NTNU
Norwegian University of
Science and Technology

Identification of Applications to Technology in the CERN Knowledge Transfer Group

Ranveig Strøm

Master of Science in Entrepreneurship
Submission date: January 2018
Supervisor: Lise Aaboen, IØT

Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

Abstract

The knowledge and technology from technology push environments may have great potential in whole other industries and markets, and thus, a key element for technology commercialisation is the identification of alternative application areas. However, application identification in a technology push context is theoretically underdeveloped, fragmented and in its embryonic stage.

Isern and Strøm (2017) found that especially the technology transfer literature treated application identification superficially. Hence, this study investigates the phenomenon in Technology Transfer Offices, through learning from research from other technology push environments. Furthermore, previous literature exposes two main approaches to application identification, exploitation and exaptation. Unifying the two different views is another recommendation, and therefore, as no former research within the technology transfer school mention exaptation, this view has gotten special attention.

A theoretical framework has been made in order to analyse the data, showing the relationship between exploitation and exaptation, as well as integrating the Resource Based View. By using the framework to investigate the underlying mechanisms of application identification in the CERN Knowledge Transfer group, as well as using the NTNU Screening Week as an embedded case, this thesis has contributed with new findings to the literature.

While the CERN Knowledge Transfer group does not focus much on application identification today, the group does not have the right capabilities nor sufficient resources to increase this focus. By exploiting external resources, more exaptive applications can be identified. However, due to limited absorptive capacity, not all identified applications will create sustained value. As a result, resources should be prioritised on initiatives that also aim to commercialise the opportunities in order to create sustained value.

Sammendrag

Kunnskap og teknologi fra teknologibaserte miljøer kan ha stort potensiale i helt andre industrier og markeder, og derfor er avdekking av nye applikasjonsområder viktig å forstå for å lykkes med teknologibasert kommersialisering. På tross av dette er teknologibasert applikasjons-avdekking teoretisk underutviklet og fragmentert.

Isern og Strøm (2017) konkluderte med at dette var spesielt underutviklet i teknologioverførings-litteraturen. Målet med denne forskningen er som følge å undersøke fenomenet i teknologioverføringsenheter, gjennom å lære fra andre teknologibaserte miljøer. Tidligere litteratur tar dessuten for seg to ulike tilnærminger til applikasjons-avdekking - 'exploitation' og 'exaptation'. Å skape teori som samler de to ulike tilnærmingene er en annen anbefaling, og derfor, siden ingen tidligere forskning innen teknologioverførings-litteraturen nevner 'exaptation', har denne tilnærmingen fått ekstra fokus.

Et teoretisk rammeverk har blitt laget for å kunne analysere dataen, som viser sammenhengen mellom 'exploitation' og 'exaptation', i tillegg til å integrere det ressursbaserte perspektivet. Ved å benytte seg av rammeverket til å undersøke de underliggende mekanismene til applikasjons-avdekking i CERN's "Knowledge Transfer"-enhet, i tillegg til å bruke NTNU Screening Week som et integrert case, har denne oppgaven bidratt med nye funn til litteraturen.

Mens CERNs "Knowledge Transfer"-enhet ikke fokuserer særlig på applikasjons-avdekking idag, har ikke gruppen de rette kapabilitetene eller nok ressurser til å øke dette fokuset. Ved å utnytte eksterne ressurser kan mer 'exaptive' applikasjonsområder bli avdekket. Likevel, på grunn av begrenset absorpsjonskapasitet, vil ikke alle avdekkede applikasjoner skape bærekraftig verdi. Av den grunn burde ressurser prioriteres på initiativer som også sikter mot å kommersialisere mulighetene for å skape bærekraftig verdi.

Acknowledgements

This Master's thesis was written by Ranveig Strøm during the fall of 2017, and finalised early 2018, at the Norwegian University of Science and Technology (NTNU) - as part of the course TIØ4945 Innovation and Entrepreneurship. The aim of the study is to investigate approaches for Technology Transfer Offices to identify applications that are further away from the original application.

In the time before, as well as during, the research was conducted, I was working as part of the CERN Knowledge Transfer group - which also was the case of study in this thesis. I am deeply grateful to the Organization for this opportunity and to all the people working in the CERN Knowledge Transfer group. An extra thanks goes to Anais Rassat, my supervisor at CERN, for massive support and flexibility.

And above all, a special and humble thanks goes to professor Lise Aaboen for knowledgeable and patient guidance throughout the time I conducted this research. As my supervisor, she has been incredibly helpful, available and down-to-earth. Thank you.

Ranveig Strøm

Geneva, January 2018

Table of contents

Abstract **2**

Sammendrag **4**

Acknowledgements **6**

Table of contents **7**

Figures and tables **10**

1 Introduction **11**
1.1 Technology push environments 11
1.2 The foundation of the thesis 13
1.2.1 Identified gap in the literature 13
1.2.2 Purpose 15
1.2.3 Research questions 17
1.3 Contribution 18
1.4 Structure 18

2 Theory **20**
2.1 Technology push application identification 20
2.2 The role of resources 24
2.2.1 The resource-based view 24
2.2.2 Dynamic capabilities and absorptive capacity 25
2.3 Theoretical framework 26

3 Methodology **28**
3.1 Research design 28
3.1.1 Qualitative Research 28
3.1.2 Case Study 28
3.2 Data Acquisition 29
3.2.1 Spend time on-site and access to secondary data 30
3.2.2 Interviews 30
3.2.3 Observations 32
3.3 Analysis of data 32
3.4 Reflections on the method 33
3.4.1 Quality of the study 33
3.4.2 Ethical Considerations 35
2.4.3 Limitations to the Study 35

4 Findings & Analysis **37**
4.1 Findings 37
4.1.1 Within the KT Group 37

4.1.2 The NTNU Screening week 42
4.2 Analysis 52
4.2.1 Application identification in the CERN KT group 52
4.2.2 Application identification during the NTNU Screening week 58
4.2.3 Value of the NTNU Screening week 60

5 Discussion **65**
5.1 The results so far 65
5.2 Consequences for the purpose of the thesis 67
5.3 From the CERN KT to other Technology Transfer Offices 70

6 Conclusion **73**

7 Implications **74**

References **79**

Appendix **86**

Figures and tables

List of figures

Figure 1: Gregor and Hevner's (2015) Knowledge Innovation Matrix

Figure 2: Theoretical Framework - Technology Push Application Identification

Figure 3: Technology push application identification in the CERN KT

List of tables

Table 1: Application identification methods in the CERN KT group

Table 2: Application identification methods during the NTNU Screening Week

Table 3: VRIO analysis - Value of the NTNU Screening Week

1 Introduction

1.1 Technology push environments

Public research centres, universities and research departments of organisations are devoted to answering the questions of tomorrow and to developing whole new technology to support their missions. While their main goal is the research and development itself, without regard for market attractiveness (Caetano and Amaral, 2011), they might see the potential to exploit the technologies elsewhere in society. The predominating integration strategy of such organisations is technology push as the technology is the starting point for the commercialisation (Kostoff and Schaller, 2001; Lee et al., 2007; Spithoven et al., 2011), as opposed to market pull where the starting point is a problem or a need. While this is the nature of technology push organisations, they may also use market pull integration strategies, and in fact there are strong interdependencies between the two approaches (Brem and Voigt, 2009). Even though this is the case, technology push of already developed technologies is the main focus of this thesis.

As the outset for the commercialisation is a solution looking for a problem (Evans et al, 2008), the process of commercialising technology is complex (Dorf and Worthington, 1987). Several scholars have pointed out an “innovation gap” between the creation of new technologies from technology push environments and market opportunities, making it challenging to assemble and evaluate information about future value creation potential (Felkl, 2013; Evans et al, 2008). Technology push inventions entail more risk than market pull innovations, and thus, they fail more often (Herstatt and Lettl, 2004). Despite this, research from technology push environments is a main source of technological innovation (Hindle and Yencken, 2004). Technology push innovations are often characterised as radical innovations or as having a radical innovation potential, and several studies stresses the opportunity and challenge of this type of innovation (Herstatt and Lettl, 2004; Henkel and Jung, 2009, 2010; Souder, 1989). If exploited, technological innovations can potentially lead to a profusion of commercial opportunities (ibid.), and when they succeed, technology push inventions often perform better than market pull innovations (Walsh et al., 2002; Kirchhoff et al., 2007).

The strategy of gaining competitive advantage through searching for alternate market opportunities for developed technologies is not novel. In fact, Schumpeter (1939) defined a third type of innovation, where new domains of use and new markets, are revealed through new applications of an existing technology. Today, 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 commercialisation cooperation between organisations (Chesbrough, 2003; Petroni et al., 2012). Both organisations and society benefit from this change as more technology is utilised 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 Shane, 2003; Etzkowitz and Leydesdorff, 2000; Feller et al., 2002; Roberts, 2007; Shane, 2001).

A key element for technology commercialisation is the identification and evaluation of the technology's market potential (Dorf and Worthington, 1987). Hence, the degree to which a technology push organisation is able to successfully commercialise technological innovations, depends on its ability to identify suitable markets (Roberson and Weijo 1988; Slater and Mohr 2006) and the associated application areas. Understanding how alternative applications to technology are identified is key to cross the technology push "Innovation gap" (Evans et al, 2008; Felkl, 2013). Moreover, detecting potential applications to technology is widely regarded as an important activity of organisations, 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).

1.2 The foundation of the thesis

1.2.1 Identified gap in the literature

A comprehensive literature review by Isern and Strøm (2017) concluded that application identification in a technology push context is theoretically underdeveloped, fragmented and in its embryonic stage. Moreover, 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. By technology push application identification I refer to the process of market opportunity recognition tied to a given technology, in which how organisations identify potential alternative application areas is the focus. If the identified alternative application actually are successfully commercialised goes hence beyond the scope of this thesis.

The reviewed literature also proved to be quite fragmented in terms of designation, consisting of studies from four different schools: business innovation, open innovation, new product development and technology transfer (Isern and Strøm, 2017). All of these somehow mention application identification and address the importance of it, but the different literature branches have different approaches to it. Furthermore, all of the studies revolve around a specific challenge, and propose methods to overcome it. While both the business innovation and the new product development literature mostly address the challenge of radical innovation potential, and proposes explorative, creative methods in order to deal with such potential, the two other camps have a whole different focus. Both the technology transfer and the open innovation literature looks into how organisations can exploit their developed technologies, and respectively they focus on the challenge of market ambiguity and the application bias. The market ambiguity challenge refers to the market risk connected with starting the commercialisation based on a technology, and to overcome it methods for creating bonds with industry are suggested. The application bias revolves around the challenge of being framed by the original application, and methods to deal with it include TRIZ-inspired methods and categorising the technologies according to pure technological functions, as well as using patent and technology databases.

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. In fact, the two pairs of schools appear to have fundamentally different motivations for application identification. Isern and Strøm (2017) concluded that each pair respectively fit into Gregor and 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. According to Gregor and Hevner (2014), the degree of innovation resulting from application identification for a known technology can be characterised as exploitation and exaptation respectively. For both cases, the application area is unknown, however, an exaptation innovation is much more innovative than an exploitation innovation (ibid.).

The recommendations from the study by Isern and Strøm (2017) includes unifying the different literature schools within technology push application identification. By building further upon 'exploitation' and 'exaptation' as introduced by Gregor and Hevner (2014), and by learning from the literature from the different schools, future research should aim to create a more nuanced picture of the relationship between the two perspectives.

Especially integrating and developing the exaptive strategy for the technology transfer school is recommended as a topic for future research. Particularly in this part of the literature, application identification is treated superficially. While several of the reviewed technology transfer articles mention application identification as a crucial step of the commercialisation process (Moncada-Paterno-Castello, 2010; Caetano and Amaral, 2011; Vohora et al, 2004), none of them gives any attention to how they go about finding the new applications. It is hence interesting to investigate how technology transfer offices identify new applications, and investigate approaches to application identification that are further away from the original application, based on the findings from the other literature camps.

1.2.2 Purpose:

This thesis aims to increase the understanding of application identification in a technology push context, focusing of Technology Transfer Offices (TTOs). As previous research belonging to the Technology Transfer school focuses exclusively on incremental innovation (Moncada-Paterno-Castello, 2010; Caetano and Amaral, 2011; Vohora et al, 2004), at the same time as we know that technology push innovations often has radical innovation potential (Herstatt and Lettl, 2004; Henkel and Jung, 2009, 2010; Souder, 1989), this is an interesting phenomenon to study with a clear gap in the literature. By creating a better understanding of the role of exaptive innovation potential in this field, TTOs will be better equipped to increase their impact and results. The purpose of this thesis is:

"To investigate approaches for Technology Transfer Offices to identify applications that are further away from the original application"

"Further away from the original application" entails that the new application has a lower Application Domain (Problem Space) Maturity (Gregor and Hevner, 2015). Applications with a lower Application Domain Maturity will be less intuitive and more creative than applications closer to the original application, and they are hence more exaptive of nature.

When the objective is to obtain as much and as deep information on a given phenomenon, extreme cases are suited as they reveal richer information (Flyvbjerg, 2006). Therefore, as the purpose relies on a deep understanding, this thesis will look into the extreme case of CERN. CERN, the European Organization of Nuclear Research, is probing the fundamental structure of the Universe by using some of the world's most powerful particle accelerators[1]. Extremely complex scientific instruments are used to study the basic constituents of matter, and the three pillars of technology at CERN - accelerators, detectors and computing - are made up of a great number of areas of expertise. CERN's Knowledge Transfer group aims to create impact on society through technology and knowledge transfer, and finding new applications to CERN's inventions is one of their main activities[2].

Many great inventions were born at CERN, creating continuous impact on society. One example is the World Wide Web[3], and also, CERN knowledge has contributed to state-of-the-art medical technologies. Knowing this, one should think that the technologies from a place like CERN would have great potential in other markets. With regards to the purpose of identifying further away applications, CERN makes up an especially interesting case. First of all, such applications often have a bigger impact on society (Walsh et al., 2002; Kirchhoff et al., 2007) - the goal itself of CERNs Knowledge Transfer group. Second, research has shown a positive correlation between complexity of technologies and exaptation (Mastrogiorgio and Gilsing, 2016), making CERN an even more interesting case for this thesis.

[1] https://home.cern/about
[2] https://kt.cern
[3] https://home.cern/topics/birth-web

Through learning from relevant literature about other types of technology push organisations while immersing myself into the peculiarities of the Organization, I hope to be able to better understand the underlying mechanisms of application identification in this context.

1.2.3 Research questions

Application identification in the CERN Knowledge Transfer group (KT group) is first and foremost the responsibility of the Knowledge Transfer Officers (KTOs). While the KTOs work to find new applications to CERN inventions on an everyday basis, applications are also found through the annual NTNU Screening Week. The NTNU Screening Week serves to find new, valuable applications to CERN technologies. It consists of roughly three different phases, although it is not a linear process: preparing to solve the problem, search for opportunities and identifying the most valuable markets.

In order to answer the purpose, and to understand this in the context of CERN, it is important to understand the process, context, aims, resources and limitations of application identification in the CERN KT group as a whole. The first research question is hence:

RQ1: *What characterises identification of new applications to technology in the CERN Knowledge Transfer group today?*

It is however also interesting to see how the methods for identifying new applications used by the students during the NTNU Screening Week compare to the methods of the KTOs. The second research question is hence:

RQ2: *What characterises identification of new applications to technology during the NTNU Screening Week?*

If the NTNU Screening Week leads to another type of opportunities compared to the opportunities being identified in the CERN KT, this could potentially be a valuable resource for the group. This is also interesting for the overall purpose. The third research question is hence:

RQ3: How is the NTNU Screening Week useful to CERN, as a resource for identifying new applications?

1.3 Contribution

This study will contribute to the field of technology push application identification. Specifically, as recommended by Isern and Strøm (2017), the research will start building bridges between Technology Transfer literature and the other literature camps within the technology push application identification literature. As there is little previous research on this field, the main contribution of this thesis will be to create an initial understanding of the role of application identification in TTOs and the underlying mechanisms of it. Also, by investigating the role of exaptation in this context, important contributions will also be made to this recently introduced branch of innovation research. By looking into the value of the NTNU Screening Week, I will also learn more about which role external resources plays with respect to application identification in TTOs. The findings of this thesis may eventually help researchers, as well as practitioners, a step closer to how to create more impact on society through identifying and exploring exaptive applications of technology.

1.4 Structure

This thesis consists of seven chapters. During the introductory chapter, the particularities of technology push application identification has been explained, and an identified literature gap has been presented. This made the foundation for the purpose of the thesis. In chapter 2, theories regarding application identification approaches as well as studies related to the resource based view, make up the theoretical framework of the thesis. In chapter 3, the methodical choices of the research will be accounted for, in which a single case study has been chosen as research design. Chapter 4 presents the findings from the research, followed by an analysis of the results. Chapter 5 discusses the key findings from the analysis with respect to the purpose of the thesis. Finally, chapter 6 contains the concluding remarks, while chapter 7 gives an overview of concrete implications for Technology Transfer Offices and the CERN KT based on the study, as well as recommendations for further research..

2 Theory

In this chapter the theory relevant to the thesis will be presented. Firstly, theory on technology push application identification will be presented and, secondly, theory on the role of resources and how to create sustainable value in organisations will complement this. Finally, the theoretical framework of the thesis will be illustrated.

2.1 Technology push application identification

Many scholars have written about the distinction between exploitation and exploration (March, 1991). Gregor and Hevner (2015) introduces a more fine-grained view, separating the technology push innovations into exploitation innovations and exaptation innovations. The two views are related to the degree of innovation, and the contrasting viewpoints lead to a different focus and prioritisation. A technology push organisation can respectively commercialise its developed technologies for either existing applications through exploitation, or new-to-the-world applications through exaptation (ibid.). For both cases, the application area is unknown, however, an exaptation innovation is much more innovative than an exploitation innovation. In figure 1 below, the exploitation view and the exaptation view is illustrated as part of the four ways organisations can innovate - however, in a technology push context the Knowledge (Solution Space) Maturity will always be high, and thus, only exploitation and exaptation are relevant.

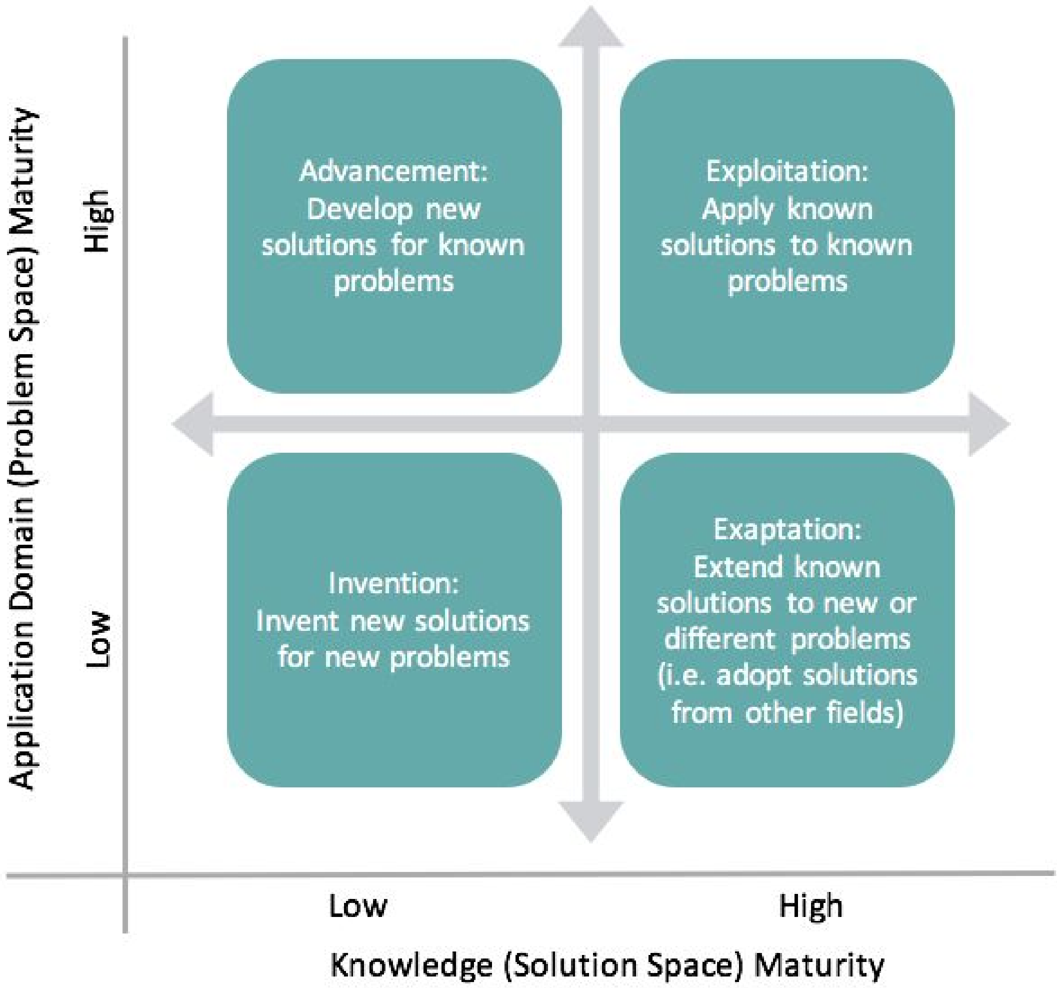

Figure 1: Gregor and Hevner's (2015) Knowledge Innovation Matrix

To uncover application areas of different innovation levels, different processes and methods for application identification are required. For exploitation innovations the main goal is to reduce the market ambiguity bias to successfully transfer the technology to new application domains (Moncada-Paterno-Castello, 2010; Vohora et al, 2004; Felkl et al, 2013) and also to create value from a technology that is already developed (Bianchi et al, 2010; Lichtenthaler, 2010; Lee et al, 2009). In such cases applications are typically identified as a result of the knowledge base of the people involved (Gregor and Hevner, 2015), and many of the methods are used to unveil opportunities for proprietary technology. Breaking down the technology into technological functions to inhibit the bias of being framed by the original application (Isern and Strøm, 2017) and, based on that, building keywords, is mentioned by many as the basic first step of application identification (Hartelt et al., 2016; Henkel and Jung; 2010; Felkl, 2013; Bianchi et al, 2010; Lichtenthaler, 2010). Some studies suggests doing searches in technology and patent databases (Bianchi et al, 2010; Lee et al, 2009) to create value from a proprietary technology. Others highlight the usefulness of integrated technology commercialisation roadmaps to detect licensing opportunities (Lichtenthaler, 2010; Caetano et Amaral, 2011). Friar and Balachandra (1999) takes another approach where the original users of a technology are targeted, and asked what new applications they should develop with the technology, and Lynn and Heintz (1992) highlights the importance of industry linkages for incremental innovations. A probe and learn process is suggested to identify applications while integrating potential customers into the process.

Considering the exaptive perspective, the goal is to discover whole new applications for the technology, which can be defined as superior opportunities (Andriani et al, 2017). The radical potential bias (Isern and Strøm, 2017) is thus the most important challenge to overcome to identify exaptive applications. 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 and Hevner, 2015; Herstatt and Lettl, 2004; Weiss, 2004). Methods suggested to identify exaptive applications are crowdsourcing, as well as creative methods such as brainstorming and ideation techniques (Gregor and Hevner, 2016). Chadha (2016) also suggested brainstorming as a useful method for exaptive innovations, entailing that all members in a group should contribute with ideas and build on each others ideas in an attempt to devise a solution for a problem (Paulus and Yang, 2000). Such explorative exercises should be conducted by interdisciplinary teams to combine knowledge within several fields and with different perspectives (Gregor and Hevner, 2015; Souder, 1989). These should have individual characteristics that typify highly creative people, and also a strong intrinsic motivation (ibid.)

In order to brainstorm successfully, the social environment needs to be open to creativity and new ideas, and it should be facilitated for that creativity blockers are inhibited (Amabile, 2012). Thus, during the brainstorming, free ideation should be rewarded and criticising ideas should be avoided. If a newcomer to a field has the requisite information, he/she is more likely to achieve a creative solution than a long-time worker in the field (Mednich, 1962). Thus, to be successful in generating creative ideas, the two sub-processes before the brainstorming itself should be completed properly: 1) analysing and articulating the nature of the problem to be solved and 2) preparing to solve the problem by gathering information (Amabile, 2012).

Mednich (1962) investigated the associative basis of the creative process, and argued that the requisite associative elements may be evoked in contiguity due to the similarity of the associative elements. Analogy is one way of identifying similar associative elements. Gavetti (2012) and Gavetti et al. (2005) argue that associative thinking or analogy is the main method for finding alternative application areas. Andriani et al (2017) builds under this, claiming that to spot cognitively distant opportunities it is necessary to deal with substantial ambiguity, and that analogy is the natural reasoning mechanism when this is the situation. Analogy is a cognitive process, enabling knowledge to be transferred from a base domain to another domain where the domains have certain similarities (Gentner, 1983). Andriani et al (2017) highlights that one can foresee the exapted function by using analogy if the exapted and the original function is based on the same underlying phenomenon.

The requisite associative elements to find a creative solution “might also be evoked contiguously by the contiguous environmental appearance (usually an accidental contiguity) of stimuli which elicit these associative elements” (Mednich, 1962). In other words, exaptation is related to serendipity (Dew, 2009; Meyers, 2007). Even though serendipity, by definition, is not intentional, one may implement processes to multiply the contexts to which the organisations resources and capabilities are exposed (Andriani et al, 2017).

Andriani et al (2017) suggests four ways organisations can accelerate the identification of exaptive innovations. The first is that organisations should ensure that available resources can be partitioned and assembled in limited-life projects where their value in a new context can be explored. The second entails that employees are encouraged to develop projects that may create value for them and the organisation, and that time and resources should be set aside for this purpose like the 15% rule at 3M (Grundling, 2000) or the one-day-a-week-rule at Google. The third has to do with expanding the intelligence that can access organisational resources and capabilities, for instance through cooperation with lead users and innovation communities (von Hippel, 2005), innovation tournaments (Terwiesch and Ulrich, 2009), innovation markets (Page, 2008). codesign and crowdsourcing (Anderson, 2012) and innovation platforms (Chouduri et al, 2016). The fourth is about the role of entrepreneurs and organisational venturing such as the creation of spin-outs and start-ups (Read et al, 2010).

2.2 The role of resources

2.2.1 The resource-based view

While the section above focuses on the opportunities an organisation confronts and how to tap into different types of opportunities, what an organisation can do also depends on what resources the organisation can muster (Teece et al, 1997). Resources can be defined as strengths that organisations can use to conceive of and implement their strategies (Learned et al, 1969), and when they succeed in doing so, the resources are valuable (Barney, 1991). There are several ways to categorise the various resources in an organisation. Barney (1991) suggests that resources can be put in either of the following categories: Physical capital resources, human capital resources and organisational resources. Often, however, they are just referred to as tangible and intangible resources.

The Resource Based View is best applied for analysing an organisation's existing resource portfolio, and to do this Barney (2001) presented the VRIN model for organisations to analyse their resources and capabilities with respect to their potential for creating sustainable value. The study based this on if the resources were valuable, rare, inimitable and non-substitutable, and if a resource had all of these characteristics the resource would create sustainable value. The framework was updated in Barney (1995), in which the factor 'non-substitutable' were swapped with 'organised' - meaning if the organisation was able to capture the value created by the resource.

2.2.2 Dynamic capabilities and absorptive capacity

In Penrose's (1959) theory of efficient management of firms' resources, a key proactive role is assigned to managers in perceiving and pursuing productive opportunities. Some organisations are better at capturing value created by a specific resource, and this can be explained by the capabilities they have developed. Due to this reason, the resource-based perspective stresses the development of new capabilities (Wernerfelt, 1984), and issues such as skill acquisition, the management of knowledge and know-how and learning becomes fundamental issues (Shuen, 1994; Teece et al, 1997). Teece et al (1997) remarked that to identify new opportunities, and organising effectively and efficiently to embrace them, requires dynamic capabilities - the ability to achieve new forms of competitive advantage. For example, organisations with an entrepreneurial culture are likely to sustain superior returns (Penrose, 1959), an idea also looked into in Barney (1986).

The benefits and tangibility of dynamic capabilities are connected to underlying processes of knowledge accumulation, allowing organisations to develop, gain, reshape and put into use new internal and external knowledge (Licthenthaler, 2009). Internal knowledge creation capability entails having a continuous internal system for handling new knowledge (Fores and Camison, 2016), something that is often based on employees exchange of existing knowledge and combining it in new ways (Danneels, 2008; Helfat and Peteraf, 2003; Rosenkopf and Nekar, 2001; Zollo and Winter, 2002). Internal knowledge creation is hence closely related to teamwork (Nonaka, 1994). When the source of ideas is external, the capability to integrate the external knowledge can be referred to as the organisations absorptive capacity (Fores and Camison, 2010; Fores and Camison, 2016; Jiménez-Barrionuevo et al., 2011; Lane et al., 2006; Zahra and George, 2002). The organisations absorptive capacity depends on its capability to acquire, assimilate, transform and apply the external knowledge (Fores and Camison).

2.3 Theoretical framework

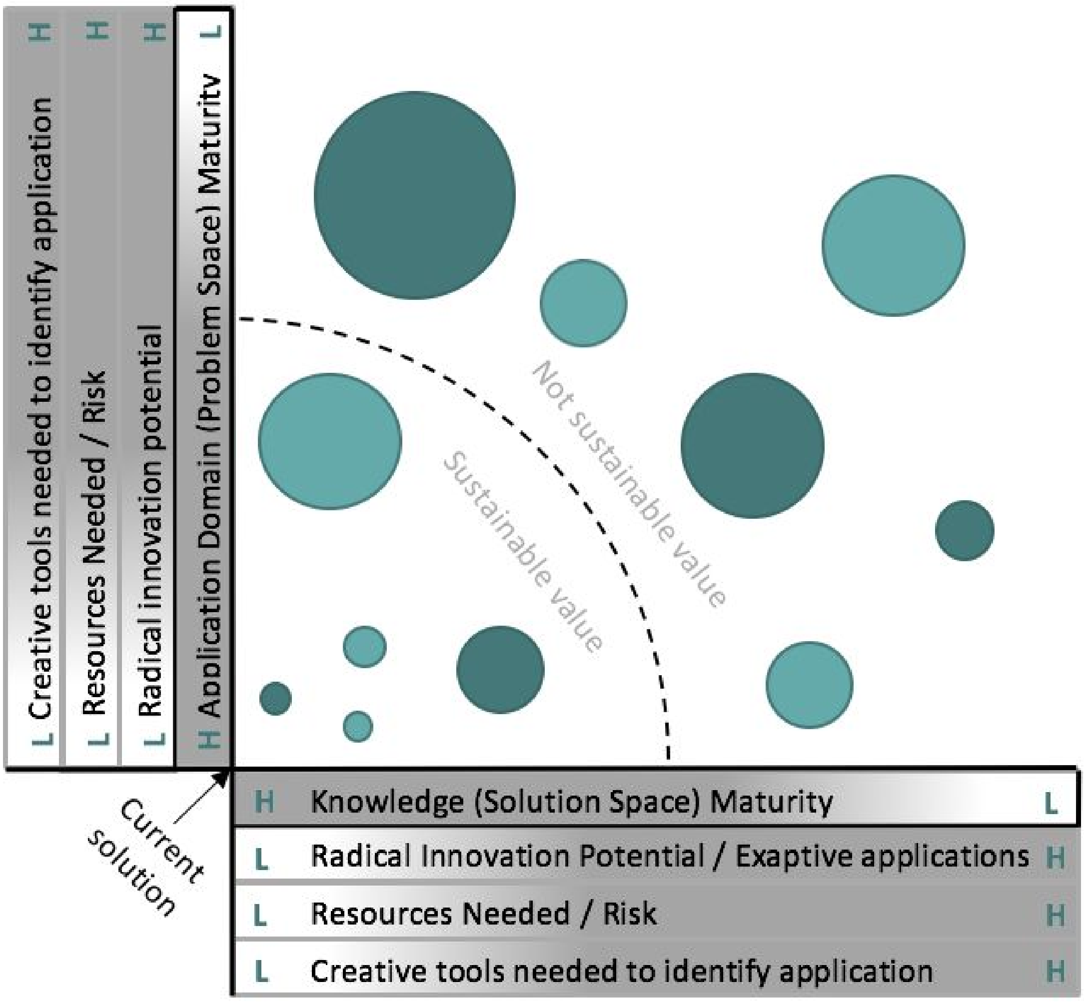

Figure 2: Theoretical Framework - Technology Push Application Identification

Figure 2 sums up the theory about application identification for technology push organisations. Based on Figure 1, Gregor and Hevner's (2015) Knowledge Innovation Matrix, Figure 2 reverses the original figure by putting the Application Domain Maturity on the y-axis of a graph and the Knowledge Maturity on the x-axis. The higher maturity of the two categories, the closer an application will be to origo - and to the original application. In the intersection between the two axes the maturity of the two categories are both at their maximum, and hence this is where the current solution is. The further away from origo, the more exaptive the potential applications are.

As scholars have highlighted before, the figure also shows how applications that are further away from the original application often have greater potential (Herstatt and Lettl, 2004; Henkel and Jung, 2009, 2010; Souder, 1989), that more creative tools are needed to identify more distant opportunities (Gregor and Hevner, 2015; Herstatt and Lettl, 2004; Weiss, 2004), that they require more resources to identify, and that more risk is associated with further away applications (Herstatt and Lettl, 2004).

Finally, the dashed line shows that some more exaptive opportunities are worth identifying due to the increased potential of them. However, at some point, due to the required resources, the identified exaptive applications will not lead to sustained value. As a result, even though applications that are further away may have a bigger potential, many of them will not create sustainable value for the organisation as it requires too much resources.

The figure builds on theories from the technology push literature, also integrating theories from the Resource Based View. While all the components of it is based on former research, I have put them together in a whole new, innovative way. The figure is actually the first to show that the relationship between exploitation and exaptation is nuanced. In line with Isern & Strøm's (2017) recommendation of unifying the theories from the different literature schools, this is a first step in this process; bridging the unnecessary gap between the two views.

3 Methodology

In this chapter, the method for the conducted research is accounted for. The method is presented using three separate plans. First an overall plan for studying the application identification process in CERN's KT group. Next, a plan for collecting the available information. Lastly, a plan for analysing the collected information. Altogether, the following sub chapters will highlight, and give reason for, the conducted research composition. In addition, a section will contain reflections on the choice of method, its effect and its limitations.

3.1 Research design

The conducted research design for the study is presented, and reflected upon, in this subchapter. The aim of research design is to create a plan for collecting and analysing data so that answering the RQs is possible (Flick, 2015).

3.1.1 Qualitative Research

The RQs in this paper were constructed to expose new aspects of the application identification process at CERN. According to Flick (2015) the best social research approach to facilitate the discovery of new findings is through qualitative research. What the application identification process looks like in the CERN KT group, why they have certain priorities regarding this and how the NTNU Screening Week can be useful for this, has no straight forward answer, and by using qualitative research, this might be enlightened (Yin, 2014).

3.1.2 Case Study

Case study research is valuable to fulfill the purpose of this study as I will "explore in depth a program, an activity, a process, or one or more individuals" (Creswell, 2003). Moreover, the RQ's are too complex for using only a survey or experimental strategies, while the case study method will explain the presumed causal links in real-life interventions (Yin, 2014).

I will use CERN as a single case, with the NTNU Screening Week as an embedded case. An extreme case like CERN is valuable when the goal is to obtain deep information and understanding of a phenomenon (Flyvbjerg, 2006). A single case study works well to represent a unique or extreme case (Yin, 1994), and this approach will give valuable in-depth insight regarding how the CERN KT group goes about application identification. Furthermore, the embedded case allows for a more detailed level of inquiry, working well to describe the context, process and features of the phenomenon (Scholz and Binder, 2011).

3.2 Data Acquisition

When data is to be acquired for a case study, it should draw from multiple sources (Williams, 2011; Eisenhart, 1989). This view is further backed by Miles and Huberman (1994) through the advantages of triangulation of data. In line with this, I have spent time on-site to gain deep knowledge about the people and processes being studied, conduct interviews, do observations, and also make use of available documents and instructions.

To ensure that this case study is scientific and easy to replicate, an accurate record of all of the data collected and used for this study has been kept. I have ensured this by carefully documenting the research design and the case study protocol including the questions and the transcribed responses.

3.2.1 Spend time on-site and access to secondary data

In order to gain as much and as deep knowledge about CERN and the KT group as possible, as well as the Organization's[4] processes, priorities and activities, I will spend six months on-site before acquiring the rest of the data. This includes working in the group on a daily basis, but also attending group meetings, walking in the hallways and having informal conversations with relevant people - giving insight into how they work and the context of technology transfer and application identification at CERN. By attending meetings and learning from the work of the group, in addition to getting access to internal documents and secondary data, this also resulted in data that has been used in the thesis. Even though I have had the chance to influence how the group work in group meetings etc. I have deliberately chosen not to do so, and furthermore I have been working with communication in the group on a daily basis and not with the business development itself.

3.2.2 Interviews

Most of the case study data has been acquired through in-depth, face-to-face interviews. A case study protocol has been kept, including a blueprint for the interviews, as well as the interview guides that were used during the interviews. The protocol is key to increasing reliability of the study (Flick, 2015, Yin, 2014). In preparation for each interview, background material about the responsibilities and peculiarities of each interview object has been collected and studied. All interviews in the study has been recorded and then transcribed. In addition, notes has been taken of key points and observations.

In order to answer RQ1, all of the Knowledge Transfer Officers (KTO's) in the KT Group has been interviewed, in total five KTO's. The KTO's are helping out with the commercialisation aspect of CERN technologies that may have potential

[4] Official way of referring to CERN

outside high-energy physics. Each KTO are responsible for a certain amount of cases, and they follow these cases from technology disclosure to commercialisation. Market assessment is part of their responsibilities, and hence it makes sense to interview them to get information about how this is done. They were asked various questions about what the knowledge transfer process looks like, how they identify applications and how much time they use on it, what methods they use to do this, what their priorities are, how they deal with different kinds of opportunities etc. I expect them to have a quite similar mindset with regards to the priorities and the aim of application identification at CERN as they are part of the same culture with the same incentives, but slightly different approaches to it due to their backgrounds and the fact that they seem to not collaborate that much..

The group leader of the KT group has also been interviewed. He was asked questions with regards to application identification, but also question regarding the overall strategy. This is important to better understand the prerequisites of application identification at CERN.

In order to answer RQ2 and RQ3, the group leader of each of the four teams at the NTNU Screening Week at CERN were interviewed during their stay. These were interviewed as they are at CERN to do market assessment for CERN technologies, and it is interesting to see how they go about identifying opportunities. Accordingly, they were asked about how they did this, which methods they used, how many potential applications they identified during the week and how many of them turned out to be worth looking further into, how they prepared etc.

The interviews were held by the author, together with another Master's student working on the same topic. It was beneficial conducting the interviews together, as we were working on the same topic in addition to the fact that it allowed one to lead the interview while the other took notes and made sure the guide was followed. The interviews were semi-structured, meaning that they were based on the interview guide, but that I only partially followed it (Flick, 2015). The interview guide contained all the questions that together made up the scope (ibid.). Semi-structured interviews allowed me the flexibility to probe after interesting experiences connected to specific episodes, whilst at the same time secure that I got the data necessary to answer the RQs.

3.2.3 Observations

To answer RQ2 and RQ3, observations were made during the NTNU Screening Week. In addition to spending the whole week with them on-site, direct observations of their group meetings were made, in which sessions were recorded by taking detailed field notes of everything happening. During the first three days of the event, three rounds of observations of the four groups discussions were conducted. Some of the group meetings were together with the inventor, the KTO's or with technical experts. This is interesting because I got to see more of the dynamics in the groups, how they worked together, how different people contributed to the discussion, what they said, what happened when the technical experts enter the discussion, how they found new ideas etc. While the information from the interviews already had "been analysed" by the student being interviewed, the observations provided raw material and richer information regarding the identification of applications during the NTNU Screening Week.

3.3 Analysis of data

I have analysed the collected data about application identification in the CERN KT group with respect to the theoretical framework. The key to analysing the data is to constantly compare it with theory (Eisenhardt, 1989). As this is a single case study, the gathered data from CERN as well as the data from the embedded case, has been analysed with respect to the theoretical framework.

Moreover, in order to answer RQ3, they have also been analysed with respect to each other.

The following steps of analysis have been applied: First, secondary data relevant to application identification from the on-site observations and from documentation has been examined and analysed. After that, all of the recorded interviews were transcribed. Next, I systematically went through and interpreted all the interviews from both the KTO's and from the NTNU Screening Week, as well as the field notes from the observations, to see how they go about application identification and what methods are used. The former step were repeated multiple times, until the substance of the interviews and the observations were clear. Following, a written report of the findings was produced. This report contains the combined findings from the analysis of primary and secondary data. Furthermore, the essence the report were placed in an overall table to better display the data. By breaking down the data and placing it in an overall table, the amount of data has been greatly narrowed down and made far more comprehensible for the further analysis. At last, based on the findings from the table, the data has been analysed with respect to the theory presented in chapter 2.

3.4 Reflections on the method

In this section, a reflection of the quality of the research design is presented. First, the research design is discussed with respect to strengths, weaknesses and ways of improvement, following a section about the ethical considerations of the study, and lastly, the limitations of the study is presented.

3.4.1 Quality of the study

It is important to evaluate the quality of research. For evaluating the value of qualitative research, trustworthiness as established by Lincoln and Guba (1985) is key. Trustworthiness in a study can be obtained by establishing credibility, dependability, transferability and confirmability (ibid.). Regarding credibility, it requires establishing confidence that the findings are credible or true. According to Flick (2015) I am using triangulation as I use more than two methods for collecting data, increasing the likelihood of obtaining a more credible result. In addition to interviews and access to secondary data, I have benefited from observation and empathising how the KT group go about application identification as well as observing the students during the NTNU Screening Week. This allowed me to gain an even deeper insight in the workings of these processes. Furthermore, ensured the credibility of the study by demonstrating sufficient knowledge of the applied theory as well as of the CERN KT and its context. This is strengthened as a result of that the author observed and worked with the group for half a year before starting the data collection. Finally, the transcribed interviews were sent to the interviewees in order for them to read through, correct misunderstandings and add comments if something could be misinterpreted or be unclear. Nothing was changed by any of the interviewees, but some elaborated on their answers to provide even more information.

Regarding transferability, it requires establishing how applicable the findings are in a different context. Practicing the single case study method gives me a possibility to gain a deeper understanding of CERN. However, as only the specific case and its peculiarities are being investigated, the results have the same characteristics. Therefore, as to the transferability, I not be qualified to create new theory from this study. That being said, an advantage of focusing on a single case, is that I will gain a deep insight about application identification in the CERN KT group, and might lay the groundwork for future studies in similar organisations.

Regarding the dependability of the study, it requires establishing that the findings are consistent and that they can be repeated easily. I have ensured dependability by securing an auditing trail, as mentioned by Guba and Lincoln (1989). The auditing trail includes the case protocol, the interview guide, as well as the case study reports. Altogether this will make it easier to later replicate the study for someone else. Regarding the collection of data, semi-structured interviews ensured that getting information about the RQs could be kept in focus even when the interviewee wanders off topic. Therefore, using semi-structured interviews ensured a higher level of dependability as the data collected from each case is relevant for the purpose of the study. Furthermore, by using the interview guide I could more easily evaluate the questions and practice the actual interview in advance. Thus, I were more prepared for the actual interview, ensuring a more consistent, and a higher-quality data collection process. To further increase dependability, I made a qualified external person look over the correlation between the collected data and findings of the study.

Lastly, regarding the confirmability, it requires establishing a degree of neutrality. This was ensured in the study by striving to analyse the case and present the findings as true and objectively as possible. That means that I had to be aware of my role as a researcher and put aside my personal interests and biases in securing that the response of the interviewees were documented fairly. By recording and transcribing the interviews, as well as interpreting them carefully through the analysis, the confirmability of the study has been maintained.

3.4.2 Ethical Considerations

When conducting a study it is important to take actions to make sure the ethical aspects are maintained. Therefore, I informed the participants of the study of its purpose and how the data were going to be used. Permission from every participant were also obtained to follow the ethical guidelines. Moreover, the confidentiality of the participants has been preserved through storing the collected data safely and deleting it after use (Thagaard, 2013). As mentioned above, the interviewees will also got chance to read through and elaborate on their answers from the interview.

2.4.3 Limitations to the Study

The research design of this paper has been constructed to be of high quality, as well as to best possibly fulfill the purpose of the study. However, there are some factors that may have a limiting effect after all. Among these are resource constraints such as time, manpower and funding. The study is sponsored by university means, and it has been conducted during 26 weeks. Moreover, despite the fact that I have written similar theses before, this is the most extensive one. These factors can affect the study and will have to be taken into account when presenting the findings from the study.

4 Findings & Analysis

In this chapter the findings from the gathered data will be presented - first from within the CERN KT group and after from the NTNU Screening Week. Furthermore, the findings will be analysed with respect to the theory presented in chapter 2.

4.1 Findings

4.1.1 Within the KT Group

The identification of new applications to a technology at CERN happens as part of the KT process. This process has many steps, but summarised it looks something like this:

- Scouting and Screening
- Meeting with the inventor(s)
- Learning about the technology, it's benefits and its limitations
- Assessment of the market - potential outside of High-Energy Physics?
- Protection and dissemination strategy
- Market technology and look for potential users
- Contract negotiation
- Relationship
- Impact

The application identification happens mostly early on in the KT process, and formally this is part of assessing the market. In theory, this should be done by using a market assessment form (MAF) to collect data from the market, which includes tools like Porter's five forces and SWOT analysis etc. In practice, this is not widely used.

When asked to specify the time the KTO's initially used on identifying new applications, this ranged between half an hour to some days. Even though the application identification is done mainly in the beginning, most interviewees highlighted that it is a continuous process. When going to conferences or talking to companies and in generally spending time working on the project, whole new opportunities can emerge. This is however rather random than deliberate.

The main method for identifying new application areas to a technology is to talk to the inventors and get relevant information that might be used. It is highlighted that the inventors usually have a good sense of where the technology can and can't be used, as they have been working with the particular technology for years, attending conferences and talking to plenty of relevant people. Therefore, in most cases, the inventor already has an idea about what the technology should be used for. Moreover, several of the KTO's mentioned in the interviews that the inventor had to be the project leader of the commercialisation, as the commercialisation will require a lot of resources from the inventor. Before starting to do extensive work related to alternative application identification, it is therefore core to ensure that the inventor and the associated hierarchy is positive to it. The knowledge and ideas of the inventors is thus used as a starting point and further worked towards - almost without looking into other potential areas.

Despite that little time and focus is dedicated to identifying new application areas to CERN technologies, everyone acknowledge, more or less, the importance of doing some research beyond talking to the inventors. In order to do this, there are some methods that are particularly used:

Googling keywords seems to be a method everyone uses for application identification, and something that they think is really valuable to do. Amongst others, it was remarked that if you are able to select the proper keywords, the search can yield really good answers and reveal whole new application areas. It is easy to think that googling is a simple tool, but for application identification in KT it has proved to be quite powerful.

"There is no obvious link between the different potential applications, and that is why Googling keywords and functions might give very good results - It forces you to open your mind"

The general perception is that after talking to the inventors and doing a quick Google search, one will have quite a good sense of which application areas are the best ones to look at and that are the ones with the most potential. And then, the efforts are quickly focused on further assessment and the potential to protect and disseminate with these application areas in mind. One of the KTO's remarked that after understanding a technology, it did not take a long time until he would start looking for customers to contact - he would find and validate applications by being customer focused. Another remarked that the had never experienced a Technology Transfer case in which the application area had not been identified first by the inventor.

Usually, one or maybe two potential markets that would be interesting to exploit are selected. It is noted that it would be better to work on several application areas simultaneously, but that it is not enough time available to explore all the potential paths that may exist out there.

Attending relevant conferences for the same type of technologies, is also a method for identifying applications that many value. The reason for this is that you straight away see which companies are attending those conferences, and chances are big that also some of these are working in relevant industries. One of the KTOs mentioned a cryogenics technology he had brought to a conference, in which a big industry player had approached him and wanted to use it.

The NTNU screening week, where entrepreneurship students come to CERN for a week to do market research on various technologies, was mentioned several times as valuable for identifying new applications. Firstly, because they are many and are spending a week calling relevant people, they actually get a lot of good information which would take months for one person to do. It was highlighted that this was detail work that the KTO's themselves did not have time to engage in. Secondly, several interviewees remarked that the students actually propose markets and applications which the inventors did not think about, which was used in the further work.

Patent databases may also be used to see what other similar technologies are out there and what are the players in the market that are working in these areas. Thompson Innovation is a tool for doing this. Moreover, Collspotting, a database linking patents and companies working together with the purpose of identifying leads, is currently being tested.

With some technologies that seem to have high potential, evaluation reports of some kind might also be commissioned. This entails paying a firm to crawl the internet, speak with relevant people to try to get all the information they can and doing the number crunching to estimate the potential value of the technology. However, this costs money and currently such reports are lying around without people really being aware of them.

When asking about how they do application identification and methods they use, we got answers like *"That is actually a really good question... There is no rule for it, no formula"*. Moreover, several of the KTO's remarked that they were supposed to follow certain steps and do certain things, but that it was not done in practice.

All of the KTO's talk about exploiting the technology in the market and the majority of the methods that are used are aimed towards current, rather low-hanging opportunities. For example, with the Medipix technology, a read-out chip for particle tracking, there are a lot of licensees. However, most of them rather offer the technology themselves, rather than focusing on a specific application. Moreover, many of the technologies that are used to do particle physics, can also be exploited in medical treatment and diagnostics, and also for aerospace applications. For many of the technologies, applications within this area are immediately looked into.

When asked how they deal with future business potential I got answers like *"it is pointless to push technology outside if the market is not ready".* Another remarked that even though they had not come across any cases like that yet, that it would probably be relevant to be aware how to deal with future business potential.

Today, there are not really different methods to identify opportunities that are further away from the original application. However, one of the KTOs used a method she called 'random checking', in which she would google keywords of the technology together with random potential applications, just to see if something might come of of it. An example of this is when she were working on metamaterials. Out of curiosity she had Googled this along with "soldiers/sole gel", just to understand if something came out of it. And then, she actually found company based in Canada that was doing exactly metamaterials with "sole gel".

Furthermore, for instance the KT fund serve to finance the development of early stage technologies that might also have potential in other industries. And also, if a technology shows future business potential, collaboration partners in the market might join an R&D partnership to further develop the technology. Also the network of Business Incubation Centres (BIC's), which are spread across nine member states, sometimes leads to the identification of applications that are further away from the original application. The BIC's serve to promote CERN technologies to future entrepreneurs and startup companies in the respective country, something that has lead to applications in whole new fields, commercialised by startups. An example of this is Innocryst, a startup company in the STFC-CERN BIC. After talking to the BIC, the company started developing a system based on X-ray diffraction imaging technology to fingerprint, in order to identify and track individual natural and man-made gemstones, based on CERN simulation software. The several of the KTO's also mentioned that they get requests from people having seen potential in technologies as a result of showing the technology portfolio on the KT website.

Table 1 below sums up the different methods used deliberately by the KTO's for application identification.

Application identification Methods	KTO 1	KTO 2	KTO 3	KTO 4	KTO 5
Information about potential applications from the inventor(s)	YES	YES	YES	YES	YES
Google Searches	YES	YES	YES	YES	YES
Based own knowledge	YES	YES	YES	YES	YES
Identifying applications through talking to potential customers	YES	YES	YES	YES	YES
Patent/Technology Databases	YES	NO	NO	YES	YES
Going to relevant conferences	YES	NO	NO	YES	YES
Random checks	NO	YES	NO	NO	NO
Discuss with other KTO's	NO	YES	NO	NO	NO

Table 1: Application identification methods in the CERN KT group

4.1.2 The NTNU Screening week

Group Orthopix

Before coming to CERN the Orthopix group prepared by looking into a market report on the technology, and checking if there had been changes in the suggested markets in the report. To find out this they called leads from the previous report. However, by doing this, they found new opportunities as the people had gotten new jobs where the technology could be relevant as well. Moreover, four of the team members had technical backgrounds and they got the task to understand the technologies as good as possible so that they could explain it to the rest of the group. After getting some understanding of the technology and its advantages, the students had a brainstorming session where they looked at where it could be interesting to apply the technology and where it could have potential. In this process, they would use the whiteboard actively, and in this phase they would not remove anything without knowing that it would not work.

"We just talked about it and around it and got new ideas. It was really cool to start out so broadly, it lead to that we came across many areas we would not have identified otherwise"

They ended up with six areas of interest, each with 1-5 sub areas that could be interesting applications to the technology - about 25 different potential application areas. For instance, the potential of the technology being used in drones for mapping the ground came up during the brainstorming. *"The group just brainstormed and then I spent some time googling it to search for more information about this".* In the brainstorming session, by thinking about obstacle detection when mapping the terrain with drones, the group thought that this must also be the case subsea. Later on it appeared that using the technology in drones would not work, while subsea was very interesting.

When they arrived at CERN, they got more information from the technical experts. The Orthopix group had quite a lot of time with the technical experts, and this time proved to be crucial in order to gain understanding about the technology's benefits. During one of the sessions with the technical expert, he stayed for two hours discussing with the students. The session went beyond the students presenting their findings and discussing them, they also ideated and took part in the brainstorming. The students would ask a lot of questions, or stupid questions as the student I interviewed said. Through asking a lot of questions and being open they would identify potential areas of use, and then the questions appeared to be not that stupid after all. During the meeting with the technical experts the students presented an idea they had about the technology being used to detect microplastic or small particles under water. *"Do you think this can work?"* the group's leader asked? *"I think that could work, yeah… I* *would never have thought about it, but it is indeed interesting".* By discussing a bit further, some new aspects of the advantages of the technology appeared, making the application they had thought about slightly less valuable. A student suggested that *"but if we're not only thinking of what they do today, but what Orthopix can allow them to do. For instance tracking where the particles go/move in the water in a certain, bigger area".* The technical expert nodded and said that such a concept would pay off with Orthopix. While some individuals were asking a lot of questions and others were ideating and conceptualising, the students with technical backgrounds served an important role in explaining the ideas and communicating with the inventor. The students seemed to be taken really seriously by the technical experts as they are paying close attention, taking a lot of notes and also asking to get contacts.

The students would also gain information from calling to leads in the different markets. For instance they would call people in the subsea sector, and they found out that the technology actually could be relevant. Moreover, when talking to people, they stumbled upon Deep Sea Mining, which turned out to be really interesting. The students explained that by calling people, they would end up with new leads and said that the "ball just kept rolling". Many of the opportunities they identified was pretty random, but a lot of the reason was due to curiosity and lack of knowledge, one of the students remarked. In certain cases, the students had been investigating an area where they thought was promising that did not really work, but while exploring these areas they came in contact with people leading them to other interesting areas. *"A lot has been coincidences, and a lot has been to just ask a lot of questions and explore and try".*

After gaining new information, the group would meet again to discuss the findings. They would share what they had learned through the various phone calls, give each other tips how they could improve the process and optimise the findings. When I was observing one of the group's discussions one suggested that the group should just ask a lot of why-questions during the phone calls to learn and be careful with 'pitching' the technology too much, while another one said that they should always remember to ask for new leads before hanging up. Based on the learnings they would also remove the sub-areas which seem to be of less interest and would consider where to focus. After the discussions they also identified new opportunities which they would investigate further through new phone calls and talking to the technical experts. The process of brainstorming and group discussion, talking to the market and talking to the technical experts would be repeated until they had gained a good understanding of where the technology could have the most potential.

Group Quasar

Before the group came to CERN they spent about a day trying to understand the technology. To do this they would call relevant experts to make them help explaining the technology, and then they would call industries they thought could be interesting, just to get a feeling of it. The focus of the time before they went to CERN was gathering enough information to be able to create a plan of how they should approach the challenge and what would be possible to do in one week. One of the students I interviewed said that he felt that he had a relatively good understanding of the technology before coming to CERN, but that this was not the case for the whole team, so they spent a lot of time trying to create a common understanding of the technology. *"It took days before everyone was able to understand the technology"* the student highlighted.

Before the students came to CERN they wrote a list of potential markets, that they identified through a brainstorming session. *"We spent hours just name-dropping potential markets and applications"* one student remarked, *"but it is really cool seeing the results when everyone is participating, it is really important to prioritise".* The team was working on a technology that could be used to connect a large variety of sensors and make them speak the same language, so in the brainstorming session they would start by asking questions like: Who has a lot of sensors that they currently do not get data from, that they could have gained value from? And then they would come up with a lot of ideas. For instance, as one the student interviewed from that group explained: *"Cars has a* *lot of sensors. Who has a lot of cars? The mail service has a lot of cars. The post delivers to people. People have phones, smart-watches, smart-houses. Could all of this be somehow connected?"*. The group would abstract the technology and just try to focus on the functions of it. Moreover, they tried to think of similar industries to those they had already identified. When the group came to CERN they would have another brainstorming session, and after this they had 20-30 keywords written on the whiteboard. They would then cluster these areas based on their similarities and put a label on them like Industry 4.0, distribution networks etc. This made it easier to approach.

In the same manner as the Orthopix group, they would then check these assumptions by reaching out to the market, as well as talking to the technical experts. This group also mentioned that new opportunities would emerge all the time by talking to people and contacting new leads. In total, the group used a day of work on seven of the identified application areas, and then, in the end they saw the potential in two of them, and the group leader estimated that they had spent two weeks of work to investigate these markets. *"The ideas we ended up with was based on our own assumptions, but then concretised a whole lot through talking to people"* the interviewed student said. For instance, the group saw the potential for using the technology in farming, as there is a wish to digitise farming these days. However, it was after having having spoken with people that they saw that there could be room for a business model there. When the group presented their findings about the opportunities identified within farming, the KTO from CERN was really impressed and said *"Wow, guys, this is really interesting to me. We never get to get into details like this. You have gone beyond what I have been thinking about".*

Group C2MON

Before coming to CERN the group tried to understand the technology. However, based on the available information, they were not able to do so. The group leader mentioned that they could not understand anything of the presentation they got from the CERN KT, as it was very technical. They understood that C2MON was some kind of alarm system, but were not really equipped to identify potential markets and application areas beyond the ones that were already known. Moreover, the available market report on the technology defined it as a scala system, a very broad definition, making it even harder to move forward. *"We kind of started from scratch when coming to CERN"* the interviewed student said. In addition to the lack of understanding, the student interviewed mentioned that many of the group members had wanted to work on another technology, and were not that motivated for working on this particular one.

When they got to CERN they got to talk to the technical experts, and increase their understanding. They asked a lot of questions in order to understand, and spent a long time breaking the technology down from something high-tech to something understandable. However, looking back, the student highlighted that they should have asked even more, and even stupider questions.

Before coming to CERN they had made a mind map with some potential application areas, but this was changed a lot when they talked with the inventors. After understanding the technology better, they had a new brainstorming session to identify areas where the technology could have potential. *"We took into consideration the former market assessment report, what the inventors had said, where it could be applied, but also where it could be interesting to apply it",* the student remarked. After the brainstorming they had identified 15 different areas that they thought it could be interesting to look into. For instance, they started out looking into the bank and finance sector because they found it interesting, but after gaining more information this one was killed off.

Despite the difficulties they had with understanding the technologies, they just had to start calling people at some point. However, a lot of the team members experienced that the people they called did not understand the technology either, and they also had a problem identifying the right people to talk with. Some group members felt they got something useful out of the phone calls, but few new application areas were identified. After the group had called for some hours, they would gather to discuss the findings and the further process. They would lay some of the ideas off, while also suggesting new ones. The ideas of this group was to a high degree based on their own knowledge, and it was clear that they built upon each other's knowledge and were combining ideas. *"I would like to dig deeper into the fish farming industry"* one of the students said, as he had knowledge in that area. Another remarked that *"this is relevant for everyone having unstructured data that can be used as historical data - and that is relevant across industries". "We should have a look into big factories",* another one claimed. *"Can we do a brainstorming on factories that have strict demands to production? We have to figure out if there is anything interesting here".* The students then mentioned many different factories like this. The students came with comments such as *"that was a good proposal"*, and there were no negative comments whatsoever.

The ideas they ended up with came from the group's various competencies and from brainstorming. The group leader explained that it was a safe environment in the group when brainstorming, and that all ideas were noted down in the beginning. Moreover, it was not okay to criticise during the brainstorming. *"A lot of the ideas may turn out to be far fetched, but it is important to separate between being creative and being critical"*, the student remarked. They ended up seeing the potential for the technology in two markets. *"One of these was the power industry, and this is maybe not that weird as we visited a company in this industry to look at challenges a few weeks ago. The other one was the fish farming industry, where some people in the group have competency and thus saw opportunities there"* the student interviewed explained. The inventors thought that the selected application areas looked promising.

Group Gempix

Before coming to CERN, the Gempix group spent the time trying to understand the technology. In order to do so, they had a person responsible for the technical aspect. As many of the team members had a hard time grasping the technology, the technical responsible made them a manual with information and basically an introduction to physics. The group leader said in the interview that the manual was amazing and helped the rest of the group getting a basic understanding of the technology, and giving all the same opportunity to understand it.

Even though the team had understood quite a lot based on the fact that many did not have the prerequisite for understanding it, the understanding was still quite superficial. The group did not get to meet the technical expert before Wednesday, so it took some time before they got technical input. Moreover, the technology had some planned developments giving increased opportunities, but based on what was available today, many application areas were not relevant at this point.

The Gempix group did not spend much time on trying to identify potential application areas before coming to CERN. There was a previous market assessment report from 2014 with eight suggested markets, but none of them had been considered as promising. However, when they arrived CERN they had a proper brainstorming session. *"We thought that if we were actually going to get a spin-off out of this, if would almost have to be a bit special and niche"* the interviewed student said. Amongst others, they had talked about how art could be verified by using the technology. That made them think about old things and things it could be useful knowing the age of, and thus they came to think about wine. And also carbon dating to see the exact age of things.

"We built on each others ideas, and I guess you can say that we contributed with different areas of interest and background, bringing forth different aspects. Some of the things that was brought up, I do not what is at all, and in such cases we have an advantage having different backgrounds".

They had come up with a lot of different ideas, mapped out on a whiteboard: six main areas, all with two to four sub areas - around 20 potential application areas in total. However, many was not investigated closer. It was part of trying to think outside the box, but then they had become very concerned about what was actually possible. They did check up some of the areas, but in the end they ended up looking into the areas that had already been identified by CERN. New opportunities did not really emerge through reaching out to the market. Opportunities were mostly identified in the beginning and then removed later if they turned out to have no/low potential. New opportunities did not really emerge when they spoke to the technical experts either. When the students presented their potential applications whey got answers like *"Well, I guess that could work, maybe"*. They had not showed any enthusiasm regarding the group's ideas, and seemed to be more fixed on working in the areas already identified. It was without doubt in those areas they got the most input. However, the interviewed student highlighted that it was very useful talking to the technical experts to increase the understanding of the technology and to specify the already identified opportunities.

During a group discussion they had with the CERN KTO, they presented all their findings and their ideas. The group split up, and while most of the team went to take new phone calls, the technical people as well as the group leader stayed to talk about their findings. The students had gained information about some of the markets that the KTO was not aware of, adding value to these application areas. *"I can tell you, this is useful for us, for me"* he said to the group. After this, the students presented an idea they had about using the technology for something called "carbon dating". This was quite technical, and it was very useful having people on the team with technical understanding to explain it. The KTO thought this new idea was very interesting and said that he had not thought about this at all, in fact, up to this point he had not been thinking about the final application at all.

Application identification methods used by the NTNU students

Table 2 below sums up different methods used by the NTNU students to identify applications during the NTNU Screening Week.

Method	Group Orthopix	Group Quasar	Group C2MON	Group Gempix
Breaking down technology into functions, thinking about where these are important	YES	YES	YES	YES
Thinking about similar markets	YES	YES	YES	YES
Areas of interest/trends	YES	YES	YES	YES
Competency in the group	NO	NO	YES	YES
Talking to leads in the different markets	YES	YES	NO	NO
Asking questions to the technical experts	YES	NO	NO	NO

Table 2: Application identification methods during the NTNU Screening Week

4.2 Analysis

4.2.1 Application identification in the CERN KT group

In the following section, the methods used for application identification in the CERN KT group will be analysed with respect to the theory about application identification in chapter 2.

When exploitation of a technology is the main goal, like in the CERN KT group, potential new applications are usually identified as a result of the knowledge base of the people involved (Gregor and Hevner, 2015). This is the case in the CERN KT group, in which most emphasis is put on the inventor's take on what would be the most interesting applications to a technology. Even though the inventor has extensive knowledge about the given technology field, relying solely on the expertise of the inventor will probably lead to many missed opportunities. First of all, having deep knowledge in a field often narrows your perspective and disables you to take new information into account (Menich, 1962). This makes it likely that any application the inventor would identify is closely related to the original application (ibid.). Secondly, the KTO's have little control over how much effort the inventor actually puts into looking for alternative application areas before taking over. The above reasons may inhibit exaptive opportunities to be identified in the CERN KT.

Beyond the initial ideas of the inventor, the identification of alternative applications gets little attention in practice. Some googling of relevant keywords is always done to some extent, and sometimes searches are also made in technology and patent databases. Furthermore, companies working with similar technologies are sometimes investigated to see if some of the areas they are working in can be relevant for the given technology, and these are often found through going to conferences on relevant topics. All of these methods will lead to the identification of exploitation innovations as they are yielding existing opportunities (Gregor and Hevner, 2015).

Only one of the KTO's mentioned a method that seem to be good for identifying exaptive applications. The KTO called it random checking, and tried to search for random, potential application areas along with keywords about the technology, just to see if it could come something out of it. However, despite the fact that the CERN KT does not explicitly do much more to identify alternative application areas, and that they do not use exaptive methods like brainstorming and other ideation techniques (Gregor and Hevner, 2016; Chadha, 2016), exaptive alternative applications are sometimes identified. By contacting potential customers within the already identified industries or meeting experts at conferences, events etc., whole new opportunities sometimes emerge. Through the interviews, it was clear that most of the applications were actually found through speaking to potential customers, and that this was done from the very start of the process, reminding of Lynn and Heintz's (1992) 'Probe and Learn' process to find new applications to technology. Finding exaptive applications like this can be argued to be serendipitous (Dew, 2009; Meyers, 2007), and according to Mednich (1962) the requisite associative elements to find a creative solution might actually be *"evoked contiguously by the contiguous environmental appearance of stimuli which elicit these associative elements".*

Furthermore, by multiplying the contexts to which the technologies and the organisations resources and capabilities are exposed, exaptive applications can be identified (Andriani et al, 2017). For instance, this can happen through cooperation with innovation communities (von Hippel, 2005) and innovation tournaments (Terwiesch and Ulrich, 2009), like the network of Business Incubation Centres and the NTNU Screening week. Both of these has the goal and motivation of creating spin-outs and startups based on CERN technologies, another thing making them suited to identify exaptive innovations (Read et al, 2010). The NTNU Screening week was especially highlighted as useful in order to identify alternative applications.

Resources in the CERN KT

Even though exaptive applications are sometimes identified in the CERN KT group, it is quite clear that they do not focus much on finding alternative applications to CERN technologies. The group leader of KT highlighted that today, most opportunities that are found are closely related to the original application. Moreover, he remarked that this was a challenge. But why is this? Why doesn't the CERN KT, in general, focus more on finding alternative application areas to their technologies? To better understand why the focus on this is as low as it is, the situation in the CERN KT group will be analysed with respect to its resources and the Resource Based View (RBV). RBV is best applied for analysing an organisation's existing resource portfolio (Barney, 2001), and is therefore a useful tool in this context.

Tangible resources

A restricted budget to do knowledge transfer

CERN's primary objective is to do particle physics, and is funded by its member states to do science. Even though knowledge transfer contributes to giving back to the member states and to society, this is secondary to the goal of CERN. As much money as possible is thus prioritised to go to science, leaving a restricted budget to do knowledge transfer. The group leader of KT highlighted that even though it would be good having more resources in KT, the prioritisation was right. This entails that the amount of resources dedicated to knowledge transfer will probably not increase in the years to come.

> *"CERN is a high energy physics lab. We don't want to change that"*.

Having restricted resources affects the capacity of the group, and makes time a scarce resource. Moreover, the KTO's have all between 20 and 30 cases they are each responsible for. All the interview objects could tell that they were always in a rush and had problems coping with the workload. A keyword for them to manage their work was to really prioritise how they spent their time, in which the identification of alternative applications would not be highly prioritised. This is due to that there are lower-hanging opportunities that can be harvested, and that creating value from these will be prioritised rather than looking for other application areas further away from the original application. This is also why the cases where the inventor had already identified applications with concrete leads would be prioritised over more vague opportunities. Moreover, the restricted budget and pressure to show results leaves little room for risk, also making it sound focusing on the close applications as explorative methods for application identification are not really recommended in situations where one does not have much room for risk (Herstatt and Lettl, 2004).

The inventor's incentives to do KT

KT is a support function at CERN, and for it to happen, the inventor has to be the main driver of the process. For the inventors, KT happens besides their daily work, and there is no compensation in terms of money. Their motivation is rather connected to that they find KT exciting and giving, that they want to create impact or because it might lead to future career opportunities. If the inventor is not willing to work in a certain direction, nothing will happen. Furthermore, the support from the inventor's supervisor will vary, as it may steal attention from other tasks they have. Thus, in order for an identified opportunity to have sustainable value, the inventor of the relevant technology, and the inventor's hierarchy, must be motivated to collaborate (Barney, 1995).

Complex, specialised technologies

Another tangible resource is the technologies themselves. Technologies from CERN are deriving from the extreme requirements of the experiments and unique environment of the Laboratorium. The fact that the technologies are typically highly complex and specialised by nature, makes the possible alternative application areas limited. Moreover, they will most lightly require modifications and quite a lot of follow-up. The industries in which CERN technologies can be applied are often the same, and it even occurs that one gets several contracts with the same company on different technologies. One of the KTO's said that it is often fairly obvious early on in which industries CERN technologies can be applied, due to the peculiarities of them.

> *"The technologies we develop for the physics are very difficult to apply in other fields. But we have a lot of skilled scientists and if they would modify some of those technologies they would spend a little bit of time in adapting those to other applications, then this would work."*

Intangible resources

Competency and skills

When it comes to competency and skills, the KTOs have all a relevant technical background in either physics or engineering, combined with some business experience. This is good for being able to tie close relations with the technical experts and communicate with the relevant industries, making them fit for exploiting opportunities that are identified, and enabling them to use their mature domain knowledge for achieving well-understood applications and optimise state-of-the-art solutions (Gregor and Hevner, 2015). They are however not very diverse in terms of their backgrounds and skills, and as they are specialised in exploitation they are likely to not have characteristics that typify highly creative people (ibid). One of the interviewees highlighted that their relevant backgrounds enable them to understand the technologies quicker, but also give them quite a similar focus - focusing on the details of how the technology works rather than looking at the overall picture. As the KTO's often work in areas where they already have quite a lot of knowledge, they are less suited to come up with a creative solution (Mednick, 1962) compared to someone with less knowledge.

Culture and Dynamic capabilities

All of the interviewees talk about exploitation of the technologies. Not even once is exploration of the opportunities of the technologies brought up, unless they were questioned about it. As the quotes below show, the KTO's did not really see the value of doing much exploration.

"Then I ask myself at that point that I got a whole long to-do list of things - should I be putting my time into this thing? Is it likely that I'm going away looking around and suddenly find an amazing application that this expert has never even thought of? Probably unlikely."

"If you find an application to a technology with low application relatedness to the original application, it is very difficult to go to those industries and try to sell the technology, as you know very little about their field."

This indicates that the culture in the CERN KT is not of an entrepreneurial character (Penrose, 1959; Barney, 1986), something that is even more evident when looking into the collaboration patterns in the group. The KTO's are each responsible for a certain amount of cases, and within CERN KT there is not much cross-case collaboration. The different KTO's do not have much insight into each others cases, and in the interviews it was mentioned that there is too little global collaboration within KT. As a result, there is little room for doing brainstorming and ideation exercises, making the environment in KT less suited for identifying exaptive innovations (Gregor and Hevner, 2016; Chada, 2016).

As there are few channels to share information or to benefit from the other's expertise to for instance identify new application areas to the technologies, the internal knowledge creation capability seems to be quite low. Moreover, another observation is that if opportunities could not yield deals or interest right now, it would not be taken much note of, and that also indicates that the absorptive capacity is low. As both the capability to create, absorb and institutionalise internal and external knowledge seems to be low, means that the CERN KT do not really have dynamic capabilities - making it hard to identify new opportunities and organising effectively and efficiently to embrace them (Teece et al, 1997).

4.2.2 Application identification during the NTNU Screening week

Characteristics of the NTNU Screening Week

Environment suited for ideation

The students used brainstorming extensively in their work, a method deemed effective to identify exaptive applications (Gregor and Hevner, 2016; Chadha, 2016), and most of the identified applications that they saw potential in had originally emerged from the ideation sessions. During the brainstorming, the students, across the groups, would ideate freely and write down everything they thought of. Having a social environment that is open to creativity is a prerequisite for successful brainstorming (Amabile, 2012), and inhibiting creativity blockers like criticism and negative comments like the NTNU students highlighted is key to this (ibid.). During the ideating, all team members would contribute with ideas and build on each others ideas, something that is also important to succeed with brainstorming (Paulus and Yang, 2000).

Interdisciplinary teams

The NTNU students have different backgrounds, in which many have technical expertise but also business development expertise. The teams are truly interdisciplinary, a characteristic that helps them combine knowledge within the different fields and with different perspectives (Gregor and Hevner, 2015; Souder, 1989). The benefit of this was easy to observe during the Screening Week. The students built on each others ideas, and in this process they had a great advantage in having different backgrounds, as different people brought up different aspects and could contribute with different areas of interest. During discussions with the technical experts with the Orthopix team, the people with a technical background served an important role to communicate with the technical experts, and while non-technical team members would more freely ideate and conceptualise, the team members with technical backgrounds would explain the concepts more technically. Also their competency and interest in different areas and industries lead to applications being identified. Both the markets the C2MON team ended up seeing the most potential in, the fish farming and the power industry, derived from areas where some team members had knowledge, and as a result saw opportunities there. All of these examples shows the benefit of having interdisciplinary teams.

Openness and curiosity

During the NTNU Screening Week, the students came up with a lot of potential application areas that whether the technical experts or the KTOs had thought of. Based on 3-4 days of work, and 1-2 working days of preparations, the students, which were completely new to the fields, managed to come up with solutions that the people working on the technology for years “would never have thought of”. Lack of knowledge leading to exaptive innovations is an idea supported by amongst others Mednich (1962), explaining how a newcomer is more likely to achieve a creative solution that a long-time worker in the field, given that the newcomer has the requisite information. This was apparent during the students brainstorming sessions where they tried to come up with alternative application areas to the technologies. Without thinking too much of if would be feasible or not, they used analogy, argued to be the main method for finding alternative applications (Gavetti, 2012; Gavetti et al., 2005), to find creative solutions. Some exaptive applications were actually identified by looking at similar applications to those already identified, and while the original turned out to not work after all, the second actually had potential. If the team had had better knowledge of the technology, they would probably have understood that the original application would not really work, and then they might not have discovered the second application. In other words, the students lack of knowledge actually lead to exaptive applications being identified.

Serendipity

Exaptation is related to serendipity (Dew, 2009; Meyers, 2007, Mednich, 1962), and by multiplying the contexts to which the technologies are exposed, exaptive applications can be identified. This was the case during the NTNU Screening Week, where it was mentioned that by talking to people in the different markets, new application areas would continuously appear. By investigating potential application areas and asking people a lot of questions, the students got new leads, leading them to new tracks and that many of these opportunities seemed to be quite random.

4.2.3 Value of the NTNU Screening week

In this section the NTNU Screening week will be analysed with regards to what resources it adds to the CERN KT and the value of these resources.

Manpower as a resource

The most obvious resource the NTNU Screening Week contributes to CERN with is time and manpower. Around 35 students work for a whole week from morning to night, in which all their resources is used on brainstorming, discussions and taking hundreds of calls. While the KTO's are indeed also customer focused, and are taking phone calls as well, they are not able to take even close to the same amount of calls. As application identification has a lot to do with serendipity (Menich, 1962; Dew, 2009; Meyers, 2007), reaching out to many people accelerates the chance to evoke the requisite associative elements to find an exaptive application (Andriani et al, 2017).

Manpower is a tangible resource, and while it is very valuable for the CERN KT to have extra manpower as it is a scarce and rare resource, it is not very unique for the NTNU Screening week. It could hence be imitated. For the week to have sustained value, it has to bring along other, more unique resources beyond the extra manpower (Barney, 1991; Barney, 1995).

A different kind of opportunities

In addition to the manpower itself, the analysis shows that the NTNU students find a different kind of opportunities compared to the KTO's. The typical case in the CERN KT is that the inventor has an initial idea about industries where a technology can be applied, and the few techniques used by the KTO's to look for alternative application areas will usually lead to exploitation innovations. The NTNU students identify many more potential applications that are further away from the original application - exaptive applications. When the NTNU students find exaptive opportunities, the opportunity itself could be defined as a tangible resource for the CERN KT. However, the capabilities and prerequisites that leads to the exaptive opportunities are intangible resources, and directly related to the characteristics of the students from NTNU - which are very different from those of the KTO's. The findings and analysis have shown that the students have a wide range of different backgrounds, that they have an entrepreneurial culture, that they use ideation and brainstorming exercises and that they work in teams. The KTOs on the other hand, do not really match any of these criteria.

The fact that the NTNU students are suited to do exploration exercises, and that they identify a different kind of opportunities compared to the KTO's, makes this week a valuable resource for the CERN KT. The combination of capabilities and prerequisites of the NTNU students can be argued to be rare, and the concept is not easily replicable as this is a part of the students master program in which several processes similar to the Screening Week is conducted. However, it will only create a sustained competitive advantage if the results are used and CERN KT is organised to capture the value (Barney, 1995). After the Screening Week, the students hand over a written market assessment report, a presentation with their main findings and a contact log with detailed information about all the leads and every conversation they had during the week. Repeatedly the KTO's and the technical experts remarked that the results are insightful and that they use leads and information from the Screening Week in their further work. This shows that the opportunities identified by the students are also valuable. However, the absorptive capacity of the CERN KT seems to be quite low (Teece et al, 1997). While new information about known application areas will be absorbed, a lot of the valuable knowledge about new identified applications will not. This entails that at some point, the benefits of identifying exaptive opportunities with value-adding potential during the NTNU Screening Week, will be neutralised by the limited capacity of absorbing the new knowledge. Even though the opportunities are valuable, the CERN KT will not be able to tap into the opportunities identified by the NTNU students.

Another limitation to the value of the Screening Week is related to the fact that the technologies investigated are highly complicated. In order for the NTNU students to successfully identify potential exaptive application areas, two sub-processes must be completed properly before the brainstorming: 1) analysing and articulating the nature of the problem to be solved and 2) preparing to solve the problem by gathering information (Amabile, 2012). Hence, the information given and made available to the students before coming to CERN, as well as the availability of the technical experts during their stay, will impact their ability to successfully identify new applications - and also the value of the week. For instance, if the valuable time at CERN that should be used on finding opportunities, is rather used to understand the technology, this will make the week less valuable. This was especially the case with one of the teams, and it was apparent that the lack of understanding resulted in that this group identified less exaptive applications. In another case, the technical expert was not available before three days into the week, in other words after the point the students stop looking for more opportunities. The result was that they did not go forward with many of their identified ideas because they started doubting the technical feasibility, as they did not really have sufficient information/understanding of the technology. Maybe, if the technical expert was available at an earlier stage, this would not have been the case. Lack of information and lack of understanding will inhibit the students prerequisite to achieve a creative solution, and this will thus lead to less exaptive applications and presumably also less potential for startups coming out of the week.

The motivation of the students

Another intangible resource is the motivation of the students, which is driving them to identify exaptive applications. While the insights from the NTNU Screening Week are useful for the KTO's, the students real motivation is identifying opportunities to base their own startups on. For the NTNU students this is not just another school project, even though parts of the goal is also to learn. But that is not why the students are working long evenings and neither why they have such a strong focus on looking for opportunities within areas they are interested in themselves. The fact that the students are future entrepreneurs, having a strong intrinsic motivation for identifying new applications, makes them suited to identify exaptive applications (Gregor and Hevner, 2015). The KTO's, on the other hand, have a pressure to show results and are constantly working on many projects in parallel. Hence, they typically look for opportunities that are easy to harvest the fruits from.

The value of the NTNU students' motivation is twofold. Firstly, it gives them a drive to do a thorough job, as their goal is to identify opportunities fit for a startup. Their motivation drives the students to work so hard to identify unique opportunities, in contrast to the motivation of the KTO's which is rather to close current deals than to identify more opportunities. Second, it might actually come startups out of the NTNU Screening Week, something that would be highly valuable for CERN. As a result of the NTNU Screening week investigated in this thesis, two groups will try building companies based on the Quasar and the C2mon technologies. That 50% of the technologies being assessed during the Screening Week might turn into a company is rare, a very concrete tangible value, and says quite a lot about the NTNU students exceptional motivation. This motivation itself could possibly be replicated, but combined with the previous mentioned resources specific for the NTNU Screening Week, this would be very difficult.

However, for CERN to benefit from the unique motivation of the NTNU students, they have to think twice before selecting the technologies to be worked on. Technologies with a long time to market or long development time can be smart to avoid, or this should at least be communicated clearly before the students choose the technology. The technical experts should moreover be aware of the students motivation and open to the possibility that the students might want to start a company based on the technology, and they should be prepared to collaborate with the potential student startups. Finally, lack of information and understanding of the technologies may also lead to a lack of motivation, as the students will choose without properly knowing the benefits of the technology.

In table 3, a VRIO analysis has been made to sum up and to analyse the resources and capabilities from the NTNU Screening Week with respect to their potential for creating sustainable value (Barney, 1991; Barney, 1995). This is based on if the resources are valuable, rare, inimitable and organised, and if a resource had all of these characteristics the resource would create sustainable value (ibid.).

Resource:	Valuable?	Rare?	Imitatible?	Organised?	Creates sustainable value?
Manpower	YES	YES	NO	NO	Temporary value
A different kind of opportunities	YES	YES	YES	NO*	Unused value (Some lead to sustainable value)
The students' motivation	YES	YES	YES	YES	Sustainable value

Table 3: VRIO analysis - Value of the NTNU Screening Week

* To some degree it is organised, but CERN is not able to capture a great deal of the exaptive opportunities

5 Discussion

In this study, a gap in the technology push application identification literature was detected regarding application identification in the technology transfer school - where no former studies have looked into how applications to technology actually are found (Isern and Strøm, 2017). The research questions were designed to investigate this, and with the final purpose of being able to say something about how more exaptive applications can be identified. This chapter will discuss the findings from the analysis with regards to the purpose of the thesis. But before this is done, a recap of the results so far will be given.

5.1 The results so far

Up to this point in the thesis, I have looked into and analysed it's three research questions. The first RQ aimed to find out *what characterises identification of new applications to technology in the CERN Knowledge Transfer group today.* By studying and analysing the CERN KT group and the KTO's processes, I have found out that application identification rarely takes place within the KT group in practice. The typical situation is that the inventor of a given technology already has an idea, or even contacts for a given application in a new market, and that this is the starting point for the commercialisation. Market assessment is part of the initial phase of the knowledge transfer process, but usually not much more than a quick internet search is done to deliberately look for alternative applications. Some other methods are used, but all will most likely lead to exploitation innovations, and the KTO's themselves seem to be better suited to work with innovations like this. The culture in the CERN KT would also make it hard to successfully identify and commercialise exaptive innovations, and the lack of time and restricted resources makes it understandable that the focus is on the lower-hanging fruits and on closing deals that require less work. Despite this, exaptive applications are sometimes identified. By talking to potential customers and experts, whole new opportunities sometimes emerge. The identification of exaptive applications is closely related to serendipity, and therefore, also by exposing CERN technologies through the BIC Network and initiatives such as the NTNU Screening Week, exaptive applications can be identified after all. However, without a startup or a partner driving the commercialisation, the exaptive applications would not be taken much note of.

RQ2 looked into *what characterises identification of new applications to technology during the NTNU Screening Week.* By studying and analysing the NTNU Screening Week, I found that the week has an environment suited for ideation and that they used brainstorming techniques to identify new applications. The students worked in interdisciplinary teams, helping them to combine their knowledge and different perspectives. By reaching out to a lot of people, new opportunities came to light, and some of them were quite random - again connecting exaptive applications to serendipity. New applications were also exposed as a result of being open and curious. Due to the fact that the students are newcomers to the fields they were investigating, they experienced a lack of knowledge. However, that lack of knowledge leads the students to investigate areas that an expert in the field would never even consider, but that actually appeared to have potential.

The last RQ aimed to investigate *how the NTNU Screening Week useful to CERN,as a resource for identifying new applications.* By comparing the situation in the CERN KT and the potential and results of the Screening Week, it is obvious that the Screening Week complements the work that is done in the CERN KT. In addition to bringing along extra manpower, the students identify a different kind of opportunities than what is typically identified at CERN. The students are better able to identify exaptive applications, but for the NTNU students to successfully identify such exaptive applications, however, they rely on getting a deep enough understanding of the technology and getting sufficient information about the technology before the Screening Week begins. Moreover, the fact that the students are future entrepreneurs and that they are highly motivated for identifying exaptive applications to base their own companies on, makes them suited to identify exaptive applications. But if they misinterpret the technology and its benefits, or if crucial information that can change the students motivation are exposed too late, this might also affect the results. The aspects above makes the NTNU Screening Week indeed useful for CERN, as long as the CERN KT does a thought out selection of technologies and provides enough information about them in advance. However, again due to the restricted resources in the CERN KT and the limited absorptive capacity, a lot of the valuable knowledge about new, identified applications will not be absorbed into the Organization. Making the NTNU Screening Week even more useful would entail ensuring that it creates more startups.

5.2 Consequences for the purpose of the thesis

The findings from the analysis are indeed interesting for understanding the prerequisites for application identification in the CERN KT group and the potential for identifying exaptive applications. Moreover, this enables me to discuss the findings with respect to the overall purpose of the thesis: *To investigate approaches for Technology Transfer Offices to identify applications that are further away from the original application*.

5.2.1 Keep focusing on exploitation within the CERN KT Group

First of all, while exaptive applications are valuable as they often have great potential (Andriani et al, 2017) the KTOs themselves should rather continue focusing on exploitation, and use their mature domain knowledge for achieving well-understood applications and optimise state-of-the-art solutions. First of all, this is due to the reason that exaptive applications entails higher risk while the goal of the KT group is rather creating value from low-risk, low-effort projects. Moreover, the KTOs do not have the right capabilities nor a culture that makes it sound to use resources on actively looking for exaptive applications. Even though this should be the priority, there are certain things the KTOs could do to identify applications that are further away from the original application. First of all, facilitating for more teamwork and creating channels to share information could be a good way of increasing the internal knowledge creation, something that can contribute to the identification and absorption of new opportunities, and potentially also exaptive applications.

5.2.2 Prioritise external resources to identify exaptive applications

To identify exaptive applications beyond those that are identified by the initial market assessment and by serendipitous means, resources outside of CERN KT should be prioritised. The NTNU Screening Week is an example of an external resource, which has proved to be valuable for identifying exaptive applications. However, due to the restricted resources in the CERN KT and the limited absorptive capacity, only parts of the results will create sustained value.

5.2.3 Resources and absorptive capacity as a limiting factor

In the KT Group today, mostly applications close to the original application (high application domain maturity, high knowledge maturity) are identified. However, opportunities with lower application domain maturity (exaptive applications) may have great potential, and hence the identification of such applications is valuable for the KT group. At some point, however, the benefits of finding exaptive opportunities are neutralised by the required resources for commercialising them and the limited capacity for absorbing the new knowledge.

The findings above are illustrated by Figure 3, showing how the CERN KT group's internal resources should be used on identifying applications that are close to the original application, while external resources should be used to identify more exaptive, further away applications. However, the findings in this thesis about the limited resources and absorptive capacity of the CERN KT, makes it clear that even though it is valuable to identify exaptive applications to technology and that external people are best suited to do this, the CERN KT is not able to tap into a big chunk of this knowledge. As the absorptive capacity in the CERN KT is limited, and as long as the more exaptive opportunities do not exist outside of for example the NTNU students reports, the value of identifying exaptive applications is not sustainable.

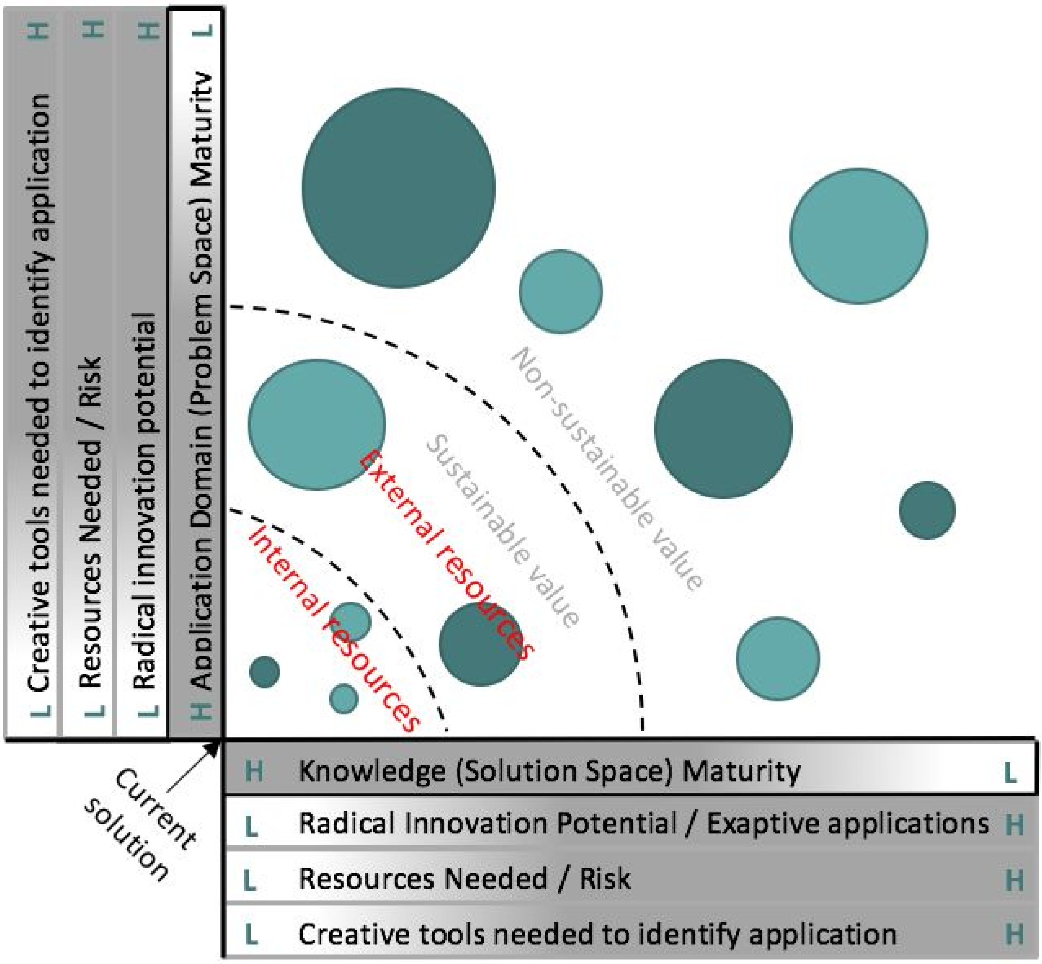

Figure 3: Technology push application identification in the CERN KT

5.2.4 Sustained value through increased absorptive capacity and use of external resources

To be able to create sustained value, the CERN KT will either have to increase their absorptive capacity or have external resources to take the identified applications to the market. This can expand the opportunities to identify further away applications, without needing much more resources.

The absorptive capacity can be increased by creating a continuous system for keeping track of the identified applications to institutionalise the external knowledge. Moreover, the CERN KT can also quite effortlessly increase the chance of external people or companies "serendipitously" seeing potential in the identified, exaptive applications by gathering the different opportunities identified and making this available to people. In other words, expanding the intelligence that can access the identified exaptive applications, through making the information public through for instance the CERN KT website or other crowdsourcing initiatives, through innovation tournaments, by communicating the various possibilities through social media and other marketing channels, and by bringing an overview of them to relevant conferences and expositions. This could lead to the right people seeing the opportunities and wanting to work further on the ideas.

5.2.5 Prioritise initiatives that have resources to commercialise the identified applications

Resources should be prioritised on initiatives that not only identify applications, but also that have the resources to commercialise them. In the case of the NTNU Screening Week, the students are not only a perfect fit for identifying exaptive applications, they also have the right motivation as they really aim to start companies based on the opportunities. Hence, it is valuable for the CERN KT, and it should be put resources into ensuring that more spin offs based on the identified opportunities come out of the week.

5.3 From the CERN KT to other Technology Transfer Offices

The findings above contributes to the literature on technology push application identification, and starts the creation of a bridge to the technology transfer school. This is only a subtle start on the quest to answer how alternative, more exaptive applications actually can be found in a technology transfer environment, as no former study mention the potential of exaptive or radical applications

(Moncada-Paterno-Castello, 2010; Caetano and Amaral, 2011; Vohora et al, 2004). More research is needed to generalise the findings from this study, as only one case study is used combined with the fact that technology push application identification is still in its embryonic stage as a research field.

Despite this, the overall findings are likely to be transferable to other TTOs, even though this would have to be confirmed through further studies. First of all, as remarked by scholars, technologies may have alternative applications that are of an exploitative nature and/or an exaptive nature, and different tools are needed in order to identify the applications of different innovation levels. However, even though the two types of technology innovation are opposing, there are degrees of innovativeness. This is related to the degree of Application Domain Maturity and Knowledge Maturity. Even though exploitation and exaptation was defined with regards to their Application Domain Maturity and their Knowledge Maturity by Gregor and Hevner (2015), I have developed this further by showing that there are degrees of exaptiveness. The less mature the two categories are, the more exaptive applications are likely to be found and more creative tools are needed to identify them - but also more resources are needed to commercialise the opportunities. At a certain point, the organisation will not have enough resources to commercialise the identified applications, and they have thus a non-sustainable value. This was found by combining existing theories from technology push application identification as well as from the Resource Based View.

What is a whole new finding based on the conducted research, is that the closer applications still should be the main priority of TTOs, as they are likely to have capabilities and a culture that is fit to exploit opportunities rather than explore. Thus, it might be hard for TTOs to internally identify exaptive applications. However, more further away opportunities may be identified by making use of external resources as illustrated in Figure 3, and by doing so, also such opportunities can create sustainable value. In order for TTOs to identify more further away applications, they should hence facilitate for ways external resources can get access to the TTOs technologies and knowledge so that they can identify applications. Another finding is that the TTOs absorptive capacity is a key element to if the externally identified applications will create sustained value, and that due to that this often is limited, external initiatives that also aim to commercialise the identified opportunities should be prioritised. By increasing the internal knowledge creation through more teamwork and creating channels to share information, more further away applications could also be internally identified.

6 Conclusion

This thesis looked into the identification of alternative applications to technology in the Knowledge Transfer group at CERN. What I found out was that while they do not focus much on this today, and despite the fact that this is valuable, the KT group does not have the right capabilities nor sufficient resources to increase this focus. However, external resources, which are better suited to identify applications, should be used to increase the amount of exaptive innovations being identified. Due to the fact that the absorptive capacity is limited in the KT group, resources should be prioritised on initiatives that also aim to commercialise the opportunities in order to create sustained value. For instance the NTNU Screening Week is a valuable opportunity for this. Not only do they identify more exaptive applications, they also have the motivation to start companies based on them.

7 Implications

There are some theoretical implications based on the learnings from the conducted study. The next time someone does research on this, I recommend to also interview the technical experts to better understand their role and viewpoints. I did not realise the importance and dependence of the technical expert when designing this research, and hence, to really create a holistic understanding of application identification, the technical expert's view should also be taken into account. Moreover, data about the actual applications that have been found in the group should also be collected in a more systematic manner.

The findings of this thesis have practical implications for application identification in the CERN KT group. Due to the lack of resources, as well as the particularities of the KT group, the KTO's should continue focusing on exploiting the technologies. However, to increase the result, and better facilitate for alternative applications being identified, the CERN KT group would benefit from implementing more teamwork into their daily routines, as well as creating channels for better sharing information and to increase the internal knowledge creation.

In order for the CERN KT group to identify more exaptive applications, resources outside of the KT group should be prioritised. However, resources should be prioritised on initiatives that also aim to take part in the commercialisation of the technologies. Based on this, the NTNU Screening week is valuable to maintain, but also involving entrepreneurs and startups through initiatives such as the BIC network. For the CERN KT to create more sustained value from the identified exaptive opportunities, the CERN KT should also consider to create a system for keeping track of the identified applications to institutionalise the external knowledge. Such information could be made available, and presented, through the KT website, crowdsourcing platforms, social media and other marketing channels.

Maximising the potential of the NTNU Screening Week

By maximising the potential of the NTNU Screening Week, the CERN KT can identify more exaptive, further away applications. Thus, ways of maximising the potential of the Screening Week will be suggested in the following paragraphs.

First of all, to increase the possibility of spin offs being created and to increase the motivation of the students, the CERN KT should do a careful selection of technologies to be worked on during the Screening Weeks. For instance, the technical experts should be aware of the fact that the students' goal is to start companies based on the technologies, and thus they should be open to applications in other areas than the ones already identified. It should be made crystal clear that the students are not just there to do the job of CERN KT in the areas they already identified. Moreover, the selection of technologies should have a high technology-readiness level and be ready for commercialisation.

In any case, it is important to clearly communicate aspects of the technologies like the ones mentioned above before the students select the technologies to be worked on. This requires the CERN KT to do a thought out presentation of the technologies to the NTNU students, and also to give access to sufficient information in advance. First of all it is important to present the technologies in a simple enough way for the students to grasp the main functions and benefits. Second, as much information about the technology, it's benefits and the work already done it terms of market assessment and commercialisation should be given to the students before the Screening Week.

During the week itself it is also important to have available resources from CERN. It is quite important that the technical experts are available several time slots throughout the week, and at least the first day, as this helps the students to move forward.

As the NTNU Screening Week requires a lot of resources, it is natural to raise the question if such initiatives could be done with less resources. To decrease the required amount of resources, it might be smart not selecting the most high-energy physics specific and complex technologies. Some technologies are lighter and more general than others, and also easier to understand for people outside the field. An alternative to this could be to add relevant physics competency to the teams. This could be an opportunity to combine the Screening Week with entrepreneurship training for motivated physicists. Giving as much information as possible to the students about the respective projects in advance might also help reducing this dependence and free up time to do market assessment, which is where the real value lies. Preparing information like that would probably be quite useful beyond the NTNU Screening Week as well. In any case, although valuable, the number of initiatives like the NTNU Screening Week the CERN KT can host is limited, and the potential value should be thoroughly considered for each of them.

Further Research

The research area of technology push application identification is fragmented and underdeveloped, and in order to make this a recognised research stream, further research on the subject is needed.

To reaffirm and further develop the findings from this study, future research should look into application identification in other TTOs. Comparing them to each other by using multiple case studies would make the findings more significant and transferrable. It would moreover be interesting to see if there are any TTOs that have had success with exploitation, but also with more exaptive innovations, and what characterises them. Also looking into other ways of exploiting external resources could be an interesting topic to investigate. An example of this could be having a closer look at the role of innovation networks like CERN's Business Incubation Centres.

The findings from this study indicate that startups are suited to identify and work with the more exaptive applications. Hence, ways TTOs can collaborate with startups and with future entrepreneurs is interesting, as well as how this can be attained through multiplying the contexts to which the TTO's resources are exposed.

Finally, Figure 3 showing the relationship between applications of different Application Domain Maturity and Knowledge Maturity, as well as the Resource Based View, should be further developed to bridge the unnecessary gap between the exploitation and the exaptation perspective. In order to do so, a way of classifying the innovativeness of alternative applications could be developed based on its Application Domain Maturity and Knowledge Maturity. As a result, identified applications could be placed where they belong on the graph, and organisations could use it as a decision tool. This could also be used to study the innovativeness of a technology push organisation.

References

ANDERSON, C. 2012. *Makers: The New Industrial Revolution.* Random House, New York.

ANDRIANI, P., ALI, A., Mastrogiorgio, M. 2017. Measuring exaptation and its impact on innovation, search and problem solving. Organization Science, 28, 2, 320-338.

AMABILE, T. 2012. Perspectives on the Social Psychology of Creativity. Publication of the Creative Education Foundation.46.1. 3-15.

AUTANT-BERNARD, C. 2001. The Geography Of Knowledge Spillovers And Technological Proximity. Economics of Innovation and New Technology, 10, 237.

BARNEY, J. 1986. Organizational culture: Can it be a source of sustained competitive advantage. The Academy of Management Review. 11. 3. 656-665.

BARNEY, J. 1991. Firm Resources and sustained competitive advantage. Journal of Management. 17. 1. 99-120.

BARNEY, J. 1995. Looking inside for competitive advantage. The Academy of Management Executive. 9. 4. 49-61.

BEISE, M. and STAHL, H. 1999. Public research and industrial innovations in Germany.

BIANCHI, M., CAMPODALL'ORTO, S., FRATTINI, F. and VERCESI, P. 2010. Enabling open innovation in small- and medium-sized enterprises: how to find alternative applications for your technologies. R and D Management, 40, 414-431.

BREM, A., VOIGT, K. 2011. Integration of market pull and technology push in the corporate front end and innovation management—Insights from the German software industry. Technovation. 29. 351–367

CAETANO, M. and AMARAL, D. C. 2011. Roadmapping for technology push and partnership: A contribution for open innovation environments. Technovation, 31, 320-335.

CHADHA, Y., MEHRA, A., GREGOR, S. and RICHARDSON, A. 2016. A Framework for Techniques for Information Technology Enabled Innovation. arXiv preprint arXiv:1606.02480.

CHESBROUGH, H. W. 2003. Open Innovation: The New Imperative for Creating And Profiting from Technology.

CHOUDURI, S., VAN ALSTINE, M., PARKER, G. 2016. *Platform Revolution.* Norton and Company, New York.

COHEN, W., LEVINTHAL, D. 1990. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly. 35. 128-152

CRESWELL, J. 2003. Research design: Qualitative, quantitative and mixed methods approaches. SAGE Publications. Thousand Oaks.

DANNEELS, E. 2008. Organizational antecedents of second-order competences. Strategic Management Journal, 29. 5. 519-543

DEW, N. 2009.Dew N (2009) Serendipity in entrepreneurship. *Organ. Stud.* 30(7):735–753.

DI GREGORIO, D. and SHANE, S. 2003. Why do some universities generate more start-ups than others?

DORF, R., and WORTHINGTON, K. 1987. Models for commercialization of technology from universities and research laboratories. The Journal of Technology Transfer, 12, 1–8.

EISENHARDT, K. M. 1989. Building Theories from Case Study Research. The Academy of Management Review, 14, 532-550.

ETZKOWITZ, H. and LEYDESDORFF, L. 2000. The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. Research Policy, 29, 109-123.

EVANS, R., BONNER, R., MALKIN, S., NICHOLS, S. 2008. "Addressing the" Innovation Gap" for Engineering Education: A Mapping Tool." Innovations 2008: World Innovations in Engineering Education and Research: 519-538.

FELKL, J. 2013. Advanced technology innovation mapping tool to support technology commercialization.

FELLER, I., AILES, C. P. and ROESSNER, J. D. 2002. Impacts of research universities on technological innovation in industry: evidence from engineering research centers. Research Policy, 31, 457-474.

FIET, J. O. 1996. The informational basis of entrepreneurial discovery. Small Business Economics, 8, 419-430.

FLICK, U. 2015. Introducing research methodology: a beginner's guide to doing a research project, Los Angeles, Calif, SAGE.

FLYVBJERG, B. 2006. Five Misunderstandings About Case-Study Research. Qualitative Inquiry. 12. 2. 219-245.

FORES, B., CAMISON, C, 2016. Does incremental and radical innovation performance depend on different types of knowledge accumulation capabilities and organizational size?Journal of Business Research. 69. 2. 831-848.

FRIAR, J. H. and BALACHANDRA, R. 1999. Spotting the customer for emerging technologies. Research Technology Management, 42, 37-43.

GAVETTI, G. 2012. Perspective - Toward a behavioral theory of strategy. Organ. Sci. 23. 1. 267-285.

GAVETTI, G., LEVINTHAL, D., RIVKIN, J. 2005. Strategy making in novel and complex worlds: The power of analogy. Strategic Management J. 26. 8. 691-712.

GENTNER, D. 1983. Structure-mapping: A theoretical framework for analogy. *Cognitive Sci.* 7(2):155–170.

GREGOR, S. and HEVNER, A. R. 2014. The Knowledge Innovation Matrix (KIM): a clarifying lens for innovation. Informing Science: The International Journal of an Emerging Transdiscipline, 17, 217-239.

GREGOR, S. and HEVNER, A. R. 2015. The Front End of Innovation: Perspectives on Creativity, Knowledge and Design. In: DONNELLAN, B., HELFERT, M., KENNEALLY, J., VANDERMEER, D., ROTHENBERGER, M. and WINTER, R. (eds.) New Horizons in Design Science: Broadening the Research Agenda: 10th International Conference, DESRIST 2015, Dublin, Ireland, May 20-22, 2015, Proceedings. Cham: Springer International Publishing.

GRUBER, M., MACMILLAN, I. C. and THOMPSON, J. D. 2008. Look before you leap: market opportunity identification in emerging technology firms. Management science, 54, 1652-1665.

GRUNDLING, E. 2000. *The 3M Way to Innovation: Balancing People and Profit* (Kodansha International, Tokyo).

HARTELT, R., WOHLFEIL, F. and TERZIDIS, O. 2016. Process Model for Technology-Push utilizing the Task-Technology-Fit Approach.

HAYEK, F. A. 1945. The use of knowledge in society. The American economic review, 35, 519-530.

HELFAT, C. PETERAF, M. 2003. The dynamic resource-based view: Capability lifecycles. Strategic Management Journal. 24. 10. 997-1010.

HENKEL, J. and JUNG, S. 2009. The technology-push lead user concept: a new tool for application identification. Unter Mitarbeit von Stefan Jung.

HENKEL, J. and JUNG, S. 2010. Identifying Technology Applications Using an adaption of the Lead User Method.

HERSTATT, C. and LETTL, C. 2004. Management of 'technology push' development projects. International Journal of Technology Management, 27, 155-175.

HINDLE, K. and YENCKEN, J. 2004. Public research commercialisation, entrepreneurship and new technology based firms: an integrated model. Technovation, 24, 793-803.

ISERN, V and STRØM, R. 2017. A technology push approach to technology commercialisation. Project thesis NTNU School of Entrepreneurship.

JIMENEZ-BARRIONUEVO, M., GARCIA-MORALES, V., MOLINA, L. 2011. Validation of an instrument to measure absorptive capacity. Technovation. 31. 5. 190-202.

KIRCHHOFF, B. A., NEWBERT, S. L., HASAN, I. and ARMINGTON, C. 2007. The influence of university R and D expenditures on new business formations and employment growth. Entrepreneurship theory and practice, 31, 543-559.

KOSTOFF, R. N., SCHALLER, R.R., 2001. Science and technology roadmaps. IEEE Transactions on Engineering Management.

LANE, P., KOKA, B., PATHAK, S. 2006. The reification of absorptive capacity: A critical review and rejuvenation of the construct. Academy of Management Review. 31. 4. 833-863.

LEARNED, E., CHRISTENSEN, C., ANDREWS, K., GUTH, W. 1969. *Business Policy: Text and Cases*. Homewood, IL: Irwin.

LEE, S., KANG, S., PARK, Y., PARK, Y., 2007. Technology roadmapping for R&D planning: The case of the Korean parts and materials industry. Technovation, 27, 433–445.

LEE, S., YOON, B., LEE, C. and PARK, J. 2009. Business planning based on technological capabilities: Patent analysis for technology-driven roadmapping. Technological Forecasting and Social Change, 76, 769-786.

LICHTENTHALER, U. 2010. Technology exploitation in the context of open innovation: Finding the right 'job' for your technology. Technovation, 30, 429-435.

LICHTENTHALER, U. 2009. Absorptive capacity, environmental turbulence, and the complementarity of organizational learning processes. Academy of Management.52.4. 822-846.

LINCOLN, Y. S. GUBA, E. G. 1985. Naturalistic inquiry, Beverly Hills, Calif, Sage.

LYNN, F. and HEINTZ, S. 1992. FROM EXPERIENCE - WHERE DOES YOUR NEW TECHNOLOGY FIT INTO THE MARKETPLACE. Journal of Product Innovation Management, 9, 19-25.

MARCH, J. 1991. Exploration and Exploitation in Organizational Learning. Organization Science 2(1), 71–87

MEDNICH, S. 1962. The associative basis of the creative process. Psychological Review. 69. 3. 220-232.

MEYERS, M. 2007. Happy Accidents: Serendipity in Major Medical Breakthroughs in the Twentieth Century (Arcade, New York).

MILES, M. B., HUBERMAN, A. M. 1994. Qualitative data analysis: an expanded sourcebook, Thousand Oaks, Calif, Sage.

MONCADA-PATERNO-CASTELLO, P., ROJO, J., BELLIDO, F., FIORE, F. and TUBKE, A. 2003. Early identification and marketing of innovative technologies: a case study of RTD result valorisation at the European Commission's Joint Research Centre. Technovation, 23, 655-667.

NONAKA, I. 1994, A dynamic theory of organizational knowledge creation. Organization Science. 5. 14-37.

PAULUS, P., YANG, H. 2000. Idea Generation in Groups: A Basis for Creativity in Organizations. Organizational Behaviour and Human Decision Processes. 82. 1. 76-87.

PENROSE, E. 1959. The Theory of the Growth of the Firm . Oxford University Press: New York.

PETRONI, G., VENTURINI, K. and VERBANO, C. 2012. Open innovation and new issues in R&D organization and personnel management. The International Journal of Human Resource Management, 23, 147-173.

PORTER, M. 1981. The Academy of Management Review. 6. 4. 609-620.

PORTER, M. E. 1985. The Competitive Advantage: Creating and Sustaining Superior Performance. NY: Free Press.

READ, S., SARASVATHY, S., DEW, N., WILTBANK, R., OHLSSON, A. 2010. *Effectual Entrepreneurship.* Taylor and Francis, Oxford, UK.

ROBERSON, B. and WEIJO, R. 1988. Using market research to convert federal technology into marketable products. Technology Transfer 13: 27–33.

ROBERTS, E. B. 2007. MANAGING INVENTION AND INNOVATION. Research Technology Management, 50, 35-54.

ROSENKOPF, L., NERKAR, A. Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. Strategic Management Journal. 22. 4. 287-306.

SCHOLZ, R., BINDER, C. 2011. Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge University Press. p. 25.

SCHUMPETER, J. A. 1982. The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. Transaction Publishers, New Brunswick, New Jersey.

SHANE, S. 2001. Technological opportunities and new firm creation. Management Science, 47, 205-220.

SHUEN, A. 1994. 'Technology sourcing and learning strategies in the semiconductor industry', unpublished Ph.D. dissertation, University of California, Berkeley.

SLATER, S. F. and MOHR, J. J. 2006. Successful development and commercialization of technological innovation: Insights based on strategy type. Journal of Product Innovation Management, 23, 26–33.

SOUDER, W. E. 1989. Improving Productivity Through Technology Push. Research Technology Management, 32, 19.

SPITHOVEN, A., CLARYSSE, B., KNOCKAERT, M., (2011). Building absorptive capacity to organise inbound open innovation in traditional industries. Technovation 31((1)): 10–21.

STIGLER, G. J. 1961. The economics of information. The journal of political economy, 213-225.

TERWIESH, C., ULRICH, K. 2009. Innovation Tournaments. Harvard Business Press, Cambridge, MA.

THAGAARD, T. 2003. Systematikk og innlevelse: en innføring i kvalitativ metode, Fagbokforlaget Bergen.

TEECE, J., GARY, P., SHUEN, A. 1997. Strategic Management Journal.18. 7. 509-533

VOHORA, A., WRIGHT, M. and LOCKETT, A. 2004. Critical junctures in the development of university high-tech spinout companies. Research Policy, 33, 147-175.

Von HIPPEL, E. 2005. *Democratizing Innovation.* MIT Press, Cambridge, MA.

WALSH, S. T., KIRCHHOFF, B. A. and NEWBERT, S. 2002. Differentiating market strategies for disruptive technologies. IEEE Transactions on engineering management, 49, 341-351.

WEISS, E. 2004. Functional market concept for planning technological innovations. International Journal of Technology Management, 27, 320-330.

WERNERFELT, B. 1984. A resource-based view of the firm. Strategic Management. 5. 2. 171-180.

WILLIAMS, C. 2007. Research Methods. Journal of Business and Economic Research. 5. 3.

YIN, R. 2014. Case study research : design and methods. 5th edition. Los Angeles, Calif, SAGE.

YIN, R.K. 1994. Case study research: design and methods. 2nd edition. Los Angeles, Calif, SAGE.

ZAHRA, S., GEORGE, G. 2002. Absorptive capacity: A review, reconceptualization, and extension. Academy of Management Review. 27. 2. 185-203.

ZOLLO, M., WINTER, S. 2002. Deliberate learning and the evolution of dynamic capabilities
Organization Science. 13. 3. 339-351.

Appendix

Interview guide - CERN KTOs

Initially

- Chitchat
- Information about our thesis(es)
- Information about anonymity, recording and transcription

About the person

- Occupation
  - Position
- Experience
  - How long have you worked in your current position?
  - Before this position?

About the tech transfer process

General

- In your opinion, what is the goal with technology transfer? //briefly
  - Why is technology transfer important?
- What does the entire knowledge transfer process look like at CERN, from research to market? // draw or illustrate and explain.
  - Can you estimate the timeline of a typical process?
    - The different parts, market research vs. IP dissemination etc
  - As a KTO, what is your role in this process?
    - In practice, how does what is done for tech transfer actually differ from the KT process?
  - How much are the inventors involved throughout this process?

- Can you explain in more detail how the process looks like in the very beginning, when an idea is registered.
  - The very first steps you take, looking for transfer opportunities.

Early stage transfer - exaptation

- Initially, how do you find out what the technology can or should be used for commercially?
  - Does the inventor usually have an idea when he/she submits the tech?

    - Is this mapped by a KTO before the technology is accepted as a technology transfer case?
    - Do you have guidelines, this is X technology field, then Y market(s) because of KT history?
- How do you deal with the future business potential of a technology?
    - Assessment of this to be ready for tomorrow's opportunities...
- How do you do market research?
- Do you use any specific methods or tools to detect new application areas?
    - If yes: How do you do this?
        - Is it a fixed process or does it differ from case to case?
            - If it differs: What decides if you use the different methods?
- Do you usually focus on one or several application areas, for further transferring?
- How much time is spent on looking for other application areas (new business opportunities) per new technology?
    - Who is involved in this step?
    - Is this done only in the beginning when a technology is accepted as a TT case, or is this an ongoing activity?
- **Case:** Given a tech case, with new, unexpected information, how is this handled?

- How do you find potential customers within an industry?
    - How do you verify customers?
- What channels do you use to contact industry / customers?
    - Social networks/ meetings/ email/ phone calls?

Finally

- Anything you wish you could change about the tech transfer process at CERN?
    - Why?
    - How is the ideal TT process, in your opinion?
- In your work, where do you spend most time?
    - Where would you like to spend more time?
- In your opinion, do you think tech transfer opportunities might be missed, when only the most obvious transfer path is pursued?
- How would you explore beyond the obvious transfer paths?
    - What would you do?

Interview guide - Leader of the CERN KT group

Initially

- Chitchat
- Information about our thesis(es)
- Information about anonymity, recording and transcription

About the person

- Occupation/position
- Experience
    - How long have you worked in your current position?
    - Before this position?

About the tech transfer process

KT strategy

- What is the goal of technology transfer at CERN?
    - In your opinion, why is technology transfer important?
- What is KT's impact today?
    - What is KT strategy for increasing its impact?
- What is KT's strategy to generate more TT cases?
- How do you think TT will change in the years to come?
- How is the ideal TT process, in your opinion?
    - What do you need to change with the TT process at CERN to have an ideal TT process?
- TT is a secondary goal at CERN, after fundamental research. How would you characterize the support you have from the management today?
- What are the most tricky parts of technology transfer at CERN in your opinion?
- Which capabilities are important to have in the group to succeed with TT?
    - As a Group Leader, what is your role in the KT process?
        - To what degree do you interfere in the individual TT projects?

Collaborations

- How does the KTO's collaborate regarding TT?
- How does KT create and maintain relationships with industry?
- KT collaborates with NTNU for the screening week, is this valuable for KT?
    - How could you make it more valuable?
- KT collaborates with IdeaSquare on CBI, is this valuable for KT?
    - How could you make it more valuable?
- Does KT collaborate with Openlab today?
- Would you want to collaborate more with external facilities or internal groups on TT in the future?

Exaptation

- Can you explain how the KT process looks like in the very beginning, when an idea is registered.
    - The very first steps the KTOs take, looking for business opportunities.
- How much time is spent on looking for other application areas (new business opportunities) per new technology?
    - Who is involved in this step?
- Do the KTOs have/use any specific methods or tools to detect new application areas?
- Some applications are easy to detect, as they might be similar to the original application - others might not be that intuitive, but still ready for the market. Do you think that the same methods and tools can be used to uncover applications of different application relatedness?
    - Does the TT process today take such differences into account?
- Today, do you think valuable TT opportunities might be missed at CERN?
    - How could the KTOs explore beyond the obvious transfer paths?
- Does KT have any guidelines on how to deal with opportunities of different matureness?
    - Do you think this could be useful to have?
    - How does KT deal with the future business potential of a technology?

Extra

- Can we maybe take a look at the budget for KT, can we ask you send it to us later?
- How many technologies are screened each year?
    - How many are accepted as TT cases?
- What does the entire knowledge transfer process look like at CERN, from research to market? //illustrate and explain.
    - Can you estimate the timeline of a typical process?
        - The different parts, market research vs. IP dissemination etc

Interview guide - Group Leaders NTNU Screening Week

How did you prepare before coming here?

Based on the information you got before coming here, did you understand the technology enough to identify potential application areas?

Did you get any information about potential application areas did you get beforehand?

Did you identify any other potential application areas before coming here? How did you do that?

How much time did you spend on the preparation?

When you came down here, how did you go about finding potential application areas for the technology?

Did you use any particular method to come up with ideas?

- Brainstorming? Other ideating techniques? Breaking down the technology into functions? Building on each others ideas? Googling keywords?

How much time did you spend on identifying potential application areas before starting to call people?

Did new opportunities emerge at a later point? How?

Did new opportunities emerge when talking to the experts?

In total, how many potential application areas did you identify and how many did you consider to be worth looking further into.

Of the applications you considered worth looking further into, how did these opportunities emerge in the first place?