneels, 2007; Gruber et al., 2008). Thus, finding a solution to the problem of matching a technology to an application is of high interest (Jolly, 1997; Shane, 2004), as the starting point for technology push innovation is application identification (Utterback, 1971; Lynn & Heintz, 1992; Chidamber and Kon, 1994).

For this thesis the search and identification of new or existing areas of application for a technology, that is already invented for a given purpose, is defined as technology push application identification (TPAI). The term is coined by the authors and will be applied in this thesis to describe any approach to application identification in a technology push context, that is found in relevant literature regardless of original terminology.

## 1.2 Purpose of Literature Review

This project thesis is a literature review investigating the subject of TPAI, functioning to provide a comprehensive overview of the field. The authors have searched thoroughly, but have not been able to find any existing literature review specifically relating to TPAI. Although, a recent literature review by Kirchberger (2016) looks into technology commercialization and remarks that the process of identifying new applications to technology seems to be under-researched. The field seems to be quite fragmented and several schools have been found to discuss the topic, often using different terminology. Indeed, like Kirchberger (2016), several studies express the need for research on TPAI. Therefore, the authors intend to meet this need with this study, and contribute to the the TPAI research field. The authors believe conducting a literature review on TPAI to be the natural first step in developing TPAI as a scientific branch. A literature review of TPAI enables the authors to gain an understanding of the extent of today's literature. Without such an overview it is impossible to know how further research can advance the previous research (Randolph, 2009). Finally, a review will highlight gaps in literature concerning TPAI, thus pointing out interesting directions for further studies on TPAI. Hence, in this study the authors will approach the following purpose:

*"To explore what literature says about identifying applications of new technology in a technology push context"*

## 1.3 Research Questions

In this literature review the primary objective is to detect what previous literature says about TPAI. To attain the purpose, it is necessary to understand what characterizes the literature considering TPAI, and to get an overview of the different tools utilized across technology push organizations. Thus, the authors have designed the following two research questions (RQs):

*RQ1: What characterizes the studies included in the literature concerning technology push application identification?*

*RQ2: What strategic tools for application identification can be found in literature concerning technology push application identification?*

The RQs lay the foundation for understanding how TPAI is approached, and what tools may be utilized to successfully detect promising new applications for technology. Altogether, the RQs will help narrow the search for relevant literature and assist in revealing findings about TPAI in literature. RQ1 is constructed to gain knowledge about the distinct studies concerning TPAI. In particular, the characteristics of interest are which school of research they represent, when they were published, the purpose of the study and its findings. On the other hand, RQ2 is constructed to give an indepth understanding of each study, especially with regards to any suggested strategic tools for TPAI. In this paper, strategic tools are defined as either methods, processes or frameworks for conducting TPAI in practice. Moreover, RQ2 implicitly adds up to getting an overview of when different strategic tools are suggested, and why.

The literature review of this thesis is the chosen method of investigation to reveal findings from the two RQs. Eventually, through careful analysis the reviewed literature will form a foundation where gaps in TPAI literature are revealed suggesting the path for further research.

## 1.4 Structure of Thesis

So far TPAI has been introduced and the need for a literature review has been argued and presented. The following chapters will present and discuss the methodology, the theory and the findings respectively. Chapter '2. Methodology' will present the plan for the review, and how the literature was found and selected, as well as reflections on the methodology. Chapter '3. Theory' will present the selected literature and give an overview of the main content, its similarities and differences, followed by a discussion of the findings from the literature review. Chapter '4. Conclusion' includes final remarks on the literature review, practical implications of the findings and suggestions for further research.



## 2. Methodology

A systematic literature review was chosen to cover the literature field in a thorough manner. In order to do this, the recommendations of White & Schmidt (2005) and Tranfield et al. (2003) was followed. A systematic review should retrieve, appraise and summarize all available theory and studies regarding a specific topic, and the method should be designed to reduce the effect of the reviewers' own bias (White & Schmidt, 2005). The following chapter will describe the methodical steps of how the literature review was prepared and conducted. The chapter will be introduced by looking into the planning of the review, giving an overview of the rationale behind the purpose, definitions and the scope of the review. The next part explains the steps taken in order to explore as much as the relevant literature as possible, as well as providing a description of the articles making up the literature, and how they were collected. Finally, the last section reflects on the methodical choices and its implications on the literature review.

### 2.1 Planning the Research

The authors spent a long time investigating the TPAI field to detect the proper scope for the literature review, as well as the most suitable keywords and terms. For that reason, the purpose has been defined and redefined several times. This is in line with the recommendations by Clarke & Oxman (2001), suggesting the initial stages of systematic reviews should be of an iterative character regarding definition, clarification and refinement. Tranfield et al. (2003) emphasized that management reviews often are regarded as a process of exploration, discovery and development, and that the definition of the review can be modified through the course of the study. However, when changes occur, the researchers have to explicitly state what changes have been made and why (ibid.).

From the very start, the authors knew that they wanted to investigate the case of "technologies searching for a problem". Because, both the authors had felt the need for a set of tools for this scenario whilst conducting market research for a technology. Moreover, knowing that any technology based organizations would experience the same need, the authors were triggered to investigate what literature says about the

subject. However, having little previous knowledge within this specific research area, the authors spent a lot of time defining the purpose. Starting with some initial searches within the field of open innovation, and among others reading Chesbrough (2003), the authors found some interesting studies. However, neither aligned with the intended topic of technology in need of an application. Next, the authors reframed their search strings to focus on technology transfer offices (TTOs) and how they work to detect opportunities for developed technologies to create spinout companies. At this point the authors had not yet discovered the more suitable denomination of the phenomenon of 'application identification'. Instead, the keyword 'opportunity recognition' was used. At the time, the authors wished to further immerse themselves with the topic. However, it was scarcely any literature covering the subject. Therefore, it was decided to solely investigate the opportunity recognition process in TTOs. Although a handful of relevant articles were acquired, also this particular issue appeared to be less investigated. Eventually, the authors stumbled upon the term 'application identification', and realized it was a far better keyword generating studies that aligned with the problem of technologies searching for a problem. Following, the authors widened the scope to include all organizations with a 'technology push' approach. Thus, they found exactly the kind of research they set out to investigate in the first place; in other words that of TPAI.

In line with the recommendations of Tranfield et al. (2013), the authors conducted scoping studies in order to assess the relevance and size of the literature. As described in the previous paragraph, decisions were continuously made based on the understanding gained from the scoping studies. Concerning the scope study on 'application identification' in a 'technology push' setting, literature did prove to be thinner than anticipated. Nevertheless, the literature acquired through this search yielded studies that were spot-on the TPAI topic. In particular, Souder (1989), Bianchi et al. (2010), and Herstatt and Lettl (2004) proved to be important for the review, both with respect to the acquisition of further studies and its theoretical contribution. Although the literature investigating the phenomenon of TPAI setting is a bit scarce, it pinpoints exactly what the authors are triggered to research and what they set out to gain knowledge about. Hence, the authors chose to conduct the literature review on this subject.

## 2.2 Literature Acquisition

A three step search procedure has been performed for acquiring literature, including the following steps: (1) Identification of relevant work through structural searches, (2) identification of relevant references cited in the selected articles, and (3) identification of relevant articles citing the selected articles found in the two previous steps.

The literature review should only consist of studies meeting all the specified inclusion criteria, and to manifest neither of the exclusion criteria. Tranfield et al. (2003) explains that the strict criteria are based on the desire to base literature reviews on top-notch evidence. As the primary relevance criteria for this literature review, the studies had to include 'Application identification' or a synonym, as seen in Table 1. Further they must be based on 'developed technologies', as opposed to emerging technologies, with the intention of detecting new application fields. Hence, to be included in the review, the studies must relate with the context of 'technology push'. Because the research field is relatively narrow, no further exclusion criteria are needed to restrict the review. All studies concerning 'application identification' for 'developed technologies' or in a 'technology push' setting should be included in the literature review, all of these may reflect aspects with TPAI.

In order to extract data during the acquisition, and to continuously have an overview of the content of the gathered literature, the authors utilized a data extraction form including general information about the studies, as well as notes on emerging themes and challenges. This is recommended by Tranfield et al. (2003) for conducting systematic reviews in a thorough manner.

### 2.2.1 Structural Search

In the first step, the authors conducted a structural search based on an identified set of keywords, built from the scoping study. In line with Tranfield et al. (2003), the review team should choose the most appropriate search strings, based on the identified set of keywords. Since all studies discussing 'application identification' based on 'developed technologies' or a 'technology push setting' should be included into the review, and due to no further exclusion criteria, only one, comprehensive search string

is necessary. To be exhaustive, the search string has to include all the synonyms for 'application identification' and 'technology push' revealed through the scoping studies. Regarding 'technology push' the synonyms revealed were 'developed technologies' and 'technology commercialization, and for 'application identification' the revealed synonyms were 'identification of application\*', 'new application\*', 'alternative tech\* application', 'area of application\*', 'field of application\*', 'tech\* application\*' and 'identification of opportunit\*'. The highly credible database Web Of Science was exclusively used for general searches, whereas the databases Oria and Google Scholar were exploited in order to find articles referred to in primary articles.

## 2.2.2 Searches in ISI Web of Science

In Table 1 below, the structured search and the applied studies are listed. In the scoping study many more combinations of search strings were used. Yet, the search string presented below consists of all the keywords leading to relevant literature. From the structural search, only a limited amount of relevant studies were found. However, the articles acquired, were of a high quality.

*Table 1: Searches in ISI Web of Science*

Keywords	Restrictions	Database	Results	Abstracts read	Articles read	Articles used	Author and publication of used articles
("Tech* Push*")  OR TOPIC: ("Technolog* Commercialization")  OR TOPIC: ("Developed Tech*")  AND TOPIC: ("Application Identification*")  OR TOPIC: ("Identification of Application*")  OR TOPIC: ("New Application*")  OR TOPIC: ("Area* of	Management, Business, Article	Web of Science	333	195	33	15	Adner and Levinthal (2002)  Bianchi et al. (2010)  Caetano and Amaral (2011)  Friar& Balchandra (1999)  Gillier and Piat (2011)  Herstatt and Lettl (2004)  Keinz and Prüggl (2010)  Kirchberger and Pohl (2016)

Application**)							Koppinen et al. (2010)
OR TOPIC: ("Field* of Application")							Lichtenthaler (2010)
OR TOPIC: ("Alternative Tech* Application**")							Moncada-Pater no-Castello et al. (2003)
OR TOPIC: ("Tech* Application**")							Schwery & Raurich, 2004,  Souder (1989)
OR TOPIC: ("Identification of Opportunit**")							Van den Hende and Schoormans (2012)
							Van den Hende et al. (2007)

Although the search string yielded some very valuable results, it also resulted in many irrelevant findings. In particular these included studies not referring to developed technologies, or studies investigating individual entrepreneurs, or even studies not concerned with application identification at all. This is due to several reasons. Firstly, the keyword 'application' and especially 'tech\* application\*' is frequently used in research for many other contexts aside from TPAI. Among others, many studies were discussing aspects of information technology (IT) applications. In addition, the search string yielded multiple studies on emerging technologies. However, regarding TPAI, the majority of studies concerning emerging technologies are deemed irrelevant as they focus on radically new technologies still under development. In other words emerging technologies does not fit with the scope of investigating TPAI for already fully developed technology.

Despite the fact that the search string resulted in many irrelevant hits, the total number of findings were only 333. As the amount of literature from the search were manageable to deal with, the authors chose to not add any exclusion criteria to decrease the amount of irrelevant hits. In order to not miss any valuable papers, the authors rather chose to manually filter out the relevant studies by reading all seemingly relevant publication titles as well as the name of the journal. As can be seen from Table 1, for about  $\frac{2}{3}$  of the studies the abstracts were read. Thus, the last  $\frac{1}{3}$  was manually filtered out due to irrelevance, easily spotted by reading headlines and the

associated title of the journal. With the slightest uncertainty concerning the potential relevance of an article, the abstract was read without exceptions.

Due to the reason that the structural searches resulted in such a low number of results, the authors also tried to conduct the same structural searches in another major academic database; ABI. However, this effort yielded no new, unique results. A lot of the same articles were found also in the ABI database.

As we discovered on a later stage, parts of the reason for the restricted amount of relevant studies is due to different terms and denominations used for describing the application identification process. Researchers have not yet settled on a given name for the phenomenon. This might be the case as the research field is still in an embryonic stage and most studies are relatively new, and thus the literature is quite fragmented. To ensure that there did not exist lots of relevant literature using some of the keywords detected later on in the process, searches were done based on these as can be seen in Table 2. However, only one of them yielded relevant literature; except those already found. The search on the keywords 'exapt\*' and 'tech\*' led to the discovery of two new qualified articles Dew and Sarasvathy (2016) and Mastrogiorgio and Gilsing, 2015. The authors noticed the low yield, from these searches, as beginning signs of the saturation of the literature.

*Table 2: Searches in ISI Web of Science*

Keywords	Restrictions	Database	Results	Abstracts read	Articles read	Articles used	Author and publication of used articles
("Technolog* Competenc* Leverag*")  OR Topic: ("Leverag* Tech* Competenc*")	Article, Business, Management	Web of Science	3	3	2	1*	
(Exapt* AND Tech*)	Business, Management, Article	Web of Science	8	8	8	2	Dew and Sarsvathy, 2016  Mastrogiorgio and Gilsing, 2015
("Opportunity Search*")	Business, management, article	Web of Science	4	4	0	0*	
("Technology	Business,	Web of	36	36	3	1*	Lichtenthaler,

Exploitation**)	Management, Article	Science					2010
("Technology Exploration")	Business, Management, Article	Web of Science	8	8	1	0'	
("Application Identification")	Management, Article	Web of Science	2	2	0	0'	

\* Searches done at a later stage in the process, after new terms for application identification were discovered, in order to find other articles using the same terms. The used articles, however, were originally found through citations in primary articles.

### 2.2.3 Literature Cited in Articles

White & Schmidt (2005) claimed that the second step of a systematic literature review was to identify relevant references cited in the selected articles. Based on this, the primary articles from the structural search were all checked for references that could be relevant. This proved to be a valuable method for finding relevant literature, and many of the most valuable studies reviewed derive from utilizing this method. The result from this method is presented in Table 3 below. Moreover, due to the reason that the scope of the phenomenon is unclear, that few authoritative studies have been identified and that the field seem to be fragmented, the method of looking for literature through the selected articles references is a convenient approach (Wohlin, 2014).

Table 3: Literature cited by selected articles

Primary Source Found	New sources cited by the primary source	Sources found, cited by the new source
Bianchi et al. (2010)	Weiss (2004) Functional market concept for planning technological innovations.	
Caetano (2011)	Kuhrana (1998) Towards holistic "front ends" in new product development  Lee et al. (2009) Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping.	
Chadha et al. (2016)	Gregor and Hevner (2015) The Front End of Innovation: Perspectives on Creativity, Knowledge and Design	
Felkl (2013)	Deszca et al. (1999) Developing breakthrough products: challenges and options for market assessment.  Evans et al. (2008) Addressing the "Innovation Gap" for Engineering Education: A Mapping Tool.	

Gillier & Piat, 2011	Henkel. and Jung (2010) Identifying Technology Applications Using an Adaptation of the Lead User Method	
Herstatt, 2004	Lynn and Heintz (1992), From experience: Where does your new technology fit into the marketplace?	
Keinz and Prögl, 2010	Danneels (2007) The Process of Technological Competence Leveraging.  Friar and Balachandra (1999) Spotting the Customer for Emerging Technologies  Henkel and Jung (2009) The Technology-Push Lead User Concept: A New Tool for Application Identification.	Danneels (2002) The dynamics of product innovation and firm competences

The method was repeated on the studies detected through the first round of checking for cited articles, but only one new relevant articles was found in this second round. However, it is crucial to remark that many of the already selected studies repeatedly showed up in the searches. Thus, signaling the saturation of the review.

#### 2.2.4 Literature Citing Articles

White & Schmidt (2005) pointed out that the third step of the structural search was the identification of relevant articles citing the selected articles found in the two previous steps. This is a potentially valuable technique, as more recent articles might be uncovered. By systematically checking the all the studies citing the selected literature in Web of Science, the authors detected four new articles, as can be seen in Table 4. Two of these were published in 2016, and are valuable to include into the review as they build on earlier studies concerning TPAI. For instance, Chadha et al. (2016) build on the work by Gregor and Hevner (2015), making the theory scientifically stronger. The articles detected through this method, were checked for articles citing them again, but it did not result in any new, relevant studies.

*Table 4: Literature citing selected articles*

Primary Source Found	New articles citing the primary source	Sources found, citing the new source
Henkel and Jung (2009)	Hartelt et al. (2016) Process Model for technology push utilizing the Task-Technology-Fit Approach  Keinz and Prögl (2010) A User Community-Based Approach to Leveraging Technological Competences: An Exploratory Case Study of a Technology Start-Up from MIT	



Henkel and Jung (2010)	Chadha et al. (2016) A Framework for Techniques for Information Technology Enabled Innovation  Felkl (2013) Advanced technology innovation mapping tool to support technology commercialization	
Gregor and Hevner (2015)	Gregor and Hevner (2014) The Knowledge Innovation Matrix (KIM): A Clarifying Lens for Innovation	

## 2.3 Reflections on the Method

### 2.3.1 Authors Pre-Understanding

The authors are graduate students at the NTNU School of Entrepreneurship. They have both had several courses concerning innovation and technology management, and have some experience with conducting market research with aim to find new, viable applications to technology. As previously mentioned, the authors experienced that tools used in this process were not optimal, and that's what triggered them to investigate what literature says about the subject. The fact that the authors have some knowledge and experience within the field, might have pros and cons. As a benefit, they might more easily understand the methods and tools proposed in the reviewed articles and also can relate to it. On the other hand, the fact that the authors have reflected on the issue in advance might frame the process of selection and interpretation.

### 2.3.2 Limitations to the Method

Although the authors have aimed to conduct a thorough literature review, following a systematic methodology, several limitations can be identified and connected to the method of collecting and analyzing data. First and foremost, this is the first time the authors have conducted a literature review. They have never before used the literature databases or conducted systematical searches, and moreover, they have never dealt with such a systematic way of discussing. Learning the methods required to put a good literature review together has taken a lot of time, and the authors have learned a lot during the process. If they were to do it again they would have a whole other knowledge base.

Furthermore, time and resources has been limited. Ideally, the authors should have exploited several sources for finding literature. In addition to literature databases, a systematic literature study should comprise unpublished studies, conference proceedings, industry trials, the Internet and also personal requests to known investigators (Tranfield et al., 2003). However, to ensure a high quality of the literature review only high quality databases and peer reviewed articles were selected.

The fact that the literature is relatively young, and that there does not yet exist any authoritative studies, makes the structural searching process difficult. The process proved that it is hard to find the relevant articles within the field of application identification, even though they exist out there. The structured searches gave limited results, and as much as half of the selected literature derive from citations of already selected studies, or studies cited by the selected studies. The authors have found core articles late in the searching process, due to the reason that the studies use different terms for the application identification process.

Another limitation was that several identified articles that seemed relevant either by reading the headline or the abstract, were not accessible, and thus were not used in the review. As a result, potentially relevant articles were lost due to this lack of access.

### 3. Theory

The purpose of this literature review is to explore what the literature says about TPAI. This chapter contains the result of the literature review, presenting previous research within the TPAI field of research and at last a discussion of the findings. For RQ1 the authors present what characterizes the studies in the literature concerning TPAI. The majority of the reviewed literature all proposed strategic tools for TPAI to successfully identify new, potential applications. However, the reviewed studies approach this issue differently, each with the intent of coping with specific challenges related to TPAI. Therefore, to answer RQ2, three groupings of tools are presented; respectively tools for customer involvement, creative tools and analytical tools.

#### 3.1 Overview of the Applied Literature

Table 5 provides an overview of the applied literature. Altogether, the 33 studies in the table compose the TPAI research field discovered by the authors. Application identification and technology push are the overarching themes of TPAI, and any study included in the literature review concerns itself with application identification in a context that can be defined as technology push. As presented in Table 5, all of the reviewed studies contain both 'Application Identification' and 'Technology Push/Developed Technologies', and thus give input about RQ1. The three other keywords 'Tools for Customer Involvement', 'Creative Tools', and 'Analytical Tools' are relevant for RQ2, and provide input on different strategic tools proposed for TPAI in practice. These terms were found by the authors whilst analysing the acquired literature.

*Table 5: Overview of the literature & its content*

Study	Application identification	Technology push/ Developed technologies	Tools for Customer Involvement	Creative Tools	Analytical Tools
Adner and Levinthal (2002)	X	X			
Bianchi et al. (2010)	X	X			X

Caetano and Amaral (2011)	X	X	X		X
Chada et al. (2016)	X	X	X	X	
Daneels (2002)	X	X	X		
Daneels (2007)	X	X	X		
Deszca et al. (1999)	X	X	X	X	
Dew and Sarasvathy (2016)	X	X		X	
Evans et al. (2008)	X	X			X
Felkl (2013)	X	X	X		X
Friar and Balachandra (1999)	X	X	X	X	
Gillier and Piat (2011)	X	X			
Gregor and Hevner (2014)	X	X		X	
Gregor and Hevner (2015)	X	X		X	
Hartelt et al. (2016)	X	X			X
Henkel and Jung (2009)	X	X	X		X
Henkel and Jung (2010)	X	X	X		X
Herstatt and Lettl (2004)	X	X		X	
Keinz and Prügl (2010)	X	X	X	X	
Khurana and Rosenthal (1998)	X	X			
Kirchberger and Pohl	X	X			

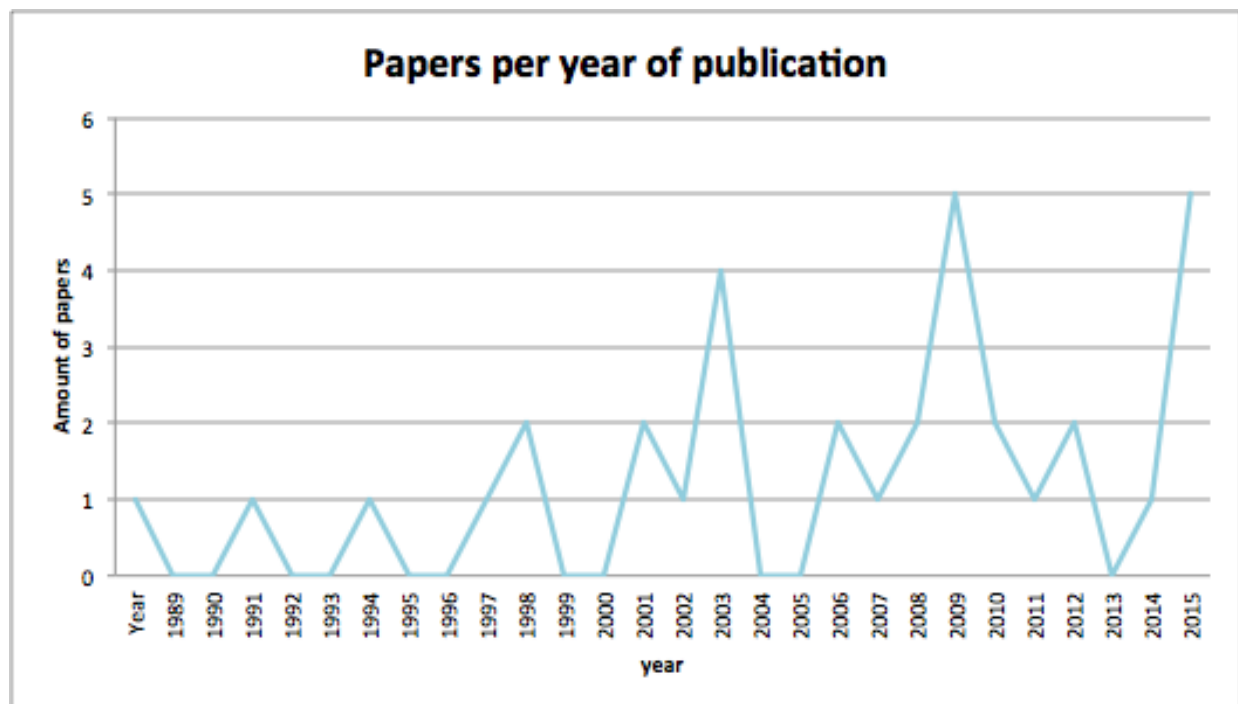
(2016)					
Koppinen et al. (2010)	X	X	X	X	
Lee et al. (2009)	X	X			X
Licthenthaler (2010)	X	X			X
Lynn and Heintz (1992)	X	X	X		X
Mastrogiorgio and Gilsing (2016)	X	X			X
Moncada-Paterno-Castello et al. (2003)	X	X	X		
Schwery and Raurich (2004)	X	X			
Souder (1989)	X	X	X	X	X
Van den Hende and Schoormans (2012)	X	X	X		
Van den Hende et al. (2007)	X	X	X		
Vohora et al. (2004)	X	X	X		
Weiss. (2004)	X	X			X

## 3.2 The Applied Literature

### 3.2.1 Sample Characteristics

The total sample of 32 studies investigating TPAI is published across 14 different journals, in which 'R&D Management', 'Technovation' and 'Journal of Product Innovation Management' are the journals where papers belonging to the subject most frequently appear. Reading the year of publication the authors could find an unmistakable rise in publications during the last decade. The oldest study from the sample is from 1989, and the most recent from 2016. However, there was just as many

studies concerning TPAI from the year of 2015 and 2016 as there were in total before the year of 2000, and half of the papers are published after 2010. In Figure 1 below, an overview of the different years of publication is illustrated.



*Figure 1 - Papers per year of publication*

Although there has been a rise in published papers, the field is still quite embryonic and underdeveloped. Not only is the total amount of studies scarce, the literature is spread across different streams of research. In particular these are the schools of open innovation, product development, business innovation and technology transfer. Very few of the studies seem to build much on each others research. However, within the product development school several articles have started more actively use findings from previous studies concerning TPAI. Furthermore, the literature has not agreed on a common term for the phenomenon. Accordingly, the detection of TPAI goes by multiple denominations in the literature; application identification, alternative application identification, new market opportunities, technology competency leveraging, application discovery, exaptation, finding application need etc. The reviewed literature revolves around different types of organizations, in which the larger part investigates TPAI in the context of firms aiming to profit from developed technologies. In addition, there is a handful of studies discussing TPAI for public research centres and university TTO's.

### 3.2.2 Tools for Customer Involvement

Several studies agree that tools facilitating for customer involvement is key for TPAI. Parts of the reviewed literature argues that the technology is known for a technology push organization, whilst the user and the market is unknown, and thus subject to ambiguity (Herstatt and Lettl, 2004; Felkl et al., 2013; Hartel et al., 2016; Adner & Levinthal, 2002). Due to this, Henkel & Jung (2010) and Keinz & Prügl (2010) describes the process of leveraging technology as challenging. Friar and Balachandra (1999) explains that the application and its customers is unknown, hence ordinary market tools for gaining market insight cannot be used. Herstatt & Lettl (2004) claims that technology push organizations have to develop and implement intelligent processes and methods for effectively reducing uncertainty, and that these must be oriented around the specific market related challenges for technology infused development projects. Moncada-Paterno-Castello (2010) highlights that customer contact is important in order to pave the way for incremental technology development. While Lynn & Heintz (1992) agrees that industry linkages are especially crucial for incremental innovations, the paper claims that this should be a priority regardless of innovation level. Overall, the studies above support the use of tools for customer involvement for TPAI.

Many different tools for customer involvement are presented in literature. Felkl (2013) highlights that the links from technology benefits to customers are abstract, and thus, TPAI teams have to seek and create a fit between them. Lynn & Heintz (1992) describes the screening of any market as a dynamic process; since a nonlinear approach is of great value in environments of ambiguity. Organizations should continuously collect and analyze market information, and having an iterative 'probe and learn' process permits customers to be integrated into the process in order to gain information (ibid.). In a slightly different manner, Friar and Balachandra (1999) introduces a learning approach to TPAI where the original customers of a technology are targeted, and asked what new applications they should develop with the technology. These new suggested applications should then be developed. The study argues that the needs of new applications are unknown and will first become known after the technology is introduced (ibid.). Therefore, the R&D department should strive to target new customer groups with a technology in the first place.

Several studies emphasize the involvement of customers and shareholders from a very early stage in order to decrease the risk of TPAI (Koppinen et al., 2010; Lynn & Heintz, 1992; Moncada-Paterno-Castello, 2010). For instance, Lynn et al. (1996) suggests the integration of customers whilst still prototyping and developing the technology. Caetano & Amaral (2011) suggests using technology roadmapping as a tool in the TPAI process, in which partnerships should be integrated into the process from the very beginning. Moreover, Vohora et al. (2004) highlights that relationships and contact with potential investors, customers and others in the given industry, should be closely maintained throughout the process. Because, the cases where a variety of potential applications have been successfully detected, typically are the same cases where market opportunities had been scrutinized together with potential investors, customers and industry in general (ibid.).

Henkel & Jung (2010) suggests to include lead users into the process; making it clear that feedback cannot come from any random customer. The importance of customers being familiar with the technology is also remarked by several others (Lynn & Heintz, 1992; Lynn et al, 1996; Van den Hende et al., 2007; Van den Hende & Schoormans, 2012). Van den Hende et al. (2007) agrees that early customer input is crucial for gaining an understanding of the potential value of radically new technologies, but proposes early concept narratives to cope with uncertainty. The study highlights that while the lead user method rely on finding expert users, the early concept narratives only need standard customers; an advantage of the latter. Van den Hende and Schoormans (2012) builds further on the former study on product narratives, concluding that product drawings combined with audio is just as powerful as prototypes. As prototypes are rarely available in the pre-development stage, the product narrative explaining the technology application is a more convenient tool in early phases according to the study (ibid.). Keinz and Prügl (2010) integrates user communities into TPAI, in which the latter is referred to as technical competence leveraging. User communities in the context of the mentioned article is referred to as unofficial social networks where technological and market related information is shared (von Hippel, 1994, 2005). Keinz and Prügl (2010) suggests finding and creating these user communities through pyramiding, as presented in theory by von Hippel et al. (1999).



Combining some of the tools mentioned above, Deszca et al. (1999) suggests to involve customers in the TPAI process by means of lead user analysis, visioning techniques and customer immersion. Souder (1989) proposes focus groups with potential users as an effective tool for TPAI, and furthermore stresses the importance of that the developer must be in a position to understand the needs of the user. For the study by Chada et al. (2016), customers are involved whenever a new-to-the-world application area is sought after. This user involvement may take form as crowdsourcing, design thinking or the technology push lead user method (ibid.). Daneels (2002, 2007) present the new product development process as linking technology competences with customer competences. Regarding TPAI, two methods are suggested, both of whom first involve delinking the technology from the original product (ibid.). After delinking from the product, one method, pure exploitation, involves creating new links among existing competences within the firm, that is applying the technology to a known application area. The other method, technology competence leveraging, involves relinking the technology to new customers. This involves exploring potential customers to see if they have a yet unidentified need that the technology can solve.

A few studies criticize the involvement of customers for TPAI. Generalizing market signals from a given niche may lead to dangerous distortions in expectations; often leading to overly pessimistic assessment of opportunities (Weiss, 2004; Adner & Levinthal, 2002). The latter study emphasizes that a probe and learn process as suggested by Lynn et al. (1996) is not very suitable for radical innovations as probing only provides discrete information connected specifically to the probed point. Herstatt & Lettl (2004) also challenges the inclusion of customers into TPAI projects. Firstly, it is not obvious who the prospective customers are, and furthermore they are often not able to articulate their true preferences about an abstract technology. Besides, technological innovations entail changes in behaviour for the customer, often resulting in way too negative feedback. However, the latter study claims that it cannot reject nor support the inclusion of customers into TPAI projects, and that lead users has at least proven its existence and relevance across industries.

A great deal of the reviewed studies address the challenge of market ambiguity, and proposes tools for customer involvement in order to reduce risk. This is true across research streams. The studies highlighting the importance of including customers at

an early stage as well as the ones stating that this is crucial throughout the TPAI process, mainly belongs to the technology transfer school. In fact, all the studies belonging to this area of research primarily suggest customer involvement tools. The more unconventional methods of customer involvement like early concept narratives, customer immersion and competence leveraging belong to the product development literature, focusing a lot on the inherent uncertainty of the 'front-end'. The latter category seem to put more emphasis on explorative methods for TPAI, while the first seem to focus on establishing linkages with industry to reduce risk. This can explain much of the critics that has been pointed towards customer involvement, as it articulates that conventional methods inhibit the detection of lucrative future opportunities. However, the studies on technology transfer seem to be more occupied with exploiting incremental opportunities.

### 3.2.3 Creative Tools

A number of studies highlight tools for creativity as essential for successful TPAI. In the reviewed literature, technology push innovations are often characterized as radical innovations or as having a radical innovation potential (Herstatt & Lettl, 2004; Henkel and Jung, 2009, 2010; Souder, 1989). Kuhrana et al. (1998) discusses that standardized processes seem to work best for incremental innovations, whereas radical innovations require an explorative approach. Furthermore, in order to generate the novel relationship between existing knowledge and a new application, a high level of creativity and associative thinking is required (Gregor & Hevner, 2015). This is supported by several other studies (Herstatt & Lettl, 2004; Weiss, 2004). Such explorative exercises should be conducted by interdisciplinary teams to combine knowledge within several fields and with different perspectives (Souder, 1989; Gregor and Hevner, 2015). Overall, the studies mentioned above believe creative tools are needed for TPAI.

Several of the identified studies propose creative tools for TPAI. For instance, Gregor and Hevner (2015) suggests the model KIM-FEI, for the 'front end of innovation' (FEI) including the 'knowledge innovation matrix' (KIM) as presented first by Gregor and Hevner (2014). KIM is a matrix of four quadrants separating innovation as; advancement, a known problem to a new solution; invention, "new to the world" innovations; exploitation, new-to-us innovations; and exaptation, known solution to a

new or different problem (ibid.). In this study TPAI is only recommended whenever the technology can be characterized as an exaptation innovation. TPAI tools suggested for exaptation, by Gregor and Hevner (2015), are crowdsourcing, as well as creative methods such as brainstorming and ideation techniques. Chada et al. (2016) builds further on the work by Gregor and Hevner (2015) and introduces the Innovation Practice Framework based on KIM. The framework relates different tools for innovation practices with the quadrants in KIM (ibid.). For TPAI, the exaptation and exploitation quadrants are relevant. The tools presented for exaptation are design thinking, crowdsourcing, genius grants for employees to work on individual projects, Henkel and Jung's (2010) technology push lead user method and brainstorming (ibid.). Regarding the exploitation quadrant, managerial scanning, benchmarking, technology roadmapping and brainstorming is suggested (ibid.).

Brainstorming is also proposed by Souder (1989), emphasizing that this should be conducted with interdisciplinary teams for generating ideas for embodiment of a developed technology. Dew and Sarasvathy (2016) on the other hand, mentions effectuation as a tool for exaptation. The entrepreneurial heuristics, or rules of thumb can according to the study be used to facilitate for TPAI (ibid.). Regarding the process introduced by Friar and Balachandra (1999) it argues to facilitate for radical innovation as a probe and learn process for TPAI.

Deszca et al. (1999) introduces a framework for new product development, wherein TPAI is included. The framework is supposed to aid creation of breakthrough products (ibid.). The paper furthermore mentions several tools for TPAI; probe and learn, empathic design, experimental marketing, and information acceleration. Among these, the study favours the latter method where interactive multimedia is used to present potential usage scenarios. Similarly, Herstatt & Lettl (2004) proposes the use of 'front loading', taking form of either learning from other recent TPAI projects or bringing problems to the front by the use of virtual simulations that otherwise would not appear before later in the process. Koppinen (2010) proposes foresight activities in order to combine future visions of technology and business with the identification of alternative development paths.

Particularly, one study criticizes the use of creative tools for TPAI. Schwery & Raurich (2004) agrees that unconventional methods are needed to detect potential

applications to technology with radical potential. However, the study claims that due to the high level of uncertainty related to the process, the approach should be more stable. This is contrast with the studies mentioned in the paragraphs above. Instead, the paper recommends an initial SWOT-analysis to assess the competitive product concept of any discontinuous innovation. Moreover, it proposes the technology choice tool and technology roadmapping, as they ensure a structured and balanced way to find new markets. A mentioned drawback is that the proposed methods narrows the creative aspect.

A substantial amount of the reviewed literature proposing creative tools, stresses the opportunity and challenge of radical innovation. Several of these emphasize that in order to trigger radical innovation, TPAI requires a more explorative approach. Gregor & Hevner's (2014) work on 'exaptation' and 'exploitation' makes up a dominant part of this, as an increasing amount of studies looking into exaptation and building on the study. A wide range of the creative tools suggested generally builds on each other. However, as an opposing view, Schwery & Raurich (2004) argues that due to the high level of uncertainty related to the process, the approach should be more stable. The creative TPAI tools are only described in literature from the product development school and the business innovation school.

### 3.2.4 Analytical Tools

Various studies present analytical tools necessary for TPAI. A part of the literature on TPAI focus on the need for efficient tools for the exploitation of technologies to capture value. Bianchi (2010) calls for an efficient TPAI approach, as organizations typically have limited resources set aside for identifying viable business opportunities outside of its core business. In addition, some of the studies suggest that technology push organizations often have a lot of underutilized technology, with respect to commercialization (Lynn and Heintz, 1992; Friar and Balachandra, 1999; Herstatt and Lettl, 2004; Keinz and Prügl, 2010). Lichtenthaler et al. (2010) describes the exploration of TPAI as a technology intelligence problem of analytical character, and several papers remarked its relevance with the rise of open innovation (Lichtenthaler, 2010; Bianchi et al., 2010; Lee et al., 2009).

A number of studies suggest analytical tools for TPAI. Of these, several propose tools for efficiently creating value from proprietary technology. Bianchi et al. (2010) presents what the study refers to as a quick and easy-to-use TPAI method for proprietary technology. The method has a fixed set of steps, starting with breaking down the technology by using TRIZ-based tools, followed by building catchwords, and doing searches in technology databases to find alternative applications. Lichtenthaler (2010) emphasizes that many firms try to capture additional value from their technologies by means of open innovation strategies. The study propose the job-related market approach in order to broaden their perspective on TPAI, and moreover detect market opportunities outside their current markets. By segmenting according to technological functions rather than product-category-defined markets, organizations can usually identify much larger markets.

According to Lee et al (2009), many organizations do not know how to create value from a technology in a strategic manner. The study proposes an approach including four different patent analysis tools to respectively detect other organizations in specific business areas of interest; organizations characterized by similar technological knowledge flows; industries that are available; and industries that are valuable. Furthermore, the study claims that technological planning and business planning must be better connected in order for organizations to be able to identify and exploit developed technologies, and proposes technology roadmapping to be better able to balance these (ibid.). Indeed, technology roadmapping is also suggested by Lichtenthaler (2010) as a useful tool to actively work to identify additional licensing opportunities. This is supported by Caetano & Amaral (2011) which suggests roadmapping as an effective tool for TPAI in an open innovation context. Mastrogriogio and Gilsing (2016) takes a different approach to TPAI for proprietary technology. Building on the research stream of exaptation innovation, the study suggests an analytical approach of calibrating the patent portfolio to facilitate for exaptation innovations. This involves acquiring patents with a high degree of technical complexity, as this increases the likelihood of successful exaptation (ibid.).

A great deal of the reviewed papers also emphasize another aspect of TPAI; the challenge of being biased by the current situation. Herstatt & Lettl (2004) remarked that organizations often are biased by the markets in which they currently operate. In addition, Bianchi et al. (2010) highlights that it is easy to be primed by the current

context and application for the technology. Furthermore, Lynn & Heintz (1992) claims that R&D personnel focus mostly on function, whilst end users are more interested in product capabilities (Lynn & Heintz, 1992). Several studies agree on the importance of breaking down the technologies to investigate its functions and elements. Indeed, a handful of studies mention it as the first basic step of the TPAI process (Souder, 1989; Hartelt et al., 2016; Henkel & Jung; 2010; Felkl, 2013).

While the above papers propose analytical tools in order to work with TPAI for proprietary technology, several others suggests means to cope with the bias of being framed by the original application. Lynn & Heintz (1992) recommends focusing on the unique tasks end users can accomplish with the aid of the technology to avoid application myopia by focusing too much on the current way of doing things. Similarly, Weiss (2004) proposes to strictly define technologies concerning their functions and problem-solving capabilities. Again this is to avoid bias toward existing customer and market segments. The study presents tools such as technology portfolios, s-curve and experience curves (ibid.). Henkel & Jung (2010) suggests to deduct "trends" from the technology. By looking after market trends in the technologies elements and basic functions, the technology push could eventually turn into a market pull situation. Souder (1989) states that in the TPAI process the technology should first be described with an eye to potential applications, describing the technology in such a way that it creates a connection between what it is, what it can do, and some potential need. Evans et al. (2008) presents the technology innovation mapping (TIM) tool for crossing the innovation gap existing between research and the commercialization of research. The tool consists of breaking down the technology through function mapping, market influence mapping and map refining and selection (ibid.). According to the paper, a benefit of mapping the technology before considering any applications is that it mitigates 'application bias' and facilitates the consideration of additional applications

Concerning the use of analytical tools for TPAI, one study criticizes this. Herstatt & Lettl (2004), problematized the method of static examination. The study highlights that this method approximates a market analysis of known application areas, and moreover that it can result in product-market combinations for which it is practically impossible to determine critical success factors.

Several studies put great emphasis on capturing additional value from TPAI, especially in cases of proprietary technology. These papers exclusively belong to the school of open innovation, and propose tools that allow organizations to monetize on technologies without much investment and risk taken. Moreover, another area of analytic tools are based on the challenge of being biased by the technologies original surroundings. All schools and fields across the reviewed literature emphasize the importance of breaking down technologies to basis functions, elements or trends. Even though this is widely agreed upon, the static examination of technologies is criticised as it approximates an analysis of known application areas. However, for several papers, exploitation seem to be the goal; to harvest opportunities that are ripe. Hence, this is not really an issue if exploitation is the goal.

### 3.3 Discussion

The purpose of this literature review was to explore what literature says about application identification in a technology push context. On one hand, RQ1 highlights the different views and areas of focus regarding TPAI found in this body of literature. On the other hand, RQ2 leads to a deep dive of the reviewed studies, taking interest in the specific tools suggested for TPAI. This literature review has given answers to the RQs and this thesis present the most crucial findings. In the following sections the findings from the literature review is discussed for each RQ in turn.

#### 3.3.1 Regarding RQ1

The reviewed literature has proven to be quite fragmented in terms of designation. The detection of new applications to developed technology goes by multiple denominations; application identification, alternative application identification, new market opportunities, technology competency leveraging, application discovery and exaptation. Although several researchers have focused on the importance of doing research within the field of TPAI, the field is still quite embryonic and underdeveloped, as seen in section 3.2.1. Indeed, the researchers have yet to agree on a common term for the phenomenon. The total sample of studies looking into TPAI consists of 33 articles, in which half of the studies were published after 2010. Moreover, they belong to different research streams and rarely build on each other's work. However, in the

two previous years, studies building on the KIM-model of Gregor & Hevner (2014) have somehow altered this trend. The latter study, belongs to the product development research camp, and separates TPAI into exaptation and exploitation. Although previous research in practice investigates either of the two fields, they have not explicitly made a distinction between the two terms. The study by Gregor & Hevner (2014) might turn out to be the first "authoritative" study in the field of TPAI.

When investigating RQ1, several literary schools have been discovered. These are technology transfer, business innovation research, open innovation and new product development. The studies within the different schools generally have separate focus; a focus that can be argued to be distinct for that school.

Regarding the technology transfer school, all of the studies suggest tools involves the creation of bonds with industry. Moreover, the focus is on methods for efficient exploitation of the developed technologies and also how to reduce risk. The few methods presented by the technology transfer school are rather superficial, and the actual details of how these processes are to be performed to help identify applications, remain unspoken. Furthermore, none of the former studies on application identification within the technology transfer school discuss how to deal with technology with radical innovation potential, and neither of them address the challenge of application bias.

The studies within the school of open innovation focus on technology exploitation and how firms can monetize on already developed technologies, and mainly look for opportunities that are ready to be harvested. Thus, the literature proposes customer involvement as seen in section 3.2.2, or the analytical methods in section 3.2.4, to assess short-term opportunities. For the latter category of studies focus is on proprietary technology and how firms can utilize tools and databases in order to detect new application fields by comparing pure technological features and industry trends. The literature on technology exploitation within open innovation is extensive, but most of the studies look at other aspects of the process than the application identification process and thus are excluded from this review. Neither in this category of research the issue of radical innovation potential is addressed, or the use of creative tools proposed.



Contrastively to the studies in the two previous paragraphs, a majority of the studies related to the school of business innovation research problematize the challenges tied to technology with radical innovation potential. For instance, the studies in section 3.2.3 problematize the uncertainty connected to radical innovations, and proposes explorative methods in order to deal with it. While most studies take for granted that technologies have radical potential, Adner & Levinthal (2002) however argues that discontinuity typically does not lie in a radical advancement in technology itself, but rather stems from a shift of an existing technical lineage to a new domain of application. Thus, discontinuous technologies are suggested to be more incremental than usually believed. Furthermore, the literature within the business innovation research is more focused on assisting managers when planning and taking decisions regarding developed technology.

As for the new product development school, the processes and tools presented generally are of the explorative kind. Many of the processes are directly inspired by product development processes, and can sometimes be seen as direct mergers of application identification with new product development tools. The studies belonging to the school of product development use vocabulary associated with product development such as 'The Front-End of Innovation', 'The Fuzzy-Front-End', 'New product Development' and 'Really New Products'. Studies within this category has a strong focus on ambiguity and the lack of knowledge firms are confronted with at the 'front-end', as well as customer contact, to successfully identify potential new application fields as seen in section 3.2.2. Moreover, this part of the literature mainly looks into how to explore new business opportunities for developed technology, and proposes explorative, creative methods as presented in section 3.2.3. The front-end of innovation consist of much more literature than the studies applied in this review, as only a handful of them look at application identification in a technology push setting.

Although the different schools each have a unique focus, the most remarkable finding is the similar focus revealed when pairing the categories in two. Respectively, the categories of technology transfer combined with open innovation, and the categories of product development combined with business innovation. Both of the pairs have several similarities within the pair, and differs distinctly between the pairs. On the one hand, research belonging to technology transfer and open innovation mainly focus on exploiting developed technologies through means of customer involvement and

analytical tools. On the other hand, the research belonging to product development and business innovation mainly focus on exploring the potential of developed technologies, and to reveal radical innovation potential through the use of creative tools. In fact, the two pairs of schools appear to have fundamentally different motivations for TPAI. The authors have concluded that each pair respectively fit into Gregor & Hevner's (2014) categories of 'exploitation' and 'exaptation'. The exploitation view is shared by the pair of the open innovation, and technology transfer schools. Whereas, the exaptation view is shared by the pair of the product development and the business innovation schools. It is, however, key to mention, that there are few papers from each of the schools mentioned in this section. Thus, the articles found in this literature review are not sufficient to form a scientific basis for how TPAI is suggested within a particular school.

### 3.3.2 Regarding RQ2

Probing the literature with respect to RQ2, a large part of the literature was found, by the authors, to focus on a specific challenge that has proven to be a barrier for TPAI, and suggest a method to overcome this. The authors uncovered three challenges, and in this study the authors have respectively coined them market ambiguity, application bias, and radical innovation potential. However, only two of the mentioned challenges were found to be present across both the different pairs of schools and the different views of exploitation and exaptation. Therefore, the latter challenge, as mentioned in section 3.2.3, is not regarded with equal importance. Concerning the first challenge, many of the studies found in section 3.2.2 focus on the fact that technology push organizations possess a high degree of market ambiguity. Regarding application bias, the studies from section 3.2.4 highlight that organizations conducting TPAI often are biased to the technology's originally intended use. Accordingly, these organizations experience a form of application myopia, that clouds their solution-space. Consequently, given these two barriers, it is vital for a technology push organization to cope with both market ambiguity and application bias, in order to best commercialize its technology.

Two major approaches for TPAI, exploitation and exaptation, have been exposed within the literature. Only a few of these studies build directly on the findings of other studies within this topic. Although, after careful analysis, the authors uncovered two

camps of studies sharing the same basic functions and main objectives; across the different categories of tools. Indeed, the two opposing objectives for TPAI are exploitation and exaptation. The two views are related to the degree of innovation, and the contrasting viewpoints lead to a different focus and prioritization. A technology push organization can respectively commercialize its developed technology for either an existing application, or a new-to-the-world application. Although this is evident looking into the reviewed literature, Gregor & Hevner (2014) was the first to explicitly separate and propose tools to cope with the unique challenges of the two categories. According to Gregor and Hevner (2014), the degree of innovation resulting from TPAI for a known technology can be characterized as exploitation and exaptation respectively. Concerning the exploitation innovation for a technology push organization, the technology to be commercialized is the known solution that is to be reapplied to solve a known problem, that is an existing application area. On the other hand, concerning the exaptation innovation, the technology is still known, however, the problem or the application area is not yet existing. For both cases, the application area is unknown, however, an exaptation innovation is much more innovative than an exploitation innovation (ibid.).

The literature review has revealed that to uncover application areas of different innovation levels, different processes and methods for application identification are required. On the one hand, for exaptation innovations, most literature deem usual market research methods inefficient to detect future opportunities. On the other hand, the studies focusing on exploitation of developed technologies, in general present more ordinary market research methods. The latter studies are more concerned about detecting existing market opportunities, through identifying existing application areas where the given technology can perform better. This approach to TPAI is generally presented as a low cost and efficient way of commercializing technology by the reviewed studies. The tools connected with the exploitation perspective include all of the analytical tools mentioned in 3.2.4 and some of the tools for customer involvement as seen in 3.2.2. Considering the exaptive perspective, the studies reviewed rather present approaches for TPAI that ideally can be used to discover the next big idea, and mostly propose unconventional, creative tools. The recommended tools are all of the creative tools as presented in section 3.2.3, and as well some of the tools for customer involvement from section 3.2.2. Regarding the tools for customer involvement, some are exploitive and some are exaptive. In particular, the authors

found the tools for customer involvement intending to efficiently exploit a technology, to find an existing application area, to belong with the exploitation camp. Similarly, the tools that focus on including customers, to better find new or more radical application areas are exaptive.

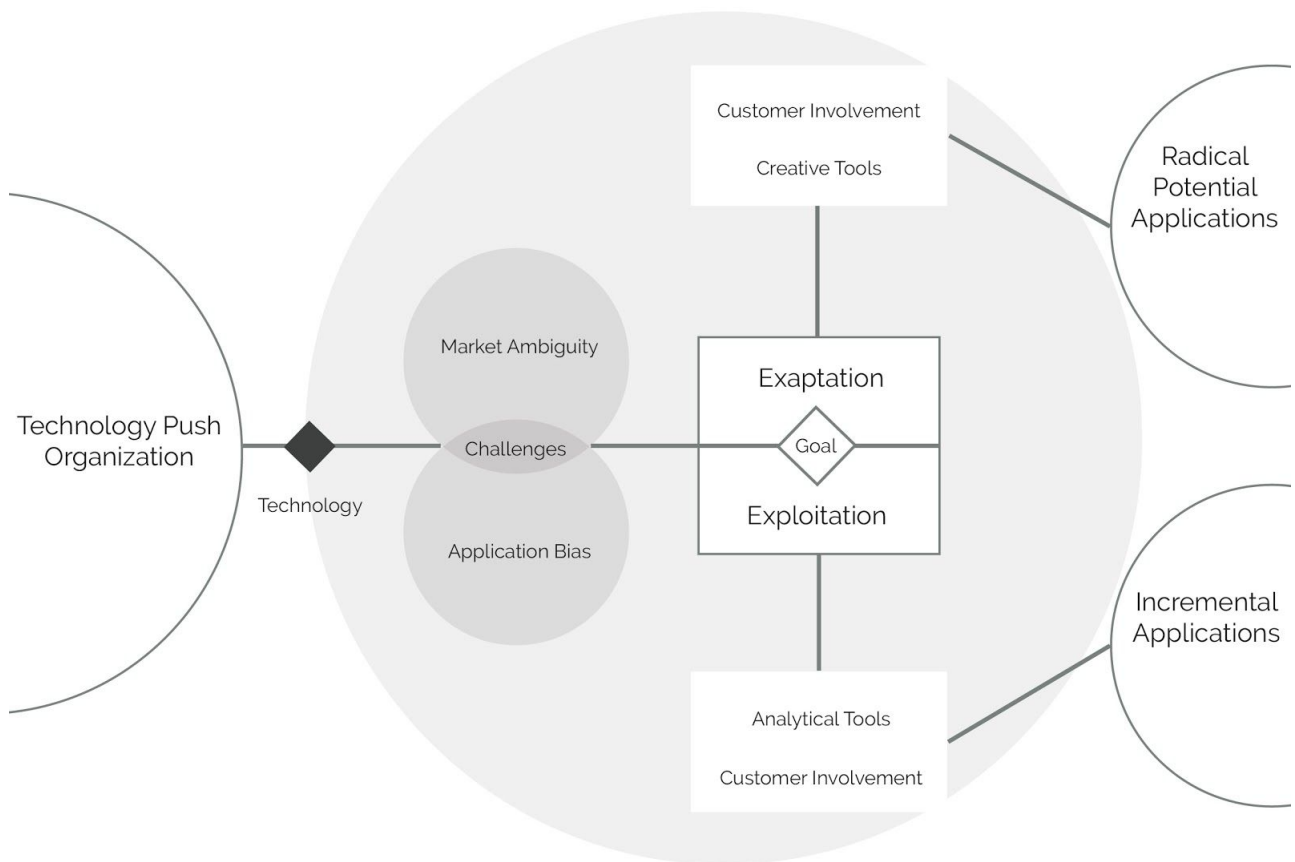


Figure 2: Framework for Technology Push Application Identification

Figure 2 illustrates the TPAI approach found by the authors in the literature review. The dark square represents a developed technology originating from a technology push organization. The two overlapping circles represent the challenges for TPAI, and are ever present in the model. They are dealt with through strategic tools after choosing one of the goals of exaptation or exploitation. Performing the associated tools for TPAI then leads to application identification of an incremental or radical innovation degree for exploitation and exaptation respectively.

## 4. Conclusion

### 4.1 Concluding Remarks

The findings from this literature review contribute to the field of TPAI. The method conducted by the authors shows that a lot of the literature had to be found through 'cited sources' and 'cited by'. This implies that the literature is fragmented, and still in its embryonic stage as a research field. TPAI is not a new phenomenon, dating back to 1989 in literature. Still, half of the reviewed studies were published after year 2010. Some of the included studies are merely a few months old. This suggests that the research field of TPAI is growing. Very few of the articles build on each other, and a variety of different terminologies are used to describe TPAI. However, Gregor & Hevner (2014) and its distinction between exploitation and exaptation has been cited rather often the two previous years.

The authors found four different research streams describing processes related to TPAI, something that divide the literature even more as the different literary schools have different approaches to TPAI. In addition, the authors have, through this literature review, uncovered two main categories that each share some major similarities. These have been called the exploitation view and the exaptation view. Regarding the exploitation view, this is the most common approach for studies belonging to technology transfer and open innovation. These studies focus on efficiently discovering existing application areas where a technology can replace a less optimal solution. For the exaptation view, this is the most common approach for studies belonging to business innovation and product development. These studies aim to discover a new-to-the-world application for the technology at hand. The authors were able to distinguish the two categories in the literature, as the tools suggested for TPAI are very different for exploitation and exaptation.

The review has moreover unveiled two major problems that organizations face when working with TPAI, regardless of aiming to exapt or exploit the developed technologies. Firstly, the challenge of 'market ambiguity' arise as a consequence of the nature of technology push projects, in which the technology is known while potential markets and customers are not. Most suggested solutions to the market

uncertainty problem somehow entail the inclusion of potential customers into the process. Secondly, the 'application bias' is a major challenge due to the reason that the TPAI process is framed by a technology's current application. A majority of the papers addressing this challenge emphasize the benefit of focusing on the unique things the technology enables end users to do, abstracting its functions and focusing on trends. It is also proposed to only include end users with sufficient knowledge and understanding of the technology in order to avoid this latter challenge. However, such a static examination of technologies is also problematized as it results in an analysis of known application areas.

## 4.2 Implications

This study has practical implications for any technology push organizations. Technology based organizations can use the findings of the exploitation and the exaptation view actively when approaching TPAI. In other words, tools from the exploitation perspective should be implemented whenever the TTO's objective for a technology is to find an existing application, and whenever it aims to use the technology to exchange or upgrade the current solution for that application. This strategy is suitable when organizations do not want to take much risk or just want to look for opportunities to monetize on developed technologies. In contrast, tools from the exaptation perspective should be implemented by a TTO for the purpose of finding a new or radical application for a technology. This is a strategy that organizations should make use of in cases in which they have margins to take risk and investigate future lucrative opportunities.

Furthermore, the TTOs should also take account of the findings from the studies concerning the barriers of market ambiguity and application bias. For the market ambiguity, the TTOs can use tools found in section 3.2.2 to mitigate this challenge. Regarding the application bias the TTOs should be aware of this challenge and strive to overcome it, and the tools found in section 3.2.4 will aid in this purpose.

## 4.3 Further Research

The research area of TPAI is fragmented and underdeveloped, and in order to make TPAI a recognized research stream, further research on the subject is needed.

Foremost, the topic would benefit from studies intending to unify the different schools relevant for TPAI, and researchers should aspire to create and reaffirm what may become a common TPAI terminology. As Gregor & Hevner's (2014) work on 'exploitation' and 'exaptation' already is starting to position itself as prominent, future research could beneficially further develop this theory. Research can also be aimed at creating frameworks for TPAI. In particular, two distinct frameworks are needed for the exploitation and the exaptation view respectively. This process could be approached through experimental case studies, where different tools are investigated. Both market ambiguity and application bias also need further research to be established as overarching challenges for TPAI.

With regards to the reviewed literature, most of it looks into firms aiming to monetize from its developed technologies. However, TPAI may be just as relevant for public research centres and university TTOs. Of the reviewed papers, hardly a handful investigate such organizations and they furthermore examines TPAI rather superficially. Moreover, they exclusively take the exploitive approach to TPAI by means of customer involvement. As public research centres and university TTOs not necessarily rely on short time success, it would make sense to integrate and develop also the exaptive strategy for such organizations, and to look at other tools for TPAI; learning from other research areas.

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