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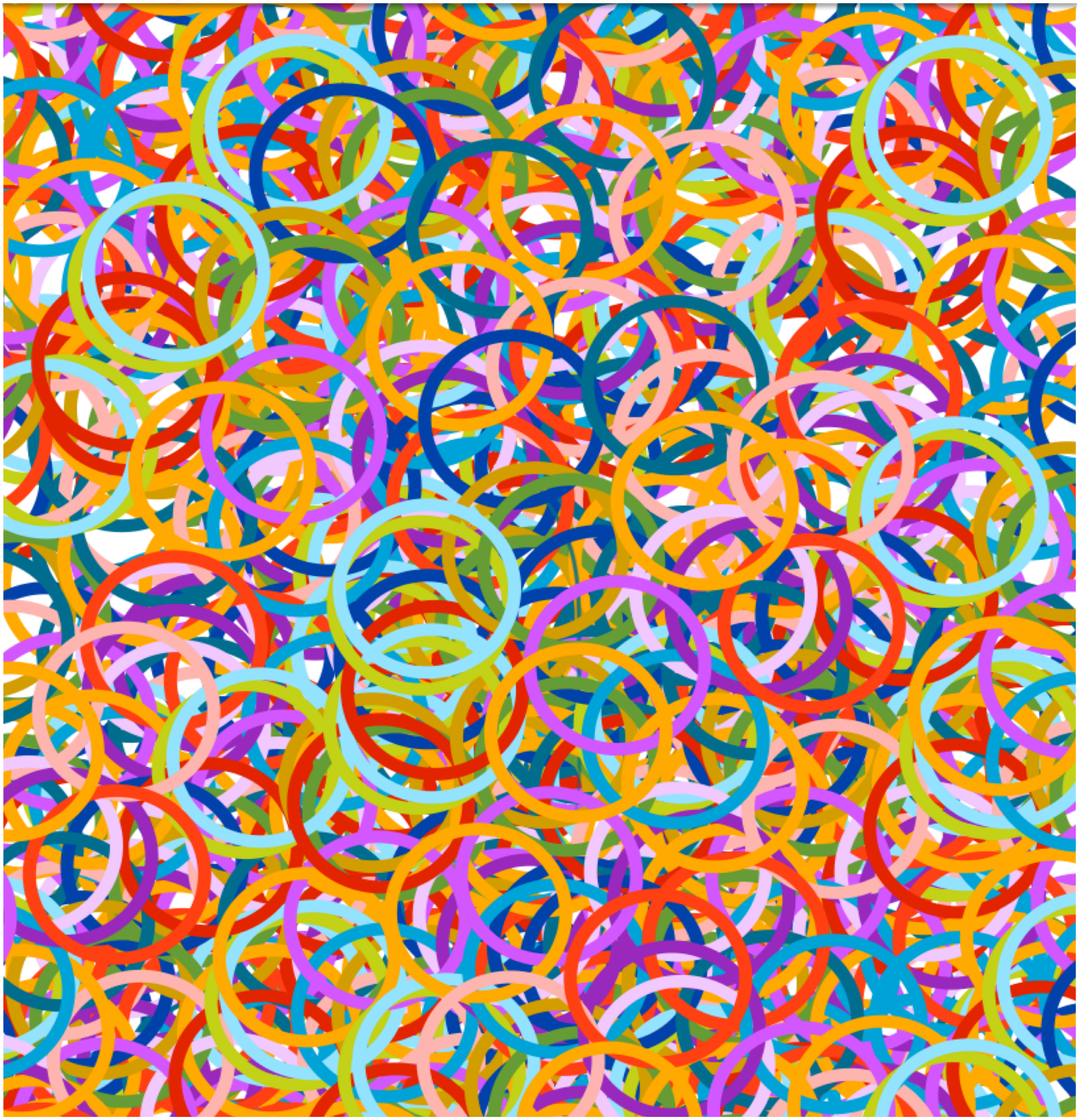

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Moonshot innovations: Wishful Thinking or Business-As-Usual?

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'Our mind-set will be to avoid the moonshot' said Boeing CEO James McNerney at a Wall Street analysts meeting in Seattle nearly 5 years ago (see Gates, 2014). The ambitious, exploratory and risky endeavour dubbed as moonshot project of the Boeing 787 Dreamliner had sunk billions of dollars in an industry where end-users demanded more comfort and convenience for less cost. According to McNerney, moonshots do not work in a price-sensitive environment. It is argued that they also tend to take the focus away from more immediate value capture opportunities as seen through Google's loss on its core Cloud Platform to Amazon Web Services (AWS). Google's parent company Alphabet which oversees Google X (a semi-secret moonshot project lab) more recently reported that it had incurred a US$1.3billion in operating loss on moonshot projects with a sizeable increase in compensation of employees and executives working on these projects (Alphabet, 2018). Notably, none of the Google X lab spin-outs (e.g. Loon – a balloon-based internet project, Waymo – self-driving car project, Wing – drone delivery project) have been identified as commercially viable. Despite the uncertainties and failures, the focus on moonshot innovations continues to proliferate in academia (Kaur, Kaur and Singh, 2016; Strong and Lynch, 2018) and practice (Martinez, 2018). Yourden (1997) even wrote an interesting book on perseverance and tenacity to keep going even after failed projects. Proponents of moonshot thinking have claimed that it can help solve society's biggest challenges (e.g. cure cancer, see Kovarik, 2018) with some suggesting to encourage such thinking by paying failure bonuses (Figueroa, 2018). Yet others remain sceptical, positing that moonshot is 'awesome and pointless' (Haigh, 2019, p.4). A proverbial question, thus, emerges: *are moonshot innovations simply wishful thinking or can they be part of business-as-usual?* In part, the answer may be two-fold – 1) understanding the value of moonshot thinking, and 2) understanding moonshot challenges.

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The value of moonshot thinking

Perhaps the most talked about moonshot programs have come out of X, formerly Google X but now a separate identity under the parent company Alphabet. Its captain, Astro Teller, delivered a Ted talk on the "unexpected benefit of celebrating failure"[1] in 2016. He identified two moonshot projects – automated vertical farming to tackle undernourishment and variable-buoyancy cargo ship to inexpensively transport cargo whilst reducing carbon footprint. Both these projects were killed as they failed to answer two inherent in all business-as-usual considerations – is it viable and feasible? The automated vertical farming could reduce water waste and save land resources but could not produce the much-needed staple crops like grains and rice. The variable buoyancy cargo ship in similar vein could reduce the need for runways and make an impact on carbon pollution but just to build one such ship for testing would cost nearly US$200 million, money that Google X could not afford to burn at the time. Other X projects such as making affordable fuel from seawater and back-to-the-future style hoverboards with magnetic levitations have failed too. However, these setbacks did not stop Teller who promotes X as a moonshot factory that plans to spin-out innovations at the intersection of huge problems, breakthrough technologies and radical solutions (see Thompson, 2017). X boasts that it is not in the game of solving business-as-usual problems and that its purpose is to create the *next* Google by bringing together inter-disciplinary teams of inventors, engineers and makers.

To understand the value of moonshot thinking, one only needs to look at X's process and ideology. The most hopeful project from X is that of Waymo that aims to change land transportation through self-driving cars. In this talk Teller argued that building self-driving car came as a natural moonshot under the environment where nearly 1.2 million are dying on our roads each year. At one stage in 2018, Waymo was valued at US$175billion by Morgan Stanley (Rapier, 2018) with other wall street firms claiming its worth to be nearing US$250billion (Ungarino, 2018). But of course, this all relies on the commercial viability of the self-driving cars and Waymo's other experiments on transport services (e.g. commercial freight, in-car services, etc.). In an interesting climax, soon after X retro-fitted Lexus into self-driving cars, they realised a major flaw in their moonshot thinking – once you make a driver less observant, s/he loses the attention to take back control in emergencies. The crisis meant Waymo was back to the drawing board, which eventually resulted in less ambitious (and arguably more viable) driver-engaged self-driving option. A more outrageous X project, which might be appropriately named, Loon promised a network of balloons floating in the air to provide internet to remote and rural places. However, after being sued for patent infringement, misappropriation of trade secrets, breach of contract and losing critical technology rights to rival firm Space Data, the Loon balloon might just have popped (pun intended) (see Harris, 2017). As if he had a crystal ball, Bill Gates in an interview with Bloomberg five years earlier had said such projects do not help solve core societal problems. He added, "when you are dying of malaria, I suppose you'll look up and see that balloon, and I'm not sure how it'll help you. When a kid gets diarrhea, no, there's no website that relieves that. Google started out saying they were going to do a broad set of things and they shut it all down. Now they are just doing their core thing" (Stone, 2013). Loon and Waymo

[1] See the full transcript of Astro Teller's Ted 2016 talk here: `https://www.ted.com/talks/astro_teller_the_unexpected_benefit_of_celebrating_failure/transcript`

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raise an important question, does moonshot thinking really help solve problems or has X has completely misunderstood what moonshot is? The quest to answer this question needs a quick lesson in history – the real moonshot story.

J.F. Kennedy stood at Rice University in 1961 and announced that he had a dream, a dream to put man on the moon and safely bring him back. The intent, planning, mental effort and execution of what followed eight years later as the Apollo 11 mission came to be known as the moonshot project. Apollo 11 heralded three men into space, landed two on the moon who took some pictures and picked up rocks and, eventually returned all of them back to earth in a compact capsule. Apollo 11 marked a giant leap in technological projects is noted as a triumph for a new era in which coordinated management systems are designed and integrated with sophisticated engineering to create successful moonshots. It showcased America's political will, technological prowess and economic capacity in the age of space race. The real moonshot was neither economically viable, nor practically feasible at the time, a far cry from X's current take on its moonshot innovations. Apollo program united the nation, forged new collaborations and pushed the existing technologies to new levels of performance and reliability – the unintended benefit of moonshot thinking. Indeed, several new technologies emerged as spin-offs from lessons learned from Apollo – Velcro and Teflon being the prominent ones amongst others that brought us freeze-fried raspberries, scratch-resistant eyewear and featherlight foil blankets. Besides Apollo itself created numerous new jobs and redefined computer engineering techniques that resulted in new microchips and information management systems (Haigh, 2009). Apollo shaped our future in radical ways – from catapulting space science to environmental movements to the utopia of the emerging tech culture (Turner, 2006). A key lesson from Apollo program is that moonshot innovations do not start with clever answers, rather they start with the painstaking task of finding the right questions. On this logic, perhaps moonshot and innovations do not belong together. Loon and Waymo have not failed if the iterations in their experimental stages resulted in deeper discussions on how humans interact with technologies and if the subsequent focus continues to be afforded on the development cycles. However, Teller's approach of failing fast and cheap seems too far from the moonshot that Apollo was. As Haigh (2017) argues, 'Letting Silicon Valley steal the term "moonshot" for projects with quite different management styles, success criteria, scales, and styles of innovation hurts our collective ability to understand just what NASA achieved 50 years ago and why nothing remotely comparable is actually under way today at Google, or anywhere else' (p. 2).

Moonshot challenges

The question is how we catalyse moonshot thinking while still focusing on viability and feasibility? While innovations tend to stretch the boundaries of strategy and human cognition (see Sund, Galavan and Brusoni, 2018), moonshots galvanise communities towards tackling a huge societal challenge and shape desired future in the process. Inherently, all moonshot innovations have common traits – they are risky, sound outrageous for the time, resource consuming and call for some of the best minds to collaborate for months and years. They are more than where a company executive wants to take the firm, almost certainly more than the desire to create new products. Understandably so, all moonshots are radical innovations but not all radical innovations can claim to be moonshoots - the defining keywords being ‘huge societal challenge’ and ‘shape desired future’.

Cancer is a huge societal challenge and so is clean energy, internet access not as much. Companies such as Grail that is working to detect and cure cancer before its symptoms become evident, are the ones that can claim moonshot innovations. Grail is testing new ways to conduct liquid biopsy and search for cancerous mutations that can be detected with any available technology. Likewise, apart from the obvious, a huge challenge for today’s urbanised society is to create construction material with low CO2 emissions. Companies such as bioMason have developed bricks with materials that do not require heat to produce, using microorganisms to grow biocement – an outrageous proposition for the prevailing traditional masonary techniques. There are several such examples, from Tesla’s home batteries to Sungevity’s remote solar design tool to the simpler food alternatives to animal-based products[2].

Notable observations amongst these examples are that in striving for moonshots, the firms did not abandon the attention towards incremental (or the so called 10%) improvements. Business-as-usual remains focused on the core activities at these firms – developing quick fail prototypes, sourcing and combining emerging technologies and looking for those quick-wins and revenue growth bets. This attention is important as by its very definition, moonshot calls for a long-term futuristic vision, looking beyond the present affordances and imagining a desired world that may never eventuate. For managers and captains of moonshot, the proverbial saying that “shoot for the moon and fall amongst the stars”may present just the right amount of pragmatism to moonshot thinking. Yet, so as far as firms continue to rely on return on investments, a prudent strategy will always be to maintain the business-as-usual through a portfolio of new ventures. The probability of landing amongst the stars is certainly higher than landing on the moon. Coming back to the opening of this editorial, McNerney said he would rather have Boeing innovate like Apple than do moonshots every 25 years. He was of course referring to period between 2006-2010, the peak of iPhone development when Apple spend just US$4.6 billion against Microsoft’s US$31 billion to shape the future of telecommunications. Moonshot innovations, at least in their current state, are simply wishful thinking and far from business-as-usual. This is disturbing since the value of moonshot is far reaching (once again pun intended) but in the age of corporate venturing, uncertainties and complex decision contexts, the pressure of viability and feasibility is continual – for, if you have promised to shoot for the moon, you better hit it.

Innovatively yours,

Anne-Laure Mention, João José Pinto Ferreira, Marko Torkkeli

The Editors

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An Intelligence-Based View of Firm Performance: Profiting from Artificial Intelligence

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Letter from Academia

Abstract. Many firms from diverse sectors increasingly use artificial intelligence (AI) to strengthen their efficiency by replacing human work. However, many of these advanced automation procedures will become standard tools in the future, and their relatively isolated application will not enable companies to gain a competitive advantage. Drawing on the distinction of data, information, knowledge and intelligence or wisdom, this paper suggests an intelligence-based view of firm performance as an extension of the knowledge-based view and the resource-based view. An intelligence-based perspective underscores the need to integrate AI applications with specific human expertise to complicate imitation by competitors. To sustain a competitive advantage over time, companies further need to develop a meta-intelligence to dynamically renew and recombine their intelligence architecture with multiple types of human and artificial intelligence. An intelligence-based view provides a systematic framework for assessing a firm's possibilities to profit from AI by generating growth and innovation beyond optimization and efficiency.

Keywords. Artificial Intelligence, Competitive Advantage, Digital Transformation, Firm Performance, Intelligence-based View, Knowledge-based View, Resource-based View.

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1. Introduction

Many firms from diverse sectors increasingly apply artificial intelligence (AI) in terms of advanced data analytics and intelligent algorithms (Davenport & Ronanki, 2018; Dubé, Du, McRae, Sharma, Jayaraman, & Nie, 2018). Most of these firms focus on AI for replacing human work in selected processes (Agrawal, Gans, & Goldfarb, 2018; Plastino & Purdy, 2018). Examples include sectors as diverse as banking, e.g. Bank of America, and logistics companies like DHL. However, merely using AI to substitute human work is only a first step. These smart automation processes will become standard procedures, and they will not enable firms to achieve an intelligence-based competitive advantage in the future. Companies rather need to integrate AI with their human expertise (Lichtenthaler, 2018a). While it may be difficult for competitors to imitate human competencies, it is even more challenging to copy combinations of human and artificial intelligence.

If we take for granted the underlying economic logic of AI (Agrawal et al., 2018) and the need for a closer collaboration of humans and machines (Daugherty & Wilson, 2018), companies still face the challenge of developing appropriate strategic initiatives to stay ahead of their competition. Many established strategy frameworks (Barney, 1991; Porter, 2008) allow for accommodating the recent developments of AI, but they do not help to fully map the competitive consequences of AI and its interplay with a firm's human expertise. In particular, the interrelationships of different intelligence types and their effect on firm performance may not be examined comprehensively with established strategy frameworks.

This paper aims at moving toward an intelligence-based view, which may provide some important contributions. First, it advances the established perspective of a knowledge-based view (Grant, 1996) by illustrating how different intelligence types help to leverage the underlying knowledge, information, and data. Second, the concept of intelligence architecture highlights the benefits of an integrated perspective on human and artificial intelligence (Daugherty & Wilson, 2018). Third, an intelligence-based view provides new insights into the competitive effects of human expertise (Gardner, 1983). Fourth, it offers new insights into firms' possibilities to profit from AI (Davenport, 2018). Fifth and finally, an intelligence-based view is inherently dynamic, and this dynamic perspective enables the integration of different types of learning processes (Sirmon, Hitt, Arregle, & Campbell, 2010).

2. Extending the knowledge-based view

A firm's ability to gain a competitive advantage at one point and to further sustain it over time is at the very heart of strategic management. Over the past decades, different frameworks have provided externally and internally driven views of understanding firm performance. Popular perspectives with a focus on external factors are the structure-conduct-performance and competitive forces frameworks (Bain, 1959; Porter, 1980). Here, the logic suggests that those firms will be successful which are competitively well positioned in an attractive industry. With regard to internal factors, the resource-based and competence-based perspectives have become very popular (Barney, 1991; Wernerfelt, 1984). On this basis, the dynamic capabilities and innovation-based perspectives put particular emphasis on the capabilities that are needed for dynamically sustaining a competitive advantage (Lichtenthaler, 2016; Rodrigues-Alves, 2018; Teece, Pisano, & Shuen, 1997).

Along with a growing importance of knowledge management in the 1990s, the notion of a knowledge-based view of the firm was developed (Nonaka, 1994). It is an extension of the resource-based perspective because it considers knowledge as the key resource (Grant, 1996). Thus, firms may achieve a competitive advantage by developing particular knowledge from underlying information and data (Rowley, 2007). Specifically, data usually describes some discrete elements, such as numbers and words. If the data is organized, structured, and useful, it becomes information, which refers to linked elements, such as equations or sentences (Ili & Lichtenthaler, 2017). If information gets meaning because it is contextualized, organized, and synthesized, it becomes knowledge, for example chapters or theories (Kogut & Zander, 1992). There are other systematizations of data, information, and knowledge, but this understanding is consistent with the knowledge-based view (Rowley, 2007).

Basically, the knowledge-centered strategy framework suggests that the possibilities to achieve a competitive advantage from data and information are limited, whereas the step from information to knowledge is key because the synthesized and organized knowledge is complex and challenging to thoroughly understand and copy for competitors. Knowledge is often complex and difficult to imitate, especially tacit knowledge, which may not be articulated easily (Nonaka & Krogh, 2009). Therefore, knowledge may provide an important basis for achieving a competitive advantage (Madhavan & Grover, 1998). The knowledge-based view further enabled analyses how electronic knowledge management systems contribute to firm performance by helping to share information and knowledge within and between firms (Bock, Sabherwal, & Qian, 2008). While the knowledge-based view has deepened our understanding of the role of knowledge and of knowledge management systems, it does not fully incorporate the impact of intelligence, neither human nor artificial intelligence.

Beyond gaining a competitive advantage due to different knowledge bases, firms may achieve superior performance because of a unique intelligence architecture, including their human and artificial intelligence. In this regard, intelligence may be regarded as the next step beyond knowledge which enables wisdom (Ili & Lichtenthaler, 2017). Specifically, knowledge becomes intelligence if it is given insight and enables understanding because it is integrated and actionable (Rowley, 2007). Following the analogy of words, sentences, chapters – referring to data, information, and knowledge – an example for intelligence could be a book. Drawing on the analogy of numbers, equations, theories, an example for intelligence could be a system or paradigm. Thus, intelligence describes knowledge that is applied and organized to enable insights that could not be gained from knowledge without intelligence. As such, the intelligence-based view is an evolution of the knowledge-based view.

At first glance, the conceptual distinction of knowledge-based and intelligence-based perspectives may appear to be only academically relevant, but it also has major managerial implications. In particular, an intelligence-based view underscores that firms with the same knowledge may have significantly different performance outcomes. Even if two firms have access to the same internal and external knowledge, they may achieve different competitive positions if one firm has superior intelligence that enables specific insights as a basis for targeted competitive moves that the other firm lacks. These intelligence-based advantages may derive from human or artificial intelligence – or from a combination of the two. Independent of the particular type of intelligence, these performance differences may not be explained with a mere knowledge-based strategy framework.

For instance, imagine two firms becoming aware of new developments based on comprehensive technology foresight. Both companies gain some new knowledge about technological developments. The company with superior intelligence may generate valuable insights from the additional knowledge, and these insights may enable it to develop new products and services based on the technologies which open up a novel market. The competitive advantage in that market is primarily based on the firm's intelligence because the two companies had similar data, information and knowledge. Accordingly, this illustrative example shows a clear contribution of an intelligence-based view beyond knowledge-based arguments. Here, it is particularly important to note that this basic example does not require AI solutions to illustrate the value of an intelligence-based strategy framework.

These conceptual arguments help to clarify why different types of intelligence are competitively relevant beyond knowledge bases. To achieve a sustainable competitive advantage, it is therefore key for companies to develop intelligence that their existing and potential competitors lack. Despite the critical role of intelligence, however, an intelligence-based view of firm performance does not imply that data, information, and knowledge are not important. Rather, knowledge is also key in an intelligence-based context. If firms hypothetically only had intelligence without any underlying knowledge, they would continually develop similar types of knowledge again and again. A company with a high level of intelligence – human and/or artificial intelligence – would start unnecessarily reinventing different concepts, processes etc. without being able to achieve the benefits from the knowledge bases that its competitors probably have developed. Accordingly, developing high levels of intelligence without any underlying knowledge is not useful from a competitive point of view.

3. Toward an intelligence-based view

Intelligence can be defined in a variety of ways (Gardner, 1983; Hunt, 2011). Basically, it involves some mental activities, such as learning, reasoning, understanding, seeing relationships and more (Mueller & Massaron, 2018). While algorithms and data analytics enable AI, no computer may entirely implement any of these mental activities so far (Mueller & Massaron, 2018). Nonetheless, there have been major advances in different fields of AI in recent years. To profit from AI, it is therefore important to systematically understand what kinds of intelligence a human typically has and whether these mental activities may potentially be simulated in the foreseeable future. Ever since, human intelligence has provided a basis for competitive advantage (Daugherty & Wilson, 2018). Some firms, such as Google and many consultancies, place emphasis on selecting candidates in some hiring processes based on selected indicators for different intelligence types. An intelligence-based view enables executives to highlight their employees' human intelligence as a particular competitive strength.

3.1. Human intelligence

There are various reasons for assuming a positive performance impact of human intelligence (Mueller & Massaron, 2018; Tegmark, 2018). In particular, it may have direct and indirect effects on firm performance. On the one hand, it may directly enable better results. For example, different human intelligences may help to take more informed managerial decisions, which positively affect subsequent performance. In a similar vein, particular engineering skills of human experts, for example at General Electric (Woyke, 2017), may contribute to solutions that are superior to competitors' products, leading to a competitive advantage that can quite easily be traced back to human expertise – even if intelligence leads to superior products only, which then provide the basis for enhanced performance. Beyond these relatively direct benefits, human intelligence may contribute to better decisions in selecting new employees, in wisely spending budgets, or in choosing the right partners for alliances or M&A deals.

All of these key strategic variables are strongly affected by the intelligence of the humans that are involved. Thus, the overall impact of human intelligence goes far beyond some amazing ideas and extraordinary talents of selected employees. In particular, it also affects the choice of AI tools. Specifically, the effective use of AI depends on the managerial decision to rely on this type of AI for that particular application. Consequently, the impact of human intelligence on firm performance may be broader and stronger than you may initially assume, even if the growing relevance of AI is taken into account. While this impact may take many indirect forms and can go a relatively long chain of effects, it may often be traced back to particular types of human intelligence. There have been multiple attempts to systematize human intelligence, but the following classification of Howard Gardner has become a well-accepted overview. Specifically, the distinction is part of the theory of multiple intelligences, which divides human intelligence into various modalities rather than viewing it as one overall ability (Gardner, 1983). The theory distinguishes seven types of human intelligence, with different potential for simulation by means of computers (Gardner, 1983).

The first type of human intelligence is bodily-kinesthetic intelligence, which refers to the control of bodily motions and the ability to thoroughly handle objects (Gardner, 1983). This type of intelligence may be imitated by robots, even if they only performance repetitive tasks. The second type is creative intelligence, which refers to developing new patterns of thought that enable unique artistic, musical, or written output. The third type refers to interpersonal intelligence, which describes a human's sensitivity to others' feelings and the ability to collaborate in a group (Gardner, 1983). This type of intelligence is related to similar notions of emotional intelligence. The fourth type of human intelligence is intrapersonal intelligence, and it refers to inward-looking and self-reflective capabilities. Thus, it enables a person to develop an understanding of one's strengths and weakness. As such, it currently is a human-only type of intelligence (Mueller & Massaron, 2018). The fifth type is linguistic intelligence, and it describes a strong ability with words and languages. This type of intelligence includes, for example, understanding written and spoken input, processing it, and providing a useful and understandable answer. The sixth type is logical-mathematical intelligence, and it refers to logic, reasoning, numbers, and abstractions (Gardner, 1983). Thus, it enables calculating results, exploring patterns and drawing comparisons. Finally, the seventh type is visual-spatial intelligence, which refers to spatial judgment and visualization in physical environments (Gardner, 1983).

In addition to these seven types of human intelligence, which have been described by Gardner (1983), some other types have been suggested, including existential, naturalistic, and a teaching-pedagogical intelligence. However, the focus here is on the original seven types because even adding several more will mostly likely not lead to an exhaustive list of intelligence types. From a management perspective, it further is not essential what particular segmentation of human intelligence is used. For achieving a competitive advantage, it rather is more important that a firm – or a firm's employees – have a particular ability and that the firm makes use of this ability. This application of human intelligence may occur in relative isolation or in combination with one or multiple types of AI.

3.2. Artificial intelligence

There are many different categorizations of AI, which generally refers to theory and computer systems that are able to perform tasks that usually would call for human intelligence (Mueller & Massaron, 2018). In the field of what is considered AI today, machine learning has recently received most public attention (Agrawal et al., 2018; Finlay, 2017). Machine learning typically relies on algorithms and statistical techniques that enable computer systems to improve their performance in carrying out a particular task (Mueller & Massaron, 2018). Machine learning relies on underlying training data, which enables the system to make predictions without being specifically programmed to complete the task. A further subset of machine learning is deep learning, which refers to learning data representations instead of focused and task-specific algorithms (Mueller & Massaron, 2018).

Another important classification of AI distinguishes reactive machines, limited memory, theory of mind, and self-awareness (Mueller & Massaron, 2018). Here, self-awareness describes systems that have an understanding of self and some consciousness. This would be the type of AI that is imagined in movies (Mueller & Massaron, 2018; Wein, 2018). As such, this distinction is not central for competition in the near to medium future. Therefore, it may be more suitable to focus on different applications and use cases of AI (Davenport, 2018; Tegmark, 2018), even if they may not be mutually exclusive. For example, machine learning provides the basis for some applications that are considered as different categories. Nonetheless, the following distinction of seven types, which stems from integrating the categorizations in multiple books and encyclopedias, is helpful for discussing the competitive implications of AI (Daugherty & Wilson, 2018; Davenport, 2018; Finlay, 2017; Ili & Lichtenthaler, 2017; Mueller & Massaron, 2018; Tegmark, 2018; Wein, 2018).

The first type of AI are expert systems, which are directed at imitating human decision-making. Typically, these systems comprise an underlying knowledge base with facts and rules as well as the inference engine which applies the rules (Jackson, 1998). The second type refers to machine learning, which includes for example deep learning and predictive analytics as core topics (Finlay, 2017). The third type involves various technologies that enable natural language processing. Here, the focus is on extracting, grouping, and categorizing information as well as translation and related applications (Millstein, 2018). The fourth type of AI describes planning and scheduling systems, which refer to the development of action strategies and sequences for subsequent execution. Typically, the emphasis is on complex solutions in a multidimensional space (Ghallab, Nau, & Traverso, 2004). The fifth type refers to robotics and machines, and this field can be further segmented in reactive machines, limited memory, theory of mind, and self-awareness (Mueller & Massaron, 2018). The sixth type of AI refers to speech synthesis systems, which include text-to-speech and speech-to-text solutions (Daugherty & Wilson, 2018). Finally, the seventh type refers to computer vision, and it comprises image recognition, machine vision, and related applications (Daugherty & Wilson, 2018). As mentioned above, these seven types constitute an integration of multiple existing segmentations of different types of AI.

3.3. Human and artificial intelligence

Applications of different types of AI may replace human work to some degree (Winick, 2018). However, a separate use of artificial and human intelligence is only one way for firms to profit from the recent advances in AI. In particular, replacing human work primarily enables firms to capture efficiency gains. While these benefits may have important positive effects on financial performance, they are one dimension of leveraging AI. If firms attempt to additionally develop novel solutions as a basis for further growth, they often need to combine one or multiple types of AI with one or multiple types of human intelligence (Lichtenthaler, 2018a). For example, enhanced algorithms for predicting customer behavior may be combined with human creativity to enable completely new business models. Thus, the augmentation of human intelligence needs to be distinguished from completely independent tasks that may be performed by AI (Daugherty & Wilson, 2018). Beyond this example of an algorithm, you may also think about a surgical device which includes AI to enhance a surgeon's physical ability versus a robot which is able to make fully independent movements.

These interactions of artificial and human intelligence are at the core of the intelligence-based view (Figure 1). By developing and applying the different intelligence types – while considering their interdependencies – firms may gain a competitive advantage relative to other firms that lack similar intelligence levels. Artificial and human intelligence draw on the underlying data, information, and knowledge (Rowley, 2007). Without these underlying components, the value of most types of intelligence would be limited. Consider, for example, an algorithm for predictive maintenance that has been developed by General Electric. Without meaningful input data, even the most advanced version of this AI would provide limited value. In a similar vein, a human's interpersonal intelligence will provide limited benefits without further information. Accordingly, artificial and human intelligence build on the underlying knowledge base. At the same time, the development and application of the different intelligence types leads to the development of further data, information, and knowledge. Thus, a firm strengthens its knowledge by accumulating and enhancing its multiple intelligences.

Along with the underlying data, information, and knowledge, the combination of human and artificial intelligence may provide an important basis for competitive advantage (Lichtenthaler, 2018a). While a thorough understanding of these relationships may be essential for executives in the context of the recent advances in AI, the different intelligences only provide a first step (Da-

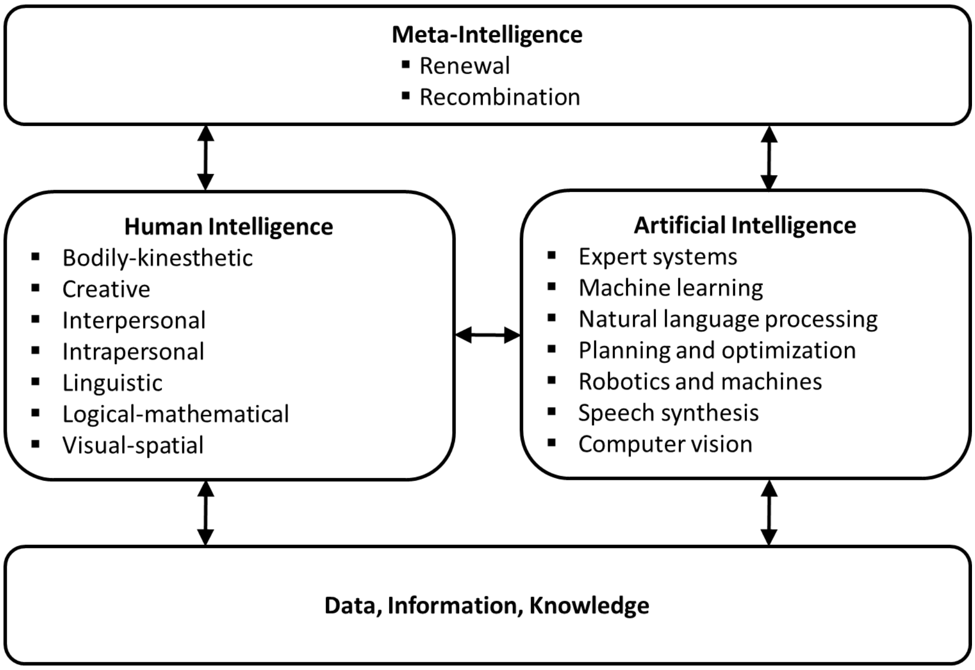

Fig. 1. Framework for an intelligence-based view.

venport, 2018). A firm's intelligence architecture may be excellent for achieving this competitive advantage today, but it will most probably be insufficient for keeping a strong competitive position in the future. Over time, a firm's intelligence-based advantage will inevitably deteriorate. With regard to human intelligence, for example, key persons may leave a firm, which needs to replace or ideally overcompensate for the different types of intelligence that are lost. Concerning AI, for example, a top position with regard to natural language processing today will not even be close to a top position in a few years because competitors quickly catch up and the evolution of this field is extremely dynamic.

As such, even the highest level of some intelligence will only enable a firm to achieve a temporary advantage, but it will often be insufficient for sustaining this advantage over time. Accordingly, firms do not only need to strengthen their different intelligence types. Instead, they also need to develop a meta-intelligence for dynamically transforming the different types of intelligence in alignment with their strategies. This meta-intelligence includes the renewal and recombination of the different intelligences (Lichtenthaler, 2019). Thus, it enables the targeted transformation of a firm's intelligence architecture to reactively respond or to proactively shape the changing competitive environment. Thus, firms need integrated intelligence – which consists of various types of artificial and human intelligence as well as the meta-intelligence (Lichtenthaler, 2019). This role of the meta-intelligence with regard to renewing and recombining a firm's multiple intelligences is particularly important for sustaining an intelligence-based competitive advantage.

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4. Conclusion and outlook

An intelligence-based view has some important implications. First, it substantially advances the established perspective of a knowledge-based view (Grant, 1996). In particular, it illustrates how different intelligence types may be developed and used for leveraging the underlying knowledge, information, and data (Rowley, 2007). As such, the focus on different types of intelligence further helps to understand major performance differences between firms with largely similar knowledge bases. Knowledge per se may not enable a firm to achieve a competitive advantage unless it is exploited in an intelligent way based on the business strategy. Thus, the multiple intelligences provide a critical missing link between a firm's knowledge base and subsequent performance outcomes.

Second, the concept of intelligence architecture highlights the need for an integrated perspective of the different intelligence types, which do not only build on the underlying knowledge, but also contribute to its extension and to the generation of completely new knowledge (Rowley, 2007). In particular, this understanding of a company's intelligence architecture highlights the need for going beyond isolated AI applications. If executives aim at fully leveraging the benefits of AI, they need to put the interfaces between AI and the remaining part of the intelligence architecture at the core of their attention (Lichtenthaler, 2019). These interfaces will be critical for achieving a competitive advantage because they may not be imitated as easily as stand-alone AI solutions, whose potential impact on gaining a competitive advantage may decrease in the future because they will be applied by many competitors. In contrast, a firm's complex intelligence architecture will continue to provide a sound basis for a sustainable competitive advantage.

Third, an intelligence-based view offers new insights into the competitive effects of human intelligence (Gardner, 1983). While superior human resources play a major role in other perspectives on firm performance, such as the resource-based view and knowledge-based view (Barney, 1991; Nonaka, 1994), an intelligence focus offers a more thorough understanding how the different types of human intelligence may contribute to achieving a competitive advantage. In particular, the focus on multiple human intelligences (Gardner, 1983) enables systematic analyses of interdependencies with AI. In this regard, it is particularly important to underscore the core role of human expertise despite the substantial advances of AI. There are manifold reasons for the continuing importance of human experts who, for example, select AI applications in companies. Even if AI further advances in the future, it will substantially depend on human expertise and intelligence to unfold a competitive impact.

Fourth, an intelligence-based perspective provides a systematic framework for exploring a firm's possibilities to profit from AI (Davenport, 2018). In particular, it helps to examine the direct and indirect performance effects of different types of AI. As such, it emphasizes the need for analyzing the interplay of AI with various types of human intelligence (Lichtenthaler, 2018a). A specific AI application may strengthen a competitive advantage if it goes along with a suitable type of human intelligence. In contrast, the same AI may provide hardly any benefit if it is not aligned with the remaining parts of a firm's intelligence architecture. This key role of the organizational context of using AI has been overlooked quite often. In many situations, AI does not automatically contribute to performance. Instead, strategic alignment is core for ensuring that the investments in AI pay off. The importance of a firm's intelligence architecture will further grow because particular AI applications will increasingly become standard tools, which many firms may use with nearly identical proficiency.

Fifth and finally, an intelligence-based view is inherently dynamic which enables the integration of individual and organizational learning processes (Argote, 1999; Sirmon et al., 2010). The recent technological advancements emphasize the need for staying ahead of competition in terms of developing, customizing, and applying the latest AI. In light of the dynamics of many firms' competitive environments, the continuous development and extension of human intelligence becomes even more critical than in the past. An intelligence-based view enables a comprehensive perspective on a firm's intelligence architecture. Here, the different types of artificial and human intelligence provide immediate starting points for adapting and transforming established competencies. Specifically, the concept of a meta-intelligence highlights the need for an ongoing transformation of the intelligence architecture (Lichtenthaler, 2019). Without renewing the different intelligence types, a competitive advantage will be lost in a relatively short time. Besides renewing the intelligences, executives need to recombine the interrelationships among the different intelligence types to ensure that the interfaces continue to contribute to a firm's future competitive position.

AI has come a long way, but for most companies the largest part of the transformation is still ahead. Executives need to acknowledge that many changes cannot fully be foreseen today. Thus, some level of experimentation and simultaneously pursuing multiple options will be inevitable (Bühring & Moore, 2018; Lichtenthaler, 2018b; Wilbert, Durst, Ferenhof, & Selig, 2018). Specific attention needs to be put on the dynamics of competition with regard to new activities in the value chain, such as data analytics, and new players in the competitive ecosystem, such as IT service providers (Brito, 2018; Ili & Lichtenthaler, 2017). Acknowledging this strategic complexity and developing a systematic strategic approach is essential for achieving a competitive advantage (Apanesevic, Arvidsson, & Markendahl, 2018; Datta, 2018). While the growing competitive relevance of AI cannot be ignored, the core strategic impact will derive from the interplay of AI with human intelligence rather than from the pure implementation of AI. In this respect, an intelligence-based understanding of future competitive advantage is an important starting point.

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Science & Wine: The Wine of the Future

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Letter from Academia

Abstract. Worldwide wine production has a great cultural and economic importance. A multidisciplinary approach is necessary to improve wine quality. The First Science & Wine World Congress was planned to be a discussion forum considering the wide wine research spectrum. The idea attracted more than 100 attendees most of which scientists. Wine sector professionals missed the call, which emphasize the necessity of implementing strategies to approach those to the academy. Among the topics discussed, the effects of wine in health was pointed out as a priority. Global forums are a good approach to discuss wine in a holist mode.

Keywords. Wine, Vine, Viticulture, Technology, Science Communication, Oenology.

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1. Introduction

Humans have produced wine for thousands of years. Wine production is an important socio-economic activity and one of the most dynamic and competitive ones in the agro-food market. Due to its importance, wine is in the center of study of different sciences (Fig. 1). The scientific discussion among experts of each scientific field is very important to validate terminology, methodologies, results, to find solutions and to propose future research. An integrated discussion about wine, however, is crucial to the evolution of each and of all areas. The wine of the future must be a healthy, authentic, enjoyable, and profit product, which results from sustainable viticulture's and produced with advanced technology. Therefore, it is important to promote a discussion about wine, including points of view such as: viticulture, oenology, environmental sciences, health sciences, informatic, enginery, economy among others. Is also crucial that this discussion includes academics and wine professionals. In my opinion, a gap between academy and wine sector still exists. The crosstalk only happens when the involvement of the other part is essential to attain their own goals. Nowadays researchers have a great pressure to publish and in most of the cases they do not have time to interact with people that could help to project better experimental designs. I agree with the ones that affirm that this pressure to publish pushes down the quality of research. On the other hand, the main concern of winemakers is to have to make money, so they only ask academy help when they need to find a solution to increase their profit. Additionally, it is essential to mention that public institutions, which could have a significant intermediate role between academy and winemakers, are over-occupied with bureaucratic issues and have fewer and fewer employees. In January 2018 it was launched the web platform Science & Wine (`http://science-and-wine.com/`), a science communication project with the main goal of sharing scientific results using simple language. This project also aims to promote networking between the academy and the wine sector. After one year of the web platform launch, I decided to organize the First Science & Wine World Congress with the same philosophy and that deserved the support of University of Porto (UPorto) and of International Organization of Vine and Wine (OIV). In this letter I will summarize some results discussed in this Congress.

1.1 First Science & Wine World Congress: some data

In the First Science & Wine World Congress were present 115 attendees from 16 different countries. Among this were represented 46 universities/research centers, 15 private companies, and two public institutes. Thirty-four works were presented as oral communication and 40 as a poster, which totalizes 74 presentations. The works were divided into the following research areas: wine traceability and authenticity; wine chemistry and sensorial wine experience; wine analysis; vine and wine technology; wine and health and wine waste. From this data, we can conclude that this first congress was a success in the number of attendees and the diversity of works presented. The number of non-academics, however, was very low, which confirms the need for stronger initiatives to bring these two parts together. New strategies to increase the relationship of the sector with the academy should be considered and implemented.

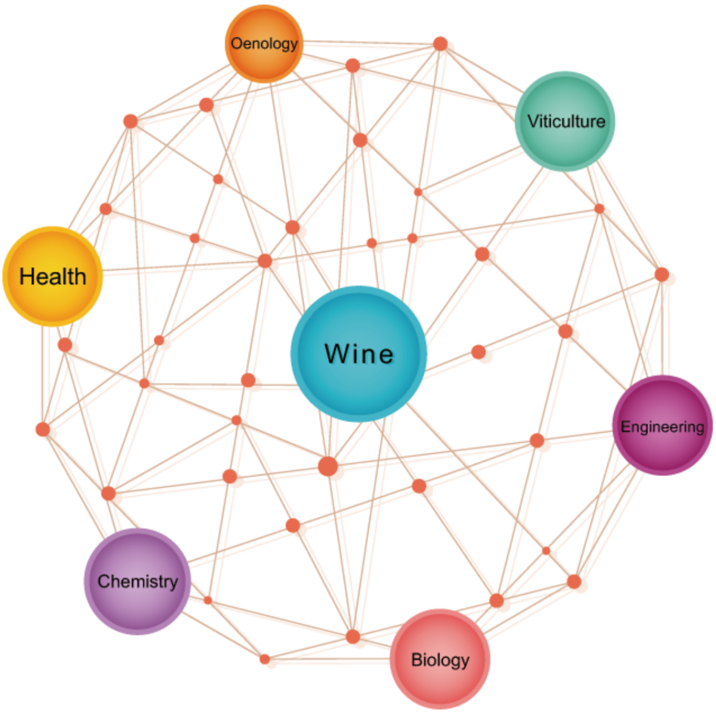

Fig. 1. Some research areas in which wine is the study subject.

1.2 First Science & Wine World Congress: The wine of the future

The wine of the future will be produced by applying high advanced technologic resources in different production phases. Starting with their use to identify grapevine varieties within demarcated territories. In Portugal, University of Trás-os-Montes e Alto Douro developed mySense, a tool that incorporates artificial intelligence to identify the varieties that exist in Douro Demarcated Region. Mysense is being tested by Instituto dos Vinhos do Douro e Porto, to achieve a useful tool to support both its regulatory and inspecting responsibilities. This networking collaboration between researchers and public institutions are crucial to the future of wine sector. Mysense is based on the submission of up to 6 images framing the element to identify, these are then analyzed by a Distributed Computational Intelligence Module (DCIM) that provides a probable identification. DCIM is based on a convolutional neural network - Xception architecture – initially trained using a data set acquired in Douro Demarcated Region and periodically improved by incorporating new validated observations. Results obtained thus so far allow to conclude that artificial intelligence techniques can indeed contribute to both quick and precise grapevines variety identification, endowing viticulture stakeholders with straightforward technological tools that will help support their regular activities. Regarding viticulture, GIS-based clustering tools will be frequently used for characterization and implantation of vineyards aiming the production of better-quality wines. Nanotechnology also has a promisor future in wine production. With nanotechnology will be possible to produce sensible sensors, antimicrobial compounds, and to improve some processing techniques. In last decade electronic "tongues" have been developed to analyze wine without the need of separating it into simple components. One of those "tongues" was formed by phthalocyanines combined with biosensors (containing enzymes such as glucose oxidase or tyrosinase and phthalocyanines as electron mediators). This sensor array, coupled with pattern recognition techniques, can distinguish the red wines and red grapes on account of their chemical nature. In the near futures, it is necessary to reduce electronic tongues costs to be possible its regular use.

In the future, consumers want to be sure that the wine is authentic, therefore is important to adopt some approaches to detect wine adulteration/mislabeling practices. Wine authenticity confirmation can only be achieved through a multidisciplinary approach involving both the geographical provenience and grapevine varietal identification using DNA-based methodologies. Furthermore, certification and control procedures can be also improved using a GC-IRMS approach to investigate the presence of stable isotope ratios.

Winemakers must produce wine, considering that in the consumer decision-making process is involved in emotional engagement and cognitive interest. Considering the intrinsic features of wine, some results show that the smell phase involves more emotional engagement than the taste phase, which involves more cognitive interest. In the sensorial context, aromatic quality of wines is a very important wine characteristic. Therefore, it is important to support research aimed to increase wine aromatic quality. As shown in this Congress, the latter is affected by grape origin, light exposure, bottle stopper, oak chips and yeast strain use. In the future neuromarketing should consider the environment where wine will be consumed, since, for example, a wine could lead to different sensorial experiences according to the music that is listening. Future consumers must know wine health effects. This is a crucial aspect for the future of the wine sector, where all must work together to understand more about it and is urgent to define joint communication strategy to avoid misunderstandings.

1.3 Conclusion

The main conclusion of First Science & Wine World Congress is that the wine of the future must be designed by a multidisciplinary team. Considering that terroir affects from grape growing to wine production a holistic approach must be considered. This First Congress has also shown that researchers want to participate in these discussions and answer positively to these challenges. Wine professionals, however, must be motivated to participate in this type of discussions and must be encouraged to include scientific research among their priorities. This congress showed that great advances are being attained in different areas such as viticulture, vine and wine technology, wine analysis and sensorial experience. More efforts are necessary to clarify the effects of wine in health, since contradictory messages are often spread by the media. These discussions are most welcome to promote critical thinking, to get new research perspectives, to encourage networking and to support political decisions.

Biographies

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The Appropriation of Blockchain for Small and Medium-sized Enterprises

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Abstract. This article aims to provide a conceptual framework for small and medium-sized enterprises (SMEs) to evaluate the appropriation of blockchain technology for their business needs and challenges. This conceptual framework aims to respond to the problem of increasing speculations surrounding the blockchain that is considered to be an absolute and innovative solution to many business related problems. However, this argument might not be realistic for SMEs despite this assumption. The main argument of the article is that SMEs should be skeptical while evaluating the appropriation of this technology for their business needs and they should follow a tailored approach whilst adopting it. Otherwise, the likelihood is high that a short-term and unstructured knowledge management process to adopt blockchain will end up with a waste of resources. The present paper conceptualizes an appropriation framework within nine factors namely, reduction of costs, internalization, digital representation of assets, unalterable data recording, network size, transparent and synchronized ledger, scalability, fair trade, and financing. Given the field's infancy state of development, the paper relies on a qualitative document analysis involving SME literature and extant literature and white papers of blockchain applications.

Keywords. Business Management, Knowledge Management, Small and Medium-sized Enterprises, New Technology, Information Processing, Business Data Processing.

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1 Introduction

Since its first launch in 2009, world's first cryptocurrency Bitcoin had gained gradual global media attention in line with its increasing price. The interest on Bitcoin peaked in December 2017 when its price hit almost $20.000 (Coinmarkecap, 2018). Whilst the increasing price of Bitcoin is criticized by senior financial executives as the biggest bubble in the global economy, its distributed ledger technology (DLT) or in other words blockchain technology that enable peer to peer value transaction has been praised from the same financial circles (Cao, 2018). While Bitcoin price shows a fluctuating trend in recent times, there is an increasing demand for adopting the blockchain in different business sectors (Kshetri, 2018).

Despite growing interest in adopting the blockchain technology, the lack of a clear roadmap in the adaptation of this technology raises significant confusion whether the DLT's are an appropriate technology for businesses that have an intention to use it. Even though this technology is considered applicable to bigger firms, i.e. those having strong knowledge management capabilities and relying on both their financial and human resources; appropriateness of this technology to SMEs that often suffer from resource constraints (Jarillo, 1989) is a significant question that needs to be answered considering their impact on the prosperity of countries (OECD, 2017a). In this respect, this study aims to develop a conceptual roadmap for SMEs whether DLTs are an appropriate technology to respond to their needs.

The use of blockchain in business management is a new field of research. Some studies available focus on presenting broader concepts about DLTs, its challenges and its future implications in business management (Swan, 2015; Mougayar, 2016; Tapscott and Tapscott, 2016; Morabito, 2017; Mendling et al., 2018; Zhao et al., 2016; Mainelli and Smith, 2015). These descriptive studies provide a comprehensive overview to practitioners and academicians how to adopt this new technology either in their businesses or their research areas.

In another strand of literature, blockchains are examined under the theme of Business Process Management (BPM). In these papers, the potential benefits of shared ledgers are demonstrated for business enterprises. According to Hull and others DLTs provide a data-aware process for companies who are seeking innovation for business collaboration (Hull et al., 2016). These ledgers help these companies to track the state of the processes in their business and execute each task using a space-optimized data structure (Lopez-Pintado et al., 2017; García-Bañuelos et al., 2017). They provide transparency for the stakeholders of an organization to understand and monitor their business process (Milani et al, 2016). Due to DLTs having no ownership, they also offer traceability of business data by evaluating blockchain records (Kim and Laskowski, 2016).

The issue of trust in business relationships is one of the major concerns for all parties (Blois, 2002) if they have not been in long-term business interactions. In this respect, the blockchain technology is exemplified as one of the solutions to resolve trust issues between the business partners who have no previous business transaction (Weber et al., 2016). It is also considered a solution to the cost of computation and data storage (Rimba et al., 2017). As a result of all these advantages, blockchain is highly recommended to be taught in business schools (Bheemaiah, 2015).

In all the above-mentioned studies, blockchain technology is presented as a useful tool for business solutions. However, the appropriateness of blockchain for SMEs has not been addressed in the above-mentioned studies. In fact, the authors of this paper have not found any study (nor conceptual or empirical ones) that show the adoption of blockchain technology, which is unsatisfactory considering the relevance of SMEs. Against this background, this article strives to contribute to the emerging field by providing a comprehensive conceptual discussion on blockchain technology in SMEs. It proposes a conceptual framework for SMEs to determine whether DLTs are appropriate solutions to improve their business operation and performance. It incorporates distinct benefits of DLTs under a comprehensive conceptual framework to make it easier for owners or owner-managers of SMEs to evaluate the suitability of DLTs for their present and future business challenges.

The main argument of this article is that DLTs are not always a suitable tool for SMEs to improve their business operations. Before investing in this technology, decision makers in SMEs should critically scrutinize whether the innovative features of blockchain are feasible in their current business processes. A failure to this can be an impair investment and disappointment for the smaller company both by wasting their financial capital and human resources for a futile initiative.

This article conceptualizes the appropriateness of blockchain technology for SMEs within nine factors. These factors reflect the major challenges of SMEs when competing with large companies and which have been stressed in the existing literature. In brief, they are: reduction of costs (Lohrke et al., 2006; Kleindl, 2000; Brouthers and Nakos, 2004), internalization (Lu and Beamish, 2001; Desouza and Awazu, 2006; Liesch and Knight, 1999), digital representation of assets (St-Pierre and Audet, 2011; Wickramansinghe and Sharma, 2005; Durst, 2008), unalterable data recording (Shiraishi, 2012; Flynn and Davis, 2015), network size (Zain and Ng 2006; Qjala, 2009; Lee et al., 2010), transparent and synchronized ledger (Kasheva et at., 2010), scalability (Sultan, 2011; Marian, 2012), fair trade (Redfern and Snedker, 2002; Davies and Crane, 2010), and financing (Zairani and Zaimah, 2013). For each factor, this paper will provide a brief conceptual framework for decision-makers working in SMEs to determine the applicability of blockchain technology to their business model.

A qualitative document analysis was utilized in this paper to conceptualize the appropriateness framework involving existing literature and white papers on blockchain applications and extant SME literature. Depending on if and when SMEs began to use blockchain technology in their business processes, the factors outlined here will hopefully encourage future research to investigate the efficiency of blockchain in SMEs. These findings may also lead to an alteration of the factors and the addition of new ones. So, this study is likely to be considered as the first attempt and groundwork for conceptualizing the appropriateness of blockchain for SMEs. This situation also means a limitation of the present paper.

The remainder of the article is as follows. Next, a description of blockchain and its types is provided. In this section, derivatives of blockchain such as smart contracts will also be explained. Then the above-mentioned features of blockchain in the context of SMEs will be discussed. In the final section, concluding remarks will be shared to make possible a better adaption of DLTs in SMEs. As the old saying goes, “Necessity is the mother of Invention” and this, indeed, blends the domains of technology expertise and the innovation process. This is, in fact, part of what makes innovation happen at the “Front End”, also referred to as “Fuzzy Front End” to depict the unstructured nature of the process that actually enacts New Concept Development Process and the final emergence of a New Concept. It is on the multidisciplinary nature of this process and supporting tools and concepts, as well as on why and how it actually happens that this article aims at.

2 Blockchain in General

The blockchain is simply a linear data structure containing chained data blocks. These blocks comprise transactions between peers. In order to make a value transaction, peers need a cryptographic key-pair to authorize transactions. One of these keys is called the public key, the other is the private key. The public key acts like a bank account where the value transaction is addressed. The private key is such a password or a signature to authorize the transaction. Combination of both keys creates a secure digital identity (Moser et al., 2013).

When a digital asset is intended to be transacted from A to B, a new hash value is created using a hash of previous transaction and destination account’s public key (B’s public key). The new hash value is signed by A’s private key (Nakamoto, 2008). These not validated transactions aggregated within a data block by blockchain nodes that perform validating transactions, creating new blocks and maintaining transaction records. The timestamp is another component of the block which is formed with the hash value of the previous block and a nonce which is a random number verifies the hash (Nofer et al., 2017). In order to be added to the blockchain, the block contains valid transactions must be linked with the previous block. To do this, the nodes using their computational power guess the correct nonce (random number) that is combined with the previous block hash and the hash of new block transactions to generate a defined result (proof-of-work). The first node that predicts a mathematically challenging process add the new block on the chain and it broadcasts to the other nodes (D’Aliessi, 2016). This process is repeated for each block following and it generates chained secure data blocks called a blockchain.

Once a transaction data is placed in the blockchain, it is not easy to alter it. To make this modification, an attacker must change the transactions not only in the latest block but also in previous blocks those are linked with each other with hash values. This kind of attack needs huge computational power. It is extremely hard to compute all data blocks due to an enormous number of random guesses needed to create new blocks and place them on the blockchain (Bheemaiah, 2015). However, there is one risk called 51% attack that may endanger the integrity of blockchain. According to this hypothetical risk, if an attacker controls more than 50% of computational (hashing) power of the blockchain network, it has the chance to solve a block before the remaining of the nodes do it. In the case of this scenario, however, the probability of solving other blocks in a row is reduced for the attacker because other honest nodes continue to mine transactions. It becomes more complicated for an attacker to surpass hashing power of all nodes because the attacker has to cope with not only with the old blocks but also with the new blocks produced by honest nodes (Bheemaiah, 2015; D’Aliessi, 2016). In today’s computational standards, execution of such an attack is still less likely to be achieved which makes blockchain highly secure value transaction system.

The blockchain technology is not only limited to simple value transaction from A to B, but it also provides a platform enabling value transaction on the fulfillment of further arbitrary conditions. This innovation is maintained by adding a new layer of blockchain and it is called smart contracts (Szabo, 1997). The smart contracts enable encoding pre-determined conditions (scripts) for value transaction between two or more parties. The code dictates how the process will take place. Due to code is placed in blockchain; it cannot be altered by anyone. For the autonomous execution of the transaction, all parties must fulfill their pre-determined responsibilities. Otherwise, value transaction never happens. This new version of blockchain eases business process management for companies by removing a trusted third party. Along with that their transaction become faster, cheaper, more efficient and incorruptible (Bheemaiah, 2015).

There is no definitive model of DLT's. Since its first application to Bitcoin, three prominent versions of blockchain came into the forefront. These three versions are categorized as Public Blockchains, Consortium Blockchains and Private Blockchains (Voshmgir and Kalinov, 2017; Mulligan et al., 2018).

Public Blockchains are open to all who would like to join this network. By downloading the digital ledger that keeps a record of all block's transactions, they can see and verify data shared in the DLT. Due to there being no central authority, a copy of the blockchain ledger is stored by every node of the network. The nodes only verify the transaction and compute the data blocks. They cannot manipulate the transactions, because they are not intermediary. Every time a new block is added, the ledger is updated. Records kept by nodes enable replication and synchronization of ledger across the blockchain network. In order to motivate nodes to dedicate their computational power to block producing (mining), consensus algorithms are developed under the name of proof-of-work or proof-of-stake. As mentioned earlier, these algorithms task nodes to solve complex mathematical problems to synchronize the ledger. When they accomplish the task, they are rewarded with incentives such as crypto currencies and these virtual currencies can be exchanged with fiat currencies. Public ledger systems have no infrastructure cost because nodes use their own computational power and their participation in the network is voluntary. However, public blockchains are slow in transaction time and their transaction capacity is limited in comparison to the other ledger types. High energy cost is another weakness of the public ledger system.

Consortium ledgers differentiate from public ledgers by determining who will act as the transaction validator. In public ledgers any one can be a node to validate the transaction, however, in consortium ledgers, developers of consortium either sets a permission mechanism for the nodes to join the network or they can build their own nodes all around the world. In providing publicly available records, transparency mechanism in consortium ledgers works as the same as public ledgers. Consortium ledger technologies also may not build its system to consensus algorithms such as proof of work or proof of stake (Bauerle, 2017b). Due to the absence of the mining process, this type of ledger systems reduces transaction times and computational cost. They are also energy efficient for the sake of preserving natural sources and more scalable in terms of a higher number of transactions (Credits, 2017).

Private blockchains are the strictest version of ledger systems. They neither allow nodes to participate without permission of developer nor the ledger records is visible publicly. It is kind of an internal type ledger system for closed community or a network. These blockchains are also criticized for nothing more than any traditional data base (Percic, 2018). If the network does need to share its transaction data or they are very sensitive to data privacy, these ledgers are a more appropriate choice for them. The other benefits of private ledgers are the same as consortium ledgers such as faster transaction times, lower computational costs, lower energy cost and high transaction volume (Voshmgir and Kalinov, 2017).

3 Blockchain in the Context of SMEs

Even though there is no globally agreed definition, companies that employ fewer than 250 employees and which has less than 50 million annual turnovers are considered as SMEs (European Commission, 2019). These companies are considered the backbone of most of the economies (Eurostat, 2011) and their survival is vital for a healthy economy. SMEs have to be strengthened to overcome the economic challenges surrounding them (OECD, 2017a).

Globalization is one of the challenges for SMEs that impose new trading conditions to keep up with. In order to compete with their global rivals, SMEs should develop new business strategies based on efficiency, flexibility and their product and process quality must be in higher standards (OECD, 2002). Furthermore, the internationalization of their businesses in foreign markets is considered a critical junction to maximize their business opportunities (Knowles et al., 2006; Shane and Venkataraman, 2000; OECD, 2017a). Nevertheless, growth through internalization, or growth in general, necessitates allocating resources not only financial and physical assets but also investing on intangible assets such as information technology tools for business process management (Alwert et al., 2005). Attaching higher importance to knowledge assets no more considered new for business enterprises (Martín-de-Castro et al., 2006), rather ignoring these resources carry the danger of knowledge attrition (Durst and Wilhelm, 2011).

In order to overcome knowledge attrition and to manage current and future knowledge resources in the best possible manner, SMEs need to rely on efficient Knowledge Management (KM) (Durst and Edvardsson, 2012). Knowledge has increasing importance for firms, regardless of size, in their strategic priority scale (Spender, 1996). If SMEs find ways to adequately manage knowledge, it provides them capabilities to achieve a competitive advantage (Teece, 2001). Knowledge management includes many processes and structures within organizations. The adoption of new innovative technologies is one of the key elements of effective KM (Kluge et al., 2001; Quintas, 2002; O'Dell et al., 2003; Edvardsson, 2009; Jashapara, 2011).

The DLTs or blockchain technology is one of the innovations of recent years that is considered to solve many traditional business-related problems. However, the hype surrounding the blockchain is sometimes misleading the decision makers in companies because of the confusion or the absence of knowledge about this technology. Moreover, a tendency of SMEs to rely on short-term unstructured methods for organizational learning (Beijerse, 2000; Matlay, 2000; McAdam and Reid, 2001; Corso et al., 2003; Bozbura, 2007; Hutchinson and Quintas, 2008) undermines a comprehensive evaluation of appropriateness of blockchain technology for this category of firms. Additionally, the fact that many smaller firms struggle with the adoption of more sophisticated

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ICTs that could help them in benefiting from the opportunities offered by digitalization (OECD, 2017a) should not be overlooked in this context.

In this respect, the innovative features of blockchain should be evaluated together with the major challenges of SMEs. This is done in the following sections.

3.1 Reduction of Costs

In comparison to larger firms, SMEs suffer often from resource constraints (Jarillo, 1989; Thong, 2001). This means SMEs have to be more careful using their resources because reversing wastage of resources might not be easier as in larger businesses (Amelingmeyer and Amelingmeyer, 2005). In order to tolerate resource constraints, SMEs have to reduce their operational costs to compete with their bigger rivals.

One of the solutions blockchain provides for SMEs is it removes intermediary for value transaction. For SMEs, this intermediary might be a bank, a broker or a middleman who secures the value transaction between the SMEs and their trading counterpart. Relying on an intermediary inevitably increases transaction costs because of the fees the intermediary takes or the margin they add (Madhok and Tallman, 1998). By using blockchain, the SMEs can reduce their transaction costs and they can compete with bigger firms in the absence of intermediary expenses.

Nevertheless, removing the intermediary every time might not be the ideal solution for SMEs. Under certain circumstances, a trusted party might be needed between two trading partners to regulate their interaction. The intermediary in this respect plays a role to resolve potential conflicts between companies and their absence might be much costly for them. Consequently, in order to decide on the appropriateness of blockchain, decision makers in SMEs should calculate both the cost of an intermediary to the business and the cost of adopting blockchain technology. If the role of the intermediary is expensive than investing in blockchain technology, knowledge transfer and knowledge utilization in blockchain will be much profitable for them. Otherwise, continuing with traditional methods will be a much convenient solution for SME's.

Another important point on removing the intermediary is all parties utilizing blockchain should use this technology in an efficient way. If counterparts of SMEs are not aware of what the blockchain is, then removing an intermediary will make no sense for their business transactions. It will bring other problems between them which will increase their business transaction cost and eliminate the trust among them.

3.2 Internalization

Internalization is one of the challenges of SMEs to increase their share in global markets. They need both additional resources (Welch and Luostarinen, 1988) and trusted relationships (Zain and Ng, 2006) to successfully implement their internalization strategies. The concern of the loss of resources makes SMEs hesitate to do business with actors who have no available and credible trading record. This hesitation may prevent the execution of a potentially profitable business for SMEs and in turn, can mean the loss of this business opportunity to bigger firms who can tolerate this risk easily in comparison to SMEs.

In this respect, smart contracts provide an opportunity for SMEs to do business with untrusted parties. It creates a platform where peers do not need to trust each other. They can make secure value transaction even they have no previous trading record. The SME's using smart contracts can set arbitrary conditions to execute business operation and as long as peers fulfill the pre-determined conditions, these contracts autonomously execute value transaction. For instance, whilst company A sends its product to B, the money of B is kept in blockchain escrow and it is released on the condition of safe delivery to company B. When B confirms the safe delivery, the money in escrow can be transferred by company A. In view of this simple transaction, neither A nor B have to know each other. They only have to comply with the conditions they previously agreed. The smart contract will autonomously execute the contract on behalf of trading parties. For the SMEs who are looking for ways to internalization of their business but hesitant to send their products to untrusted customers, smart contracts can be a suitable solution to improve their business opportunities.

However, if the parties in the respective business transaction have no trust issue and they have aligned interests, the adoption of blockchain might not be necessary for SMEs (Mulligan et al., 2018). It would be wise not to spare their limited resources for adoption of the blockchain.

3.3 Digital Representation of Assets

The blockchain ledgers are comprised of digital codes. As indicated earlier, by using hash functions, digital assets are represented in blockchain with unique hash codes. This makes it easier for the business counterparts to follow their business process by tracing the codes. The major concern in this regard is these digital codes should not represent the assets that can change form. For instance, if an SME doing apple juice business, blockchain does allow them following up the supply chain from the collection of apples to return into a juice. Due to apples turn into juice, their quantity is transformed from countable apples to liquid. This transformation cannot represent as a digital asset in blockchain because they are no more in the same form. Therefore, the input and output data will be incompatible in blockchain ledger. The reason for any leakage cannot be explained by looking at digital codes whether the reduction is the cause of stolen apples or wastage while apples are squeezed. If an SME aims to trace one certain asset that can be represented digitally, blockchain will satisfy their needs, otherwise, they should search for another option that can respond to their inquiries.

3.4 Unalterable Data Recording

If blockchains are used for the purpose of online documentation, they are not flexible systems to tolerate human error. The data recorded in blockchain is unalterable. When a transaction is made between peers and it is validated by nodes there is no way to alter these records in the blockchain. In this respect, peers must be certain about the accuracy of the data when they are confirming the transaction. This issue may not be the ideal solution for SMEs who may look for flexible and alterable databases, because SMEs have less formal business processes than bigger enterprises (Singer, 2015). SMEs are more inclined to make mistakes in their data management. Therefore, if SMEs are seeking unalterable data recording system blockchain will be an appropriate solution for their needs, otherwise, they should refrain from investing in the blockchain.

3.5 Network Size

The major advantage of blockchain is it eliminates the dependency of peers to a central authority. Its decentralized nature increases the significance of network effect. The potential benefits of blockchain increase as long as the size of the network increases (Carson et al., 2018). Thus, it becomes stronger to the outside attacks as it grows (Bauerle, 2017a).

For SMEs who would like to reap the full benefits of the blockchain, they need to have or be part of a robust and big network that distributed grid of nodes. If a small group of companies aims to use blockchain, they are more vulnerable to the outside attacks due to their computational power can be surpassed by bad outside actors. Therefore, before investing in blockchain, SMEs should consider whether their network capacity will be enough to pervade distributed nodes. If they are sure enough then they should initiate a blockchain network or enter into a blockchain network that is maintained by a big player.

3.6 Transparent and Synchronized Ledger

The blockchain can also provide a shared repository which is generated by multiple writers. Shared ledgers have two benefits for business enterprises aiming to use it. Firstly, they provide transparency for untrusted shareholder and none of these parties can corrupt the data. Secondly, a copy of the ledger is kept by each node which is backed up in case of a crash of their data storage tools. The DLTs in that sense support SMEs by providing synchronized data recording systems, if there is a concern of consensus on accurate transaction records. Any conflict in records can be resolved by examining the shared ledger. Therefore, if SMEs needs transparent, synchronized and shared repository blockchain will respond to their needs.

On the other hand, transparent and synchronized ledgers carry the risk of revealing all private transaction information to the blockchain network. All nodes in the blockchain can see who is doing business with whom and what their price margins are. This could be a double-edged sword for SMEs. It can either improve competition between SMEs and companies buying products with higher prices look for other companies offering the products at more reasonable prices. Or, it can endanger the business relationship between the market actors involved due to higher prices may perceive as unfair pricing by the majority of companies and their network can be disrupted. Therefore, before initiating a blockchain project, SMEs should be aware of the transparency issue and its likely consequences.

3.7 Scalability

Scalability is another issue that should be considered to determine the appropriateness of blockchain. The higher transaction speed might be an important expectation for SMEs whilst adopting the blockchain. For instance, a speedy transaction might be important for an SME to make possible a quick payment system.

Most of the well-known public blockchains such as Bitcoin and Ethereum have limitations in scalability. For instance, whilst in Bitcoin blockchain, seven transactions can be made per/second, this rises in Ethereum to 15 per/second (Mendling et al., 2018). In comparison to the Visa which can accomplish 2000 to 50000 transactions per/second, public blockchain technology is quite slow for those SMEs who are seeking scalable value transaction methods. However, consortium and private type blockchains provide solutions to the scalability problem of blockchains. For example, a consortium blockchain called "Red Belly Blockchain" offers 600,000 transactions per/seconds for its customers who use their blockchain platform (Crain et al., 2017). In this respect, SMEs should evaluate their transaction volume how much they needed. If they need higher transaction volumes they should use consortium or private blockchains, if transaction volume is smaller, public blockchains will respond their needs with lower volumes.

Apart from the transaction volume, latency is another issue for the quick value transaction. Due to network congestions, sometimes confirmation of transaction may take longer than centralized value transaction systems. For instance, in Bitcoin blockchain, the average confirmation time is taking 60 minutes, for Ethereum network it takes 3 to 5 minutes. However, in Visa, it is only a second (Mendling et al., 2018). This challenge is now projected to be overcome with private and consortium networks which aim to reduce confirmation time as like centralized systems. In that sense, if SME's looking for quick confirmation in their transaction, they should rely on private or consortium type blockchains. If confirmation is not an urgent matter for them, then public blockchains will be an appropriate solution for their needs.

3.8 Fair trade

Global competition may sometimes lead companies to lean on unethical business practices, such as unethical production methods. In order to maximize their profits or competition capabilities, these companies might abuse economic, environmental and social issues associated with their business operations. These issues inevitably necessitate tracing their supply chain practices.

In this respect, blockchain technology can provide a solution for SMEs who would like to demonstrate they are complying with fair trade principles provided by the World Fair Trade Organization (WFTO). The customers who are sensitive to these principles can trace the provenance of the products they purchase through blockchain ledger (Teo, 2018). The transparency provided by blockchain can boost the trust between SMEs and their customers and contribute to a competitive edge.

3.9 Financing

A frequently raised challenge of SMEs to realize their business ambitions is their lack of or access to financial capital (OECD, 2017b). In order to access the necessary financial resources, they can try and get a loan from a bank or get access to alternative financing instruments provided by other financial intermediaries. As for getting a loan, interest rates required by financial institutions might not be attractive to initiate their project, e.g. to grow internationally in view of the higher costs that SMEs may face in comparison with the bigger companies (OECD, 2017b). On the other hand, the audience who could provide financial capital to SMEs might be reluctant due to the increased risks involved in financing or missing profit opportunities. Moreover, SMEs seeking funding may also not want to offer equity for investment (KPMG, 2014).Therefore, SMEs should attract those investors who have a good understanding of SMEs and their way of thinking in order to support their expansion strategies.

In that sense, blockchain technology offers SMEs a fundraising opportunity called Initial Coin Offerings (ICO). In an ICO, the SME who owns a project creates a certain amount of digital token and sells it to the potential investors. These investors buy these tokens in exchange for a service provided by the SME or increasing demand on the token in crypto markets that brings higher profits. This win-win situation enables SMEs to reach the necessary funding they needed, and it provides higher profits to their investors.

The ICO's have both advantages and disadvantages for SMEs. They enable quick and less regulated funding process for SMEs and they do not need to loss of equity. On the other hand, due to ICO's are not regulated in many countries, they might subject to fraud cases if they are complained about by their investors. Therefore, the SMEs should consider both advantages and disadvantages of ICO before they set off this journey.

In line with the above-mentioned discussions the appropriateness of the blockchain framework for SMEs can be summarized as follows:

Table 1. Framework for testing the appropriateness of blockchain technology for SMEs.

Conceptual Framework for Appropriateness of Blockchain for SMEs		
Major Challenges	**Appropriate**	**Inappropriate**
Reduction of Costs	For removing Intermediary	If intermediary: Regulates the business interaction Resolves the Business Conflicts
		Lacking the ability to use
Internalisation	Untrusted business interaction (Smart Contracts)	No trust issue
Digital Representation of Assets	Intransmutability	Transmutability

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Conceptual Framework for Appropriateness of Blockchain for SMEs			
Major Challenges	**Appropriate**		**Inappropriate**
Unalterable Data Recording	No flexibility		Flexibility is needed
Network Size	Bigger Network		Small Network
Transparent and Synchronized Ledger	If incorruptible data is needed		Confidential transaction
	Competitive Market		
Scalability	Higher Transaction Volume (Private and Consortium DLTs)	Lower Transaction Volume (Public DLT)	
	Short Latency (Private and Consortium DLTs)	Long Latency (Public DLT)	
Fair Trade	Sensitive in Tracing Provenance of Products		No sensitivity
Financing	Less regulated funding No loss of equity		Risks of fraud investigations

4 Conclusion

The enthusiasm over blockchain in recent years draws a promising picture that this technology can be a solution to many problems of SMEs. It may help SMEs in different sectors including agriculture, financial services, healthcare, insurance, property management, technology and utilities (Carson et al., 2018). In theory, these arguments have convincing points to overcome the above-mentioned problems. However, this technology is still in an immature stage and a few years are needed to see feasible applications of blockchain in the SME world.

Even though blockchain has the potential of providing cost efficient and transparent solutions to SMEs, the adoption of this technology might not be necessary to respond to these companies needs in a successful manner. The hype around this technology should not deceive owners and owner-managers that every aspect of blockchain is useful for their companies. It is strongly recommended that smaller companies who are interested in this technology and its application should thoroughly evaluate the pros and cons of this technology skeptically and when they are fully certain, then, they should adopt it. They should also remember that those firms who adopt this technology first will have a leading edge over their rivals.

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The blockchain also provides a different alternative for SMEs to use it in their BPM. In that sense, SMEs should follow a tailored approach to pick the right blockchain application to respond to their needs. Choosing the right blockchain model for SMEs necessitates given higher priority to KM. As with the information and knowledge picked up here and there, blockchain will not bring the desired benefits but mainly disappointments. SMEs that aim to benefit from this technology should follow proper knowledge management process.

Even though a small group of SMEs manages to accomplish adopting blockchain technology to their business model, without robust and bigger network benefits of this technology will be not at the required level for them. Therefore, more SMEs should be part of this network to maximize its advantages. In order to attract more SMEs to use blockchain technology, global and national trade unions or organizations should encourage and guide SMEs on how to use this technology. They should provide them with incentives and knowledge management programmes to adopt this technology in their business routine.

Moreover, due to this technology is very novel, there is huge confusion on global and national policy makers to regulate this technology. The absence of globally agreed regulation inevitably increases confusion and hesitation on the companies to benefit from blockchain technology, because of potential money laundering investigations. In order to remove ambiguity upon the blockchain, a global regulative framework should be submitted as soon as possible by international trade organizations to encourage more companies to use it securely.

As for the final note, this article was the first step to integrate blockchain technology into SME related future projects. Based on the ideas discussed in the paper and the framework proposed, a number of future research avenues can be derived in order to investigate the appropriateness of applying blockchain in SMEs. In a next step, it is suggested to empirically study the nine factors and their suitability in SMEs. Additionally, future research could either investigate all the nine factors individually or in combination to find out whether blockchain can improve business operations in SMEs, and if yes, how. It is also recommended to focus on certain industries, e.g., smaller financial intermediaries and company size, e.g., small companies, to develop an in-depth understanding of blockchain in SMEs.

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A study of how uncertainty emerges in the uncertainty-embedded innovation process

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Abstract. This paper aims to understand about *how uncertainty emerges in the innovation process.* Since uncertainty is embedded in the innovation process, to understand how uncertainty emerges in the process one needs to understand how innovation process unfolds over time. Since an innovation process involves various resource recombination activities occurring in several phases, to understand how innovation process unfolds one needs understand "*how do various resource recombination activities occur over time for the creation of novelty?"* This knowledge would enable us to understand the conditions under which vital activities of resource recombination can/cannot be undertaken and coordinated as well as would allow us to understand the underlying decisions made by the innovators for their efficient undertaking and coordination. This paper investigates the innovation process in two companies through performing qualitative study. The innovation processes are analysed in the light of a conceptual model developed based on the Dubois' (1994) End-product related activity structure model, Håkansson's (1987) "ARA model" and Goldratt's (1997) "Critical chain concept". The findings suggest that uncertainty emerges in the innovation process in a cycle of interaction with resource void, activity void and actors' limited cognition due to lack of knowledge, undue optimism, and rationally justified reason for disregarding information. Accordingly, a great deal of compromises is made while undertaking the activities.

Keywords. Uncertainty, Innovation Process, Activity Void, Resource Void and Actors' Limited Cognition.

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1 Introduction

Companies execute innovation strategies to gain competitive edge over their competitors by creating novelty and to ensure survivability and sustainability in the often-changing market (Yamin et al., 1997; Porter and Stern, 2001). However, it is not easy to execute innovation strategy because the innovation process is embedded with uncertainty (Kirzner, 1979; Gartner, 1990; Fleming, 2001; Jalonen, 2011; Pavitt, 2013). Managers face different types of uncertainties along the innovation process, such as, technological, commercial, organizational, market, regulatory/institutional, social/political, acceptance/legitimacy, financial, timing, and behavioural uncertainties (Jalonen, 2011). Uncertainties affect the transformation of an idea into novelty (Kline and Rosenberg, 1986; Van de Ven et al., 1999) as a result, many promising ideas fail to be realized. Braeutigam's (1979) quote conveys how uncertainty is present in an innovation process: "Will an innovative effort result in an implementable technology, and if so, when? ... will the implementation of the technology be delayed by a regulatory authority, and if so, for how long? And finally, when the regulator permits the use of an innovation, what level of benefits will the firm ultimately receive? (p. 98)". Amid such uncertainties the organization that can manage this process efficiently has greater survivability and sustainability in the market (Dodgson, 2015).

There is ample of research in field of innovation studies which focused on the topic of uncertainty especially on the effects it creates on the innovation process (Damanpour, 1996; Rogers, 1983; Fleming, 2001; Ortt and Smits, 2006; York and Venkataraman, 2010). However, Fleming (2001) argued that "Despite this widespread acknowledgement of the importance of uncertainty, most research gives the topic brief consideration in route to other issues and little work has attempted to identify and empirically validate the causal sources of uncertainty" (p. 117). Jalonen (2011) also argued that in most of these studies the presence of uncertainty has been taken for granted as an independent variable having some specific effect on the process, and little is known about the causal sources of the uncertainty and how it manifests in the process. Although Jalonen (2011) categorised different sources of uncertainties based on an extensive literature review of 101 articles, he did not explain in which way they emerge in the process. Both Jalonen (2011) and Fleming (2001) argued that it is important to know the sources of uncertainties as well as how they manifest themselves in the process as this knowledge would enable practitioners avoiding the uncertainties thereby coordinating their innovation management activities efficiently. On the contrary to their view that uncertainty can be avoided in an innovation process by learning about its different sources, in a recent study Luthfa (2017) argued that uncertainty is unavoidable because of its embeddedness in the process. Based on the argument that uncertainty is embedded in the innovation process (Fleming, 2001; Rehn and Lindhal, 2011; Pavitt, 2013), she argued furthermore uncertainty is not only a factor affecting the process itself but also the outcome of the process (p. 23) and therefore one needs to be prepared to deal with those always during the undertaking of the process. However, there is little we know about how uncertainty manifests itself in the innovation process from the existing literature (Luthfa, 2017; Jalonen, 2011).

This paper argues that the knowledge about how uncertainties emerge in the innovation process would not only enable researchers to learn about the conditions under which uncertainties emerge in that process but also would enable researchers to know the conditions under which vital actions for novelty creation can/cannot be undertaken and coordinated efficiently. As we know, innovation in an interactive process that entails various resource recombination activities and their efficient coordination (Schumpeter, 1934; Rogers, 1967, 1983; Richardson, 1972; Utterback and Abernathy, 1975; Rescher, 2000), thus when uncertainties emerge in the innovation process those affect the undertaking and coordination of those various resource recombination activities subsequently affect the novelty creation. Furthermore, the knowledge about the conditions under which vital actions can/cannot be undertaken and coordinated would enable researchers to understand how to manage those conditions most efficiently for the efficient coordination of the activities. Therefore, this paper aims to deepen our knowledge of *how uncertainty emerges in the innovation process*.

Based on the argument that uncertainty is not only a factor affecting the process itself but also the outcome of the process (Luthfa, 2017; p. 23) to understand how uncertainty emerges in the innovation process this paper argues that it is necessary to understand how the process itself unfolds over time; that is, how various [resource recombination] activities occur in several stages or phases over time (Schumpeter, 1934; Rogers, 1967, 1983; Richardson, 1972; Utterback and Abernathy, 1975; Rescher, 2000). Therefore, to fulfil the purpose of the study the following research question have been posed: *How do various resource recombination activities occur over time for the creation of novelty?*

This paper has been structured as follows. The literature review section reviews existing knowledge of uncertainties in relation to the innovation process and reveals the gap in our current knowledge. An uncertainty-embedded innovation process model has been developed in the theoretical framework section to illustrate and analyse how innovation process unfolds overs time as well as to explain how uncertainty manifests in the process. The methodology section discusses about the choice of the method, data collection and analysis technique. In the empirical section two stories of the innovation processes have been discussed. Finally, after the analysis of the processes a conclusion has been drawn, theoretical and managerial implications have been stated and suggestions are made for further research.

2 Literature review

2.1 Innovation process and uncertainty in the innovation process

According to the "process philosophy" (Rescher, 2000) any process implies a set of sequentially linked activities towards an end; an outcome (Richardson, 1972; Dubois, 1994). An innovation process is an integrated series of connected development of meaningful events or sequence of resource recombination activities where one ends and the other begins and finally a novelty is produced (Schumpeter, 1934; Rogers, 1967; Richardson, 1972; Dubois, 1994; Rescher, 2000). However, the end of a process is never the final end as it always paves the way for greater changes (Rescher, 2000). The temporality of an end of a process makes the end of the innovation process (novelty) a temporary solution as well as a unique one from what has been created before and what will be created afterwards. In this study novelty has been defined as something new, therefore unique and significantly improved from the earlier ones (Oslo manual, 2005) for both who creates it and who consumes it. Since novelties are new they are not identical to one another (Martinez-Ruiz, et al., 2011). The distinctiveness of the novelties makes it difficult for the innovators to know or to plan which activities to undertake in advance. No actor has precise knowledge about what resource recombination activities will bring that distinct solution. Under limited availability of knowledge actors experience uncertainty: a condition when actors' existing knowledge and prior experiences become inadequate or divergent from understanding what activities are required to take the next step or what outcome might come from those activities (cf. Knight, 1921; Reddy, 1996; Lenfle and Loch, 2010; Jalonen, 2011; Håkansson and Olsen, 2012). According to Lenfle and Loch (2010) the innovation process is like "proceeding in the dark" where one's theoretical knowledge is not necessarily enough to deal with the reality. According to Håkansson and Olsen (2012) the innovation process contains the "elements of exploration into the unknown, into the unexpected and quiet often also into the impossible, the irrational" (p.81). Under such conditions, actors respond to the way the stories of innovation unfold over time (Håkansson and Olsen, 2012). Since "way leads on to way" (Lundgren, 1995; p. 91) actors' response to the evolution of the innovation story can lead the entire innovation project onto a different trajectory from what has initially been anticipated (Lundgren, 1995; Håkansson and Olsen, 2012) and in this manner can create further uncertainty in the innovation process. Therefore, uncertainty also becomes an outcome of the innovation process; the outcome of the way the activities are undertaken and coordinated. Therefore, several researchers (e.g. Fleming, 2001; Lenfle and Loch, 2010; Jalonen, 2011; Rehn and Lindahl, 2012; Håkansson and Olsen, 2012) argue that innovation process is inherently uncertain meaning uncertainty is unavoidable in the process.

2.2 Different types of uncertainty in the innovation process

According to Galbraith (1977) a great deal of uncertainty exists about how to define the concept of uncertainty. Unlike risk, which is measurable (Knight, 1921), uncertainty cannot be measured (Galbratih, 1977; Jalonen, 2011) because it involves unstandardized operation or non-systematic activities (Utterback and Abernathy, 1975). An innovation process is both risky and uncertain. It is risky because it entails significant investment therefore entails significant cost (Gompers and Lerner, 2001; Eveleens, 2010; Muller, 2013; O'Sullivan, 2013) unless the outcome of the resource recombination process is widely accepted by the users (Rogers, 1967). It is uncertain because an innovator's knowledge or experience or resources is inadequate or unavailable or imperfect to steer those non-systematic resource recombination activities as well as to predict the final outcome of the process (Knight, 1921/2012; Galbraith, 1977; Daft and Lengel, 1986; Brashers, 2001; Håkansson and Olsen, 2012; Holmen and McKelvey, 2013).

The term "uncertainty" and its different types in relation to the innovation process has been discussed in several studies (e.g., McMullen and Shepherd, 2006; Bessant, 2008; Foster, 2010). Among those different types, technological uncertainty has been the most discussed one, because it is usually considered synonymous with technological invention (cf. Fleming, 2001; Jalonen, 2011). According to Fleming (2001) technological uncertainty is high when innovators try to recombine unfamiliar components. In contrast, technological uncertainty is low when innovators try to combine familiar components. The degree of technological uncertainty is inversely proportional to the degree of prior knowledge and experiences of handling familiar activities. High technological uncertainty may increase the likelihood of failure in comparison with low technological uncertainty but may increase the likelihood of creating radical innovation if managed efficiently (Dosi, 1982; Fleming, 2001).

Many studies have also emphasised regulatory/institutional uncertainty (Braeuitigam, 1979; Freel, 2005; Prieger, 2007; Bessant, 2008; York and Venkataraman, 2010) which has a significant impact on the innovation process. Regulatory uncertainty is created by the policy makers, who wield their power to prohibit, stimulate, monitor, and regulate activities in the innovation process (Freeman, 1974; Rogers, 1983; Nelson, 1993; Foster, 2010). Generally, policy makers adopt policies for supporting innovation but sometimes the same policy can become the source of uncertainty (Jalonen, 2011). For example, government policy encouraging the establishment of coal-based and nuclear power plant in Bangladesh to ensure power supply is threatening the possibility of innovation in the renewable energy sector. High regulatory uncertainty affects managers' ability to assess risk and opportunities thereby affect their ability to make the trade-offs necessary for investment in new technologies (Marcus, 1981). The fields of biotechnology, nanotechnology, and medical technology is especially affected by this type of regulatory uncertainty (Fleurke and Somsen, 2011).

Social and political uncertainty also create significant impact on the innovation process. Innovation process takes place in interaction among various actors such as business firms, individuals, and public and private institutions (Edquist and Hommen, 1999; Lundvall, 2007). The purpose of engaging in interaction with others is to gain access to different types of resources (technological, financial, immaterial) which are necessary for undertaking resource recombination activities, and to gain insider-ship in a foreign market to escape institutional uncertainty (Håkansson, et al., 2009). However, not always collaborating partners are willing to share resources such as intellectual property (IP) rights (Spencer, 2003) unless there is a great deal of trust among the actors. Unless rtsut is well established actors fear the loss of IP rights in the hand of opportunistic actors. Trust plays an important role in exchange relationship (Morgan and Hunt, 1994; Nooteboom, Berger and Noorderhaven, 1997; Das and Teng, 1998; Madhok, 2006). Institutional bodies like public and private funding agencies may not provide firms financial resources necessary for innovation (Kline and Rosenberg, 1986; Van de Ven et al., 1999; Gompers and Lerner, 2001; Powell et al., 2002; Håkansson and Waluszewski, 2002; Tidd and Besant, 2009; Muller, 2013; O'Sullivan, 2013). Under such circumstances, actors experience social and political uncertainty (e.g., Milliken, 1987; Holmen, 2001; McMullen and Sheferd, 2006; Ortt and Smits, 2006; Jalonen, 2011; Håkansson and Olsen, 2012; Luthfa, 2017).

One type of uncertainty leads to other types of uncertainties if not handled efficiently and timely. For example, regulatory uncertainty can block necessary technological, material, non-material (knowledge) and financial resource flows among actors thus can affect the resource recombination activities and finally can delay the production, introduction, and diffusion of a product to the market. Thus, regulatory uncertainty can lead to acceptance/legitimate and commercial uncertainty (Prieger, 2007; Jalonen, 2011; Luthfa, 2017). Resource constraints make the transformation of an invention into innovation difficult (Kline and Rosenberg, 1986; Van de Ven et al., 1999; Gompers and Lerner, 2001; Powell and Grodal, 2005). Such uncertainties can create cognitive inertia among managers (Porac and Thomas, 1990; Eisenberg, 1995) leading to response uncertainty (McMullen and Shepherd, 2006). Under the condition of response uncer-

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tainty, one cannot calculate how to respond to a situation which is different from their anticipated reality.

2.3 Sources of uncertainties in the innovation process

One of the main sources of uncertainty is managers' lack of knowledge about the innovation process (Jalonen, 2011) that is how to recombine resources. Since novelty implies something new or significantly improved from the already available one, managers may not necessarily have complete information about how to recombine the resources or which resource recombination may bring the desired output. Under the condition of limited information, actors (hence, managers) experience cognitive limitation (Eisenberg, 1995); not knowing what to do or how to do. According to Eisenberg (1995) a cognitively limited actor is unduly optimistic; therefore, she tends to overlook necessary information to deal with a situation yet justifies her decisions or actions as rational under that condition. If managers overlook necessary information during the innovation process that may cause technological uncertainty by creating difficulties during resource recombination and eventually may lead to further uncertainties along the process.

Some other studies (e.g., Baraldi, et al., 2001; Fonseca, 2001; Håkansson and Waluszewski, 2002; Nerkar and Shane, 2003; Waluszewski, 2004; Baraldi and Strömsten, 2006; Hoholm and Olsen, 2012; Alexis, 2014) indicated that a possible source of uncertainty is the resources' own conflicting properties. Resources (for example, raw materials, machinery, knowledge) are heterogeneous (Penrose, 1959). When heterogeneous resources are combined they can create resistance to one another during integration. For example, if different types of components with different configurations are integrated they may create resistance to one another or when new views are incorporated traditional practices may create resistance and managers may find it difficult to come to consensus about how to handle the process. Due to resistance in resource combination it is possible that a great deal of friction will occur when new resources will be integrated in an existing resource base (Waluszewski, 2004). However, it is not known to what extent the frictions, tensions, or resistance encountered during the resource combination will stabilizes or destabilizes the resource bases and thus will affect efficient linking of later activities in the innovation process. According to Waluszewski (2004) the outcome of the resource recombination is "never given". Despite the indication that uncertainty in the innovation process may arise from the conflicting properties of resources and their combination, it is not substantiated in the existing research. According to some authors, a resource-recombination perspective needs more attention for a better understanding of the innovation process as well as to know if they have any impact on the emergence of uncertainties in the innovation process (e.g., Arthur, 2007; Petruzzelli and Savino, 2014).

Since activities constitute the basis of the innovation process (cf. Rogers, 1967; Richardson, 1972), logically unsuccessful coordination of the activities may give rise to uncertainties. According to Dubois (1994) every activity undertaken and coordinated in a process produces an output, which is used as an input for the next activity in the same process. In a process a future activity is dependent on the outcome produced from the previous activity (Thompson, 1967; Lundgren, 1995; Dubois, 1994; Håkansson et al., 2009; Bankvall, 2011). However, Dubois does not explain what happens in the activity chain in a process if an activity fails to produce a desirable outcome. Since activities are path dependent (Arthur, 1994; Lundgren, 1995; David, 2000; Sydow, et al., 2009) it is logical to argue that a single error in one activity in a process may lead to errors in ensuing activities in the same process. A failure in an activity may therefore hinders the production of the desirable outcome, unless an alternative path of activities can be created, or the iteration of a previously failed activity can produce a promising outcome. However, to what extent path-dependency of activities can create uncertainties in the innovation process is insufficiently considered in the literature.

2.4 How uncertainty emerges in the innovation process – what has been discussed in the literature and what needs further attention

Emergence of uncertainty is not a one-time phenomenon but rather it manifests itself or emerges throughout the innovation process over time (Fleming, 2001; Lenfle and Loch, 2010; Jalonen, 2011; Håkansson and Olsen, 2012; Rehn and Lindahl, 2012). Therefore, understanding of how uncertainties emerge in the innovation process lies in our understanding of how the process unfolds over time.

As defined earlier, innovation process entails some interconnected resource recombination activities over time (Schumpeter, 1934; Rogers, 1967; Richardson, 1972; Dubois, 1994; Rescher, 2000). However, the activities are not independent of the actors who undertake them (Rip, 2012) just as our actions are not independent of us (Luthfa, 2017). According to Rip (2012; p. 160) "actors and activities are mutually dependent". The activities are also not independent of the resources because one cannot undertake the resource recombination activities without the resources (Håkansson, 1987). According to Schumpeter (1934), resources are the central element for the novelty creation. The resources contribute to the creation of new resources as well as to the creation of novelties when they are combined through undertaking specific activities (Waluszewski, 2004). Furthermore, resources are not independent of the actors who control them and exploit them through undertaking the activities (Håkansson, 1987). The actors interact with other actors in a network context to gain control of the resources and to be able to exploit or recombine them through interactions (Drucker, 1985; Powell et. al., 1996; Etzkowitz and Leydesdorff, 2000; Pittaway et al., 2004; Lundvall and Nielsen, 2007; Håkansson et al. 2009; Tsai, 2009; Antikainen, Mäkipää, and Ahonen, 2010; Aune and Gressetvold, 2011; Perks and Moxey, 2011; Håkansson and Olsen, 2012). Thus, just as much the activities are inseparable for the actors who undertake them, resources are also inseparable from the actors who control and exploit them (Håkansson, 1987). This makes activities and resources as well as actors and resources mutually dependent. Therefore, to create knowledge about the innovation process it is important to consider the interrelation and interaction among the actors who undertake the resource recombination activities in a network context, activities which are undertaken by the actors who control and recombine the resources and the resources which are recombined for novelty creation by those actors.

Then again, due to mutual dependency among the actors, activities, and resources, the courses of action in an innovation process are affected not only by the actors who undertake or control them but also by the successful or unsuccessful activities of integrating and transforming the necessary resources into novelty. Furthermore, Rip argues (2012, p.158) innovation process is part of larger processes, and are entangled with organizations in a network, other technologies, sector dynamics, and societal responses. Due to the entanglement of different actors in a network context as well as their different levels of interactions for resources to undertake the activities, new events emerge continuously in the process. Emergence of new events lead to creation of new paths (new sequences of activities) as well as to creation of new actors (Lundvall, 1995) and new levels of interactions among them (Rescher, 2000; Rip, 2012). Due to so many different levels of interactions it becomes difficult for a single actor to control, steer, or plan the innovation process in advance (Lenfle and Loch, 2010; Håkansson and Olsen, 2012) that is, lead actors to uncertainty.

So far innovation processes have been studied either from the perspective of activities (for example, Bush, 1945; Anthony and Day, 1952; Maclaurin, 1955; Ruttan, 1959; Rogers, 1967; Kline and Rosenberg, 1986; Rothwell and Dodgson, 1992; Hobday, 2005; Godin, 2006) or from the perspective of actors (Etzkowitz and Leydesdorff, 2000; Edquist, 2005; Hobday, 2005; Lundvall, 2007) or from the perspective of resources (Fonseca, 2001; Petruzzelli and Savino, 2014) however not from an integrated perspective. This paper offers to create knowledge of the innovation process and how uncertainties emerge in the process by integrating these three different perspectives.

Håkansson's (1987) ARA model (Actor-Resource-Activity model) model illustrates the different layers of complexity involved in the interactive process of business among actors, resources and activities, thereby highlighting the complexities involved in the interactive process like innovation. However, the ARA model cannot explain how exchanged resources among the actors are utilized for production such as transformed from one form to another in a chain of transformation. The ARA model thus cannot explain how novelty is created in an innovation process. Dubois' (1994) "the end-product related activity structure model" complements the ARA model by illustrating how sequence of activities take place in a process, how outputs are produced from the activities and how the final outcome is produced at the end of the process. According to Dubois' model, output from an activity creates the basis for linking and coordinating the next activity in the chain. Thus, this model has great potential to create knowledge of how novelty is created at the end of a sequence of activities, which represent the innovation process. However, both the ARA model and the end-product related activity structure model assume that resources are available, if not available in house, from network of partners for undertaking activities when several studies showed the opposite result (e.g. Van de Ven et al., 1999; Holmen, 2001, Spencer, 2003; Ortt and Smits, 2006; Chaturvedi, et al., 2009; Muller, 2013). Both models are limited in explaining the consequences of resource unavailability on the activity undertaking thus are limited in explaining uncertainty in the process. The limitation in these two models can be complemented by integrating the project management literature (the Critical Chain Concept) which has the potential to explain how the activities can or cannot be undertaken in the innovation project if resources are not available (Goldratt, 1997). According to Goldratt (1997, p. 89) when resources are not available activity chain breaks in a process. Logically, if activity chain breaks actors may experience uncertainty. The project management literature can also be applied since the innovation process is often regulated under specific projects where numerous activities are undertaken sequentially over time and number of actors are involved. Accordingly, in the following section a conceptual model has been developed by integrating the ARA model, the end product related activity structure model and the theory of constraints to study how innovation process unfolds over time and at the same time to understand how uncertainties emerge in the innovation process.

3 Theoretical model

The conceptual model has been developed in this paper by integrating three models: the ARA model (Håkansson, 1987) and the end-product related activity structure model (Dubois, 1994) of the IMP school (Industrial Marketing and Purchasing) of the Uppsala University and the theory of constraints (Goldratt, 1997). The resulting model is called the uncertainty-embedded innovation process model (see figure 1).

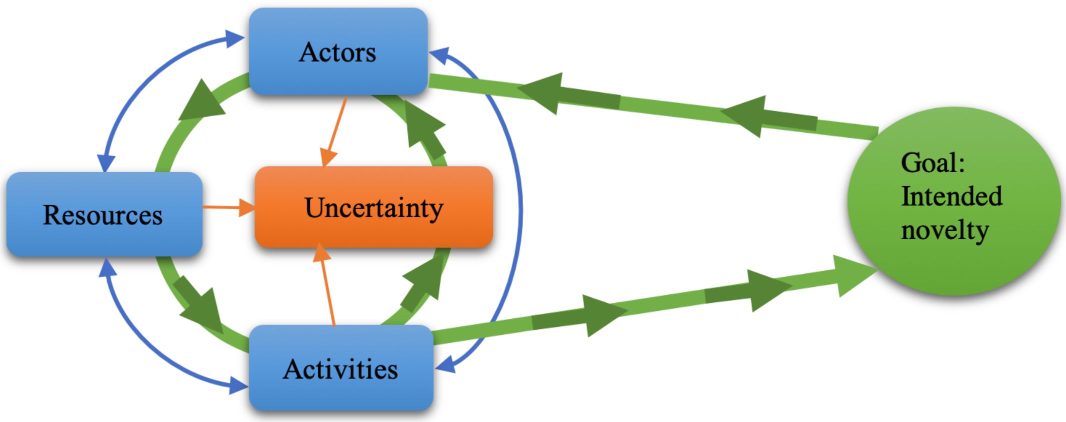

Fig. 1. The uncertainty-embedded innovation process model (Author's own)

The model (figure 1) depicts how an innovation process progresses over time in continuous interaction among actors, activities, and resources and the goal. The green arrows and path represent the interaction among actors, activities, and resources and the goal. The innovation process begins with an idea of creating a novelty (Rogers, 1983) which is represented by the goal in this model. The goal can be generated in the market by users' demand, or by the policy developed by the policy makers, or from the outcome of a scientific discovery (cf. Cyert and March, 1963; Rogers, 1983; Lundgren, 1995; Ingemansson, 2010). The goal guides the choices of resources, their combination, development of relationship with other actors and activities like research and development, production, commercialization, and diffusion (Rogers, 1967, 1983). The same goal limits the choices of resources, actors' activities and relationship with others (cf. Cyert and March, 1963; Gollwitzer and Moskowitz, 1996). However, due to entanglement of different actors in the innovation process (Drucker, 1985; Powell et. al., 1996; Etzkowitz and Leydesdorff, 2000; Pittaway et al., 2004; Lundvall and Nielsen, 2007; Håkansson and Olsen, 2012) and under the condition of limited information and knowledge (Knight, 1921; Reddy, 1996; Lenfle and Loch, 2010; Jalonen, 2011), no single actor can steer the innovation process as planned (Lenfle and Loch, 2010; Håkansson and Olsen, 2012). As the process advances over time, new events emerge in the innovation process; new resource combination takes place, new combining activities are undertaken, and new sources of resources appear which then shapes up the goal depending on the changes created from the previous interactions (cf. Rescher, 2000). An innovation process unfolds through dynamic interaction between the outcome of the process and the "holy trinity of a network" (Lundgren, 1995, p.93), i.e. the actors, activities, and resources as well as the reciprocity among them. In figure 1, reciprocity among the actors, resource and activities is represented by the blue double-sided arrows among the aspects.

Reciprocity among the three aspects, the actors, resources and activities, makes them self-reinforcing as well as make them affect each other in a negative manner in a cycle of cause and effect relationship. Any unconducive condition in any of these elements creates a negative impact on the other. For example, if actors fail to carry out an activity the failure may affect the outcome, which in turn may affect the linking of further activities in the chain. If an actor cannot explain the unconducive condition, based on its previous knowledge and experience of similar conditions, it cannot possibly fix the broken chain. Under such condition actors will experience uncertainty (cf. Knight, 1921). The orange arrows in the figure 1 show how uncertainty emerges as an outcome of the interaction among actors, activities, and resources. In the following, there is a list of some conditions when uncertainty may emerge in the innovation process:

1. Actors' are limited in cognition due to lack of knowledge of the detail of the technology, or due to undue optimism of having enough knowledge or information to deal with a problem therefore ignoring important information (Eisenberg, 1995). Actors limited cognition leads to uncertainty in the process as that hinders them from engaging the appropriate resources for undertaking the recombination activities.
2. Actors have conflicting expectations, and strategies for reaching the same goal (Cyert and March, 1963; Håkansson an Olsen, 2012). Their differences can evolve over time along with the changes of demands for resources and nature of activities they are undertaking together (Lundgren, 1995). If the differences sustain the process can proceed towards a different trajectory (cf. Rescher, 2000) than anticipated due to path dependency (Arthur, 2000). Differences can also lead to conflict, leading to breaching of trust (Morgan and Hunt, 1994; Nooteboom, Berger and Noorderhaven, 1997; Das and Teng, 1998; Madhok, 2006) and termination of relationships (cf. Izushi, 1997; Coles, 2003), thereby disrupt the resource flows among the partners and undertaking of the activities.
3. Resources are not always available either due to focal actors' inability to produce them, unwillingness of other actors to exchange necessary resources, by any institutional restriction, by the unsuccessful combination of differential and conflicting resources from previously undertaken activities (Goldratt, 1997; Fonseca, 2001; Gadde and Håkansson, 2001; Spencer, 2003; Håkansson and Walusewski, 2002; Waluszewski, 2004; Chaturvedi, et al., 2009; Hoholm and Olsen, 2012; Muller, 2013; Petruzzelli and Savino, 2014). Due to resource unavailability the linking of activities may become uncertain and eventually a condition called inertia can appear in the activity sequence (Goldratt, 1997).
4. Activities are path dependent (Lundgren, 1995). A firm's allocative decision made in the past limits and/or enable its decision in the present (Arthur, 1994; David, 2000; Sydow et al., 2009). An outcome of previously undertaken activities determines future activities, resources which are to be utilized and relationship which are to be nurtured. If the outcome is desirable the process may proceed smoothly, but if not, it may change an actor's courses

of action that the one anticipated as well as can bring inertia in the process (Goldratt, 1997).

To sum up, uncertainty emerges in the innovation process under the aforementioned conditions prevailing in actors, activities, and resources.

4 Methodology

The unit of the analysis in this study is the innovation process - sequence of activities, and how they were undertaken and coordinated over time to produce a novelty. Study of the innovation process will also enable us to learn about how and why activities are not undertaken and linked that is, anomalies in the activity undertaking can tell us about the uncertainties under which activities could not be undertaken. The focus was given to the evidences which would tell about the various resource recombination activities performed and not performed, how the partner firms made resources available or were not willing to exchange resources and why, how the partners enabled and hinder activity undertaking of the focal firm and why, challenge regarding access to resources and how the actors solved those problems, and their roles in the process. A series of inquiry was performed, one leading to another until a coherent picture of the innovation process could be portrayed. Accordingly, number of people have been interviewed who were involved both directly and indirectly in undertaking different types of activities in the innovation process.

Innovation process unfolds over time. Therefore, to create knowledge of the innovation process it is important to tell a story in sequence of events. However, the sequence of events does not take place in a linear form but rather takes place in complex manner as the innovation process involves complex interaction among multiple actors, number of activities and various resources (Powell, et al., 1996; Edquist and Hommen, 1999; Pittaway, et al., 2004; Perks and Moxey, 2011). Among many of the benefits, a qualitative study offers the possibility of unfolding complex events over time through an in-depth narration (Kinnear and Taylor, 1996; Van de Ven and Poole, 2005; Marschan-Piekkarri and Welch, 2005; Silverman, 2013; Yin, 2014).

Initially, the theoretical understanding of the innovation process was not clear as a result the reality that has been encountered during data collection did not match with the theoretical map that has been developed from the existing theories. According to Easton (2000) this is often the reality that what we encounter do not always fit our mental map developed from our previous knowledge. Therefore, to develop new insight researchers need to move between the theory and reality over time in attempt to reduce the gap through several encounters. This approach is called the "systematic combining" (Dubois and Gadde, 2000). For facilitating the systematic combining approach, a case study has been designed which enables several encounters with the reality through intensive enquiry thereby enable refining the theoretical understanding gradually (Easton, 2010). The advantage of applying the case study is that when a gap is experienced between what one knows of the reality and the reality out there, one can go back to find answers to what happened the way it did over time through several encounters by returning for interviews. Another reason for choosing case study was its ability to deal with variety of data (Piekkari, et al., 2009) gathered from various sources, such as documents, artefacts, interviews, observations (Yin, 2014) thus could enable data triangulation (Yin, 2014).

Two case firms were selected from two different industries from two different countries with opposite economic conditions, business culture and institutional contexts. One company belongs to the industrial manufacturing industry and the other to the agricultural/biotechnology sector. The companies differ greatly in their product characteristics, production methods and contexts as well as demand different resources, actor involvement and nature of activities to perform innovation process. Furthermore, the companies were chosen from two countries from two different continents with opposite economic and political conditions, infrastructure, in hope of gaining interesting insight into the process. The underlying reason for choosing two disparate companies instead of two similar companies was that their differences would provide interesting insights into the innovation process, as they were more likely to exhibit different innovation process patterns, giving rise in different ways to uncertainties, than if they were from the same industry. Eisenhardt (1989) stated "creative insights often arise from the juxtaposition of contradictory or paradoxical evidence ... The process of reconciling these contradictions forces individuals to reframe perceptions into a new gestalt" (p. 546)." Moreover, one of the firms' innovation process exhibited a critical case. Its innovation story originated in a country where it faces high political instability, resource constraints and poor infrastructure. It was expected that the innovation process of this firm would exhibit patterns that would run counter to the existing theories and concepts (Patton, 2014) developed from observing companies in the developed countries thereby would allow the testing and refinement of existing theories (Emmel, 2013). Only two companies were selected as smaller number of cases, even a single case enables a researcher to deeply explore the research phenomenon (Mason, 2010; Easton, 2010; Patton, 2002). Furthermore, only two innovation stories from these two firms have been selected to take advantage of the possibility of detail observation and exploration of the phenomenon (Easton, 2000, Patton, 2014; Emmel, 2013; Yin, 2014) thus to be able to build an in-depth story into the innovation process. The selection criteria for choosing the case companies were that they should be undergoing or have undergone activities of innovation and should come from different contexts that is, they show disparity. The size of the firms was not considered as it was immaterial for fulfilling the purpose of the study. Initially, some companies were contacted from two countries based on their online profile. Companies which showed interest to take part in the process were selected for the data collection. Data collected from only two companies have been selected for the study.

Data were collected during 2013-2016 during the author's PhD research. The main means to collect data was face to face interview. On some occasions data were collected through phone calls and Skype interviews. Additional data, which had technical elements, were collected from scientific articles, PhD thesis, Youtube videos, Wikipedia, online brochure, newspaper articles, and direct observations. Interviewees were selected depending on their roles in the studied innovation processes. From the manufacturing company CEJN, the CEO, construction manager/engineering team, logistic manager, purchase manager, sales manager, assembly workers have been interviewed for their direct involvement in the innovation process. From the biotechnology company, the director of the agri-business, agricultural advisor, post-doctoral researcher, laboratory technician, and a researcher have been interviewed for their direct involvement in the innovation process. The data come from total 30 in-depth interviews, four field observations/factory visits, and email conversation. After each data-collection occasion (interviews) the data were transcribed. In one case the data needed to be translated as well from Bengali to English.

Initially, the data were not collected in the order in which the story has been told in the empirical section. After all the necessary data were collected, the data have been organized from beginning to end, keeping in mind the theoretical construct, to create a coherent picture of the innovation process (interaction among the actors, activities, and resources) and the uncertainties within it. Data have been analysed by applying the "pattern matching logic", where empirical patterns are compared with the conceptual model that the researcher formulated before data collection (Yin, 2014). During the analysis the theoretical model was used to see whether the reality fits to the model or not. When there was a fit, it was considered as a support for the theoretical argument and when there was no fit attempt has been made to explain why this was the case. At first within intra-case data analysis was done, and later a cross case analysis was done to reveal the similarities and differences among the cases to uncover certain patterns useful for refining and developing the theories.

During data collection I have faced some challenges, for example, the case companies did not allow me to interview their partners. As an Industrial Marketing and Purchasing researcher this was unsatisfactory. However, since activity links can also be studied from a single company's perspective (Bankvall, 2011), I collected data on the activities and their internal and external links (with the collaborators) from the case company's perspective. It was not possible to convince the respondents to answer all the questions for confidentiality, so I used the data that were obtainable. The credibility was ensured by sending the draft transcripts to the respondents after data transcription. I attempted to make analytical generalization of the data (Yin, 2014). The new understanding derived from the analysis could be used to reinterpret the cases in other context in the future. However, as researchers vary in their philosophies the same innovation process studied by other researchers in another context may exhibit different result. The study is dependable as the errors and biases have been removed by verifying the data with the respondents. Audit trail comprising raw data are available for inspection.

5 Empirical data

5.1 Case 1: Innovation process of e-Safe by CEJN AB

History behind the e-Safe innovation

When the Swiss government decided to ban the use and import of unsafe couplings in all industrial facilities in the country, followed by an accident in one of the factories in which a worker lost his hearing, the management were forced to bring a safer version of coupling called e-Safe. Although CEJN's engineers were aware that during coupling disconnection factory workers were at risk of injuring their eyes, eardrums, skin, and bones, even risks death, for them these risks were just theoretical, until the accident happened in the customer's facility. According to the construction manager Peter, "the accident was a major turning point for us; we realized something needed to be done . . . we set the objective of creating a safety coupling for our customers". Therefore, CEJN made a quick market survey on customer's expectations of the safety coupling; its features or functions, their willingness to pay for a certain performance, size, and user-friendliness. During this time CEJN also convinced the Swiss authority to let its customers use the general quick coupling following the precautions asked by the government authority, until the safety coupling is developed and ready to be used.

Commencing the project – Setting the objectives and Building the team

In the head office the management set up an engineering team comprising of mechanical engineers, product designers and developers to commence the project. The management was very optimistic about the team's credibility therefore they felt no need to engage any external consultants. Peter, the construction manager said, "In teams, we consulted about the different parts of the general coupling, how they function, and specified mechanical difficulties of disconnection". A general coupling has two main parts, considered as a female and a male part, each part is connected to two different hoses or pipes or one hose and one piece of [hydraulic] equipment such as a blow gun. The two parts are connected through a latch. In a general coupling the latch lets the two parts separate from each other without much effort. The problem occurs when the male and female part disconnect from each other without much effort and their disconnection let high air/fluid pressure come out of the pipes abruptly as a result the pipes fly out of the hands of the workers. According to the CEO, "To prevent accidents we planned to develop e-Safe where male and female parts will be disconnected slowly. We decided to increase control over the latch by adding additional metal slots. A controlled latch would allow a slower disconnection of the male and the female parts from one another and in this manner would prevent kickback that causes the hoses to fly out of the workers' hands".

Delegating the tasks, and Discussing the options

Different groups were assigned to bring different designs. Evaluation of all the designs showed that integration of new and modified parts entailed changes in the exterior of the coupling, leading to increased weight and development cost. There was nothing more the team could do to prevent this change. According to the construction manager, Peter, "we wanted to hold the male part inside the female part for few more seconds before releasing it completely, and to do that we needed to add more components .... Our engineers suggested different configurations, all of which were good ... these would require a lot of work, a lot of adjustments of various components...we have to be rational ....we could not expect to make a major change for a simple fix in a simple function.....moreover, time was not in our favour...we knew we had to return to the market before someone else did."

Facing the dilemma and making compromise

Based on the chosen design among many others different parts were modified and a new part was developed. Some standardised activities were undertaken such as metals were cut, moulded in certain shapes, machined to produce the void inside the couplings and heat treated at extreme high and low temperatures for hardening, strengthening, and tempering and later on all parts were assembled. As anticipated the integration of the new and modified parts enhanced the size of the exterior and reduced the size of the interior however, the team did not expect that would reduce air flow inside the hoses. Safety assurance came at the cost of reduced performance. Although the solution was feasible in the eye of the engineers the customers were not very satisfied with the solution. Their dissatisfaction was reflected through their purchase decision According to the construction manager, "We had to consider the customers' expectations as well as the ban imposed by the Swiss government and the possible threat by our competitors . . . we chose the option that in our opinion was the best in terms of safety, performance, cost effectiveness, and use-friendliness. To ensure the functionality that we wanted we had to forgo the space inside the coupling . . . we had to compromise. . . . The safety coupling was worse than the one we had before in terms of price, weight and performance but we achieved what we aimed for."

Restarting the project for a sustainable solution –Lack of access to the desirable technology and inertia in the process

After a while, the management realized that they needed to bring a sustainable solution because customers are not entirely satisfied with the new coupling. CEJN employed some new engineers who may have new insight into the matter. The new team noted that the safety coupling incorporated two components which need to be reduced into one to create space internally and to reduce the exterior. The team found out that there is a patented locking latch technology in the market which could be of use. However, the inventor, named Björn, refused CEJN's request. Peter said, "Having no access to the key technology we decided to ask our strategic suppliers to develop a locking latch for us but our suppliers lacked the Metal Injection Moulding technology (MIM) which is needed to build that latch. We also tried to find a similar technology in other parts of the world, but all efforts went in vain. We felt that we could not really go any further with the process. It was, somehow, a bit of vacuum without the right technology."

Breaking the inertia – Access to the desirable technology and knowledge

In 2010, Björn sold his patent to CEJN, when he could no longer run his small business. He showed willingness to help CEJN's team developing the safety coupling. Björn initially took part in the technology transfer process. During the first few meeting he showed the team how the key technology (locking latch) functions so that the team could integrate the latch properly in the existing coupling. There was not complete match of his latch with the current design so with much discussion and several attempts of trial and error along with Björn the team came up with an improved design of the new coupling called e-Safe. Major changes were made in the different body parts. After the prototype development in the warehouse the management decided to go for mass production of the latch by applying the MIM technology. They contacted a well reputed Chinese supplier who is skilled at using this technology.

Latch development in collaboration with the Chinese supplier – Exchanging knowledge, repetitive failure, and compromises

The team sent the design and the technical description of the latch to the supplier; dimension of the latch, needed harness of the materials, and the drawing. The team of CEJN and the supplier team had some discussions about the procedure, learn from each other about the safety coupling and the MIM technology. However, latch development took around 20 trials and errors before accepted by the team CEJN. Every time latches were developed as per the designs and measurement, they cracked under high air pressure. None of the team could understand what was wrong. The process was time consuming and not cost efficient. Peter said, "After a while, we realized that the supplier needed to see the complete design of the coupling so that they could have a complete understanding of the coupling. We had initially feared losing the IP but as the time was running out, this worry abated; the priority was to bring a solution to the Swiss market as quickly as possible. We felt that there was an information gap between us and the supplier.

Although we were sceptical about revealing the whole design for fear of losing we realized that it was the right thing to do at that time". After getting access to the full design the supplier could see what was causing the problem accordingly, could solve the problem with little adjustment. Finally, after six months the new latch could be integrated in the existing general coupling in the main facility in Sweden. The customer is satisfied today. According to the CEO, "In the end, the final product design resulted from cooperation between the engineering team here and that of the supplier. Although the coupling now costs more, it is worth it".

5.2 Case 2: Innovation process of Salinity Resistant High Yielding Wheat Seeds by ACI Ltd. Bangladesh

History behind the Salinity Resistant High Yielding Wheat Seeds innovation

The initiative of developing this salinity resistant high yielding wheat variety (SRHYWS) was taken by the biotechnology and the agricultural division of a Bangladeshi company in 2012 in response to the government's "Food for all" policy and farmers' growing interest in cultivating staple food crop varieties. Although the country's agricultural researchers had long-term aspiration to solve the food insecurity problem but could not do much for a long time due to bureaucratic red tapes which hindered transferring of advanced technology from the developed countries for development of such seeds. According to the Executive director of the Agricultural business, "when the government encouraged such initiative, especially encouraged private companies to join in wheat research ACI Ltd. joined the race". Among all other crop varieties, the special focus was on wheat production because this crop has previously been paid less attention by farmers, despite its food value and potential to increase food security.

Commencing the project – Setting the objectives and Building the team

As an initial action to develop SRHYWS, ACI met with the countries' leading researchers in this area to decide on the technique they should use to develop this variety. Usually there are two ways to develop such seeds such as by using the chemical ethyl methane sulfonate (EMS) and gamma radiation. Researchers applied these methods earlier during 1974-76 and developed a stress tolerant wheat seeds called BARI Gom 25. This time the researchers wanted to develop a wheat variety by exploring the gene that carries the specific trait of salinity resistance, concentrating on that specific trait without disturbing the other genes through random radiation or chemical treatment. According to the advisor, "We needed to acquire knowledge of genetics of from experts to create newer genetic variation. So, I recommended ACI to collaborate with researchers from the developed countries." Accordingly, they contacted a professor at Lund University, Sweden, who applied a technique called the TILLING technique which is applied on crops for genetic modification through mutation.

Delegating the tasks and Discussing the options

In April 2012 ACI invited the professor and his team in Bangladesh. They visited the company, some public institutions, laboratory facilities in Bangladesh to get an idea about their potential collaborator. The team of the experts then discussed about how to start working on the project, how to look for funding for the project, how to write a proposal for funding, research strategy, long and short-term goals, milestones, technology transfer, human resources, accordingly signed an agreement. Both parties decided to share the expenditure of research and development in their respective countries accordingly signed an agreement. The parties also agreed to plant and harvest wheat during Swedish summer and Bangladeshi winter when the temperature is similar, to enhance the speed of the development process. However, since the Swedish professors lacked funding, ACI Ltd. agreed to help the professors to develop a strong funding application so that funding can be obtained from Swedish Research Council. In the meanwhile, Swedish team formally established a company OlsAro Crop Biotech AB and applied for funding with the help of the researchers in ACI Ltd. The goal of acquiring funding was to undertake the activities in Sweden, provide training to some researchers from ACI so that they can handle the activities efficiently, and have researcher exchange in between the countries.

Beginning the actual R&D work – Access to the key technology

For the initiation of the project BARI Gom 25 was selected as the base variety because of its ability to resist stress to a certain extent. The first batch of seeds were called M1 variety and were treated with the chemical agent EMS using the TILLING technique in the Lund University laboratory in 2012. Theoretically, after treatment, the cells of the seeds will be mutated at DNA level and over time the seeds will exhibit the change through their production of crops. After the first EMS treatment the seeds were planted in the laboratory, crops were grown, harvested, seeds were collected, data on the seeds were gathered and sent to ACI to produce the third generation (M2 generation seeds). In ACI, the seeds were then planted, harvested, and seeds (M3 generation seeds) were collected following the same procedure that was undertaken in Sweden. With mutual consent 60 to 70 percent seeds were sent back to Sweden for next generation production (for M4 generation). While the process was still running smoothly OlsAro decided to test the seeds in an outdoor field by renting a land from a farmer's cooperative in Malmö without the consensus with ACI.

Conflict among the parties on the way to handle the activities

ACI was not happy with the decision to plant the seeds in the field since the Swedish collaborators lacked funding and human resource to support the production and monitoring in the field. The advisor said, "We were confident in the expertise of the researchers, trusted them, there was no reason to doubt their knowledge in this field, therefore, no necessity to discuss anything in detail about the process however, we expected them to inform us about this decision". In 2014 summer, the agricultural advisor of ACI visited Sweden to discuss the project's progress and he became highly dissatisfied when he found considerable amount of damages in the plants caused by birds/rabbits, and/or hares. His dissatisfaction increased when OlsAro asked for money from ACI for the field test, which was initially agreed to be carried out by the Swedish team. The advisor said, "Despite a great deal of dissatisfaction, we agreed to pay for the field test since it could not carry out the process on its own".

Government restriction on resource transfer, breaching of trust and uncompromising actors

When ACI agreed to transfer the money, it was restricted by the government policy in Bangladesh. According to the advisor, "It usually takes a long time to transfer money from Bangladesh to a foreign country. Government does not allow transfer over a certain amount of currency to other country." Due to the delay in transferring money from Bangladesh OlsAro denied sending M4 generation seeds to Bangladesh as a result ACI missed one planting season for six months.

The tension was high between the parties at this time; ACI became sceptical about OlsAro's commitment and OlsAro losts its trust on ACI. After a while the communication had stopped completely and today the two companies are running R&D in their respective countries. However, ACI was finally able to pay half of the research cost in Sweden as promised but they did not receive the seeds.

Re-evaluating alternatives, restarting the project, involvement of the local actors and compromised goal

After skipping a season, ACI decided to use the older generation seeds (M2 seeds) which they had in their laboratory. With much scepticism, due to lack of expertise, ACI started the project again. According to the advisor, "We engaged some local researchers to undertake the activities in the laboratory. They planted the seeds, harvested the crops, and collected a new generation seeds called M3. We sought for expert helps from the public research institutes and with the help of a public university (BAMRAU) we planted M3 generation seeds in the field. We ran further experiment in our green house by planting these seeds under high saline condition. We failed to get high salinity resistant seeds, but we found 17 lines of healthy green plants with much higher yields than those conducted before following the routine activities. Finally, we decided to go on pursuing high yield, since it as one of the properties the Bangladeshi government asked for. However, we have not yet given up hope of finding a salinity-resistant wheat, it may take a longer time... wish we could maintain the collaboration with the Swedish researchers, we could have found that trait in the wheat too."

6 Analysis

6.1 Innovation of e-Safe

Conditions under which uncertainty emerged during the first attempt to produce e-Safe

During the first attempt to create the new safety coupling uncertainties manifested themselves due to (1) *complexities of the physical resource configuration* (i.e. interconnectedness), (2) *the unavailability of an important component* or resources and (3) *the actors' lack of knowledge* of how to address the complexities.

1. The evidence from the safety coupling development reflects the existing theoretical explanations (cf. Baraldi, 2001; Fonseca, 2001; Håkansson and Waluszewski, 2002, Waluszewski, 2004; Petruzelli and Savino, 2014) which suggest that uncertainty can arise when an existing resource combination creates resistance against a new resource, with its internal resource interdependencies or interconnectedness. Such uncertainty could be resolved by recreating the interdependencies in the existing resource combination, however, CEJN's engineers did not have that knowledge.
2. During reconfiguration engineers failed to reduce the size of the exterior and increase the interior. That is, absence of the right type of latch led to some failed activities, although attempted. Data furthermore showed that due to lack of the right kind of latch, engineers

had to forgo the expectation of fixing the air flow performance in the coupling, that is, they had to forgo the expectation of undertaking a certain activity relevant for the innovation of the e-Safe. This created uncertainty by creating a void in the activity chain.

3. Their lack of knowledge (resource) led to lack of understanding of what activities to undertake and how to recreate the interdependency. Thus, the three conditions affect one another and create conducive environment for uncertainty emergence. However, data shows that the engineers did not acknowledge their knowledge deficiency or cognitive limitation because they were unduly optimistic about producing the desirable coupling on their own. Undue optimism can make actors reluctant to search for alternative information or encourage actors to rationally ignore the chances of discovering new knowledge for decision making (Eisenberg, 1995).

Outcome from the conditions causing uncertainties in the innovation process and what existing theories can or cannot explain

An activity void was created in the activity chain when a necessary resource was missing. According to the ARA model and the end product related activity structure model, resources activate activities (Håkansson, 1987); logically the unavailability of the resource/s hinders the activation of the activities. However, the IMP theorists do not explain what happens in the activity sequence in a process when resources are not available, as the basis of their theory indicates that resources are always available, even if not in house, at least through business relationship (Håkansson and Snehota, 1995). Here, the data questions the basic assumption of the ARA model and the activity structure model. For example, data show that due to absence of the desirable locking latch (resource) engineers could not reconfigure (activity) the coupling the way they expected.

Then again, according to the concept of path dependency (Arthur, 1994; David, 2000, Sydow, et al., 2009) one can expect that a void in the activity chain, that is, an absence of an activity [undertaking] should stop undertaking of the next activity in the chain. Data showed that when a void was created in a specific area in the activity chain, other activities in the process did not stop taking place. Here the data defy the path dependency concept. This result can be explained by Dubois (1994) "the end product related activity structure model" which shows that an activity chain in a process can be composed of different complementary and parallel layers of activity chains (Dubois, 1994). Data show that when an activity void occurred in an area of an activity chain, engineers decided to compromise that specific area of the activity chain (hence, the void) and continue with other activities which can be complementary to the activity which created the void. Their decision led the process to concentrate on other activity undertaking thus forced the process towards a different trajectory producing a different outcome than expected. Here the data follow the path dependency concept where it argues that a change in previously undertaken activities in a process can force the process into different trajectory (Arthur, 1994; David, 2000, Sydow, et al., 2009). Then again, the decision to compromise the void instead of filling it up with trial and error led to further uncertainties when the customers did not prefer the outcome.

Conditions under which uncertainty emerged during the second attempt to produce e-Safe

During the second attempt to create the new safety coupling (e-Safe) uncertainties manifested because of (1) the *unavailability of the key technology (resource)* caused by another *actor's unwillingness* to sell the key technology and (2) the *unavailability of the key technology (resource)* caused by *failed attempt to create key resource.*

1. Several studies demonstrate that a key cause of resource unavailability in the innovation process is linked to IP rights and actor's preferences not to cede patent to others (Chaturvedi, et al., 2009; Eveleens, 2010). CEJN acted on its best judgment (rationally considered) to maximize its own utility (by not showing the IP) but that action was in fact irrational because it created cognitive limitation in supplier by limiting necessary information and knowledge (Eisenberg, 1995). Thus, a certain activity undertaken by an actor can create cognitive limitation in another actor thus can affect the latter's ability to undertake important activities.
2. Data also showed that resource void was created from the failed output (resource) from the repeatedly failed planned activities under well-established method. The Chinese supplier was trying to develop the latch according to the specifications provided by CEJN by applying the MIM technology, with all the necessary materials (resources) in house, and design of the coupling (resources) yet the supplier failed to produce the desired component around 20 times. Inaccessibility to certain parts of the information (design) hindered the supplier from comprehending the complete measurement of the coupling as a result hinders them from developing the latch on time.

Outcome from the conditions causing uncertainties in the innovation process and what existing theories can or cannot explain

Trust played significant role on actors' willingness to exchange information and different types of resources in this case (Håkansson and Snehota, 1995; Madhok, 2006). The data shows that at the end after several failures CEJN realized that they had no choice but to trust the supplier with the complete design of the coupling. This implies that dependency or vulnerability for resources may promote trust development among actors (Luthfa, 2011). In this case CEJN's decision to extend trust was made rationally as CEJN was vulnerable in the relationship. Furthermore, we see that at the end the engineers did not compromise the void in the activity chain instead they continued to fill the void with repeated activities (trials and errors) until they could reach the desirable latch. The engineers here followed the planned activity chain and the goal. It shows that in the second phase of the development of the e-Safe the team followed a linear activity chain to develop a novelty that is the team did not try other routes to reach the output by making compromises in the process. As a result, we see that the process reached the outcome without deviation from the expected goal.

6.2 Innovation of Salinity Resistant High Yielding Wheat Variety seeds – conditions under which uncertainty emerged

Conditions under which uncertainty emerged during the innovation of SRHYWV seeds

Uncertainty emerged in the SRHYWV mainly because of (1) the *differences among the actors about how they should handle the process* based on their best judgment of utility maximization and (2) *resource unavailability* due to actors' unwillingness to share the resources due to breach of trust and (3) *actors' limited cognition* about how to undertake the activities.

1. According to the theory when actors differ in their activity handling, opinions, and expectations (Cyert and March, 1963; Holmen, 2001; Håkansson and Olsen, 2012) their differences can significantly affect their commitment in the relationship by diminishing trust (Morgan and Hunt, 1994; Nooteboom, Berger and Noorderhaven, 1997; Das and Teng, 1998). Data show that there were number of disagreements between the actors in the later phases of the process, for example, where to plant the seeds, who to bear the expenditure, how to handle the process and so on. Although initially ACI trusted their partner therefore were not concerned about how the process was handled by the other later their undue optimism that their partner is acting as planned and expected turned into fear that the partner is being opportunistic when the signed agreement was breached.
2. There disagreements led to conflicts and conflicts led them to not to trust the other. Lack of trust among the partners lead to poor exchange relationship (Madhok, 2006) as well as lead to termination of relationship (cf. Arias, 1995; Izushi, 1997; Coles, et al., 2003). When actors in a relationship feel that the other is opportunistic that hampers proper interactions among them, discourages commitments and trust, and eventually weaken relationship (Wilson and Jantaria, 1998). Data shows that in the later phases they lost trust on each other, they considered their opinion in the matter of production to be rationally driven based on their experiences and education and both acted accordingly without having the consent of the other. Their rational acts led them to termination of the relationship as a result ACI did not get access to the seeds which were to be sent by OlsAro. Without the seeds ACI missed a season and could not continue the process to develop the seed variety.
3. When ACI had to terminate the relationship with OlsAro, they faced deep uncertainty – not knowing how to proceed with the process. Their limitation in cognition came from their lack of knowledge and expertise in the relevant field. Then again, their limited cognition drove them to gain access to other expertise which could enable them to sustain the process with compromised goals.

Outcome from the conditions causing uncertainties in the innovation process and what existing theories can or cannot explain

This result suggests that when both actors are rationally driven in a relationship and therefore not adaptive for the greater benefit the outcome of their interaction can in fact reflects actors' irrational behaviour or cognitive limitations. This result therefore emphasises the importance of being adaptive in partnership (Håkansson and Snehota, 1995; Gummesson, 2002) or being boundedly rational (Simon, 1955) in interaction with others that is being compromising. Furthermore, in SRHYWV innovation, resource unavailability (financial support) was created by the external actor (government) who was not directly involved in the process. The government affected the interaction between the parties with a constraining policy. In this case a void was created in the activity chain for six months by the act of the government which prohibited the exchange of certain resources among the actors (Freeman, 1974; Rogers, 1983; Nelson, 1993; Foster, 2010). Furthermore, we see that although initially the actors did not try to eliminate the void by undertaking other activities in parallel, later they realized that they should continue to undertake the activities they could. The act of compromise in the activity chain reduced the possibility of achieving the goal of producing the salinity resistance seeds.

6.3 Cross case analysis – The conditions under which uncertainties emerged in the innovation process

Resource unavailability/void

The data showed that in both cases uncertainty started because of resource unavailability which again was caused by actors' limited cognition (lack of knowledge and necessary information, undue optimism, rationally justified activities) to develop the necessary resources (Eisenberg, 1995) as well as by failed activities of resource combination. For example, CEJN's engineers did not have the knowledge of developing the hose pipe technology, ACI did not have the knowledge of TILLING techniques. CEJN's engineers were optimistic that they would be able to produce the locking latch without anyone's help therefore ignored the opportunity of getting help from someone (consultant) knowledgeable. ACI was strictly focused on the contract instead of looking at the benefits they could accrue from making somewhat adaptation to their partner's expectations. Resource unavailability was caused by external actor's (state) prohibition to resource exchange in case of SRHYWS. A probable reason is institutional differences among countries, which allowed the external actor to play such role on creating resource unavailability in the process in the case of SRHYWS. On safety coupling innovation the negative effect of the institutional differences was not observed. In the case of e-Safe resource unavailability was caused by conflicting properties of the resources which however is not noticeable in the case of SRHYWS due to the nature of the products.

Activity void/limitation

In both cases it is evident that resource unavailability (void) led to a condition called activity void. In this paper, activity void is considered as a condition when the activity which is necessary for producing novelty does not take place as a result no desirable output is produced. In another word activity void is a condition when possibilities of undertaking the necessary activities are limited due to limited resources and/or actors' limited cognition. Data show that when actors experience resource unavailability they reached the activity void. When they reached activity void they compromised some activities that is instead of undertaking the planned activities they undertook some other activities which could be supported by available resources and existing expertise and knowledge. For example, in the first phase of e-Safe development CEJN let go of the possibility of increasing the interior and reducing the exterior of the coupling since they had no knowledge of how to undertake the necessary adjustment activities. The outcome (the coupling)

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was rejected by the customers and it created uncertainty in the marketing of the coupling. In case of ACI the researchers let go of the possibility of bringing in the salinity resistant properties in the seed as planned and instead they continued to undertake other experiments which they could support with their available resources and expertise. As a result, they had to forgo an important property in the seeds (salinity resistance).

Actor's cognitive limitation and trust in the relationship

In both cases actors' limited cognition played an important role in creating uncertainties in the innovation process. CEJN's cognitive limitation led to lack of understanding of what activities to undertake and how to recreate the interdependency in its first attempt to develop the e-Safe. ACI's cognitive limitation led to lack of understanding and significant uncertainty about how to develop the SRHYWV seeds. In both cases trust was a significant issue behind resource unavailability. However, in case of safety coupling innovation actors' vulnerability lead to extension of trust among them and in case of SRHYWS vulnerability discourages trust development. Thus, data shows that trust among actors plays an important role behind the innovation process. It is presented in the data that when trust was extended by the actors, actors were more willing to exchange important resources which again enabled actors undertaking necessary activities on time in comparison with the situation when actors were not encouraged to extend trust in the relationship. However, trust does not reduce void in the activity chain directly, but it encourages actors to engage in beneficial exchange relationship which in turn enable undertaking of the activities in the process.

To sum up, based on the data one can argue that when an innovator compromises planned activities in an activity void, the innovator needs to accept that the process can move towards a different trajectory as path leads to paths (Arthur, 2000) thereby can increase further uncertainty by producing an undesirable outcome. Here the innovator's dilemma is whether to compromise the activities in the activity chain to reduce the void and continue with parallel activities or to fill up the void by undertaking the planned activities as long as it takes and delay the market penetration.

The following table 1 shows the conditions under which uncertainties emerged in the innovation process. Some of the conditions under which uncertainties emerge placed in the columns. Some of these conditions have been observed in both cases and some have not been observed. The conditions are resource void, actors' limited cognition (lack of knowledge, undue optimism leading towards over confidence, lack of adaptability in the relationship, lack of trust) and activity void. Resource void initially led the activity chain to an activity void, when no activity took place and later led to failed activities and undertaking of unplanned activities as actors compromised their planned activities. Due to compromises made in the activity chain undesirable outcomes were produced which again led to further uncertainties.

The following model, summaries how uncertainty emerged in both cases despite differences in their product characteristics, production method and industrial affiliation. The model shows that in both cases uncertainty emerged in interaction among actors' cognitive limitation, resource void and activity void, each leading the other over time as the process progressed towards reaching the goal.

Table 1. Conditions under which uncertainties emerged in the innovation process of e-Safe and SRHYWV seeds

Conditions causing uncertainties		Safety coupling innovation (e-Safe)	Salinity resistant wheat seed
Resource void	Resource unavailability	Observed	Observed
	Resources' conflicting properties	Observed	Not observed
Actors' limited cognition	Lack of knowledge, expertise	Observed	Observed
	Undue optimism	Observed	Observed
	Lack of adaptability	Not observed	Observed
	Lack of trust	Observed	Observed
Activity void	Failed planned/desirable activities	Observed	Not observed
	Unplanned activities	Observed	Observed

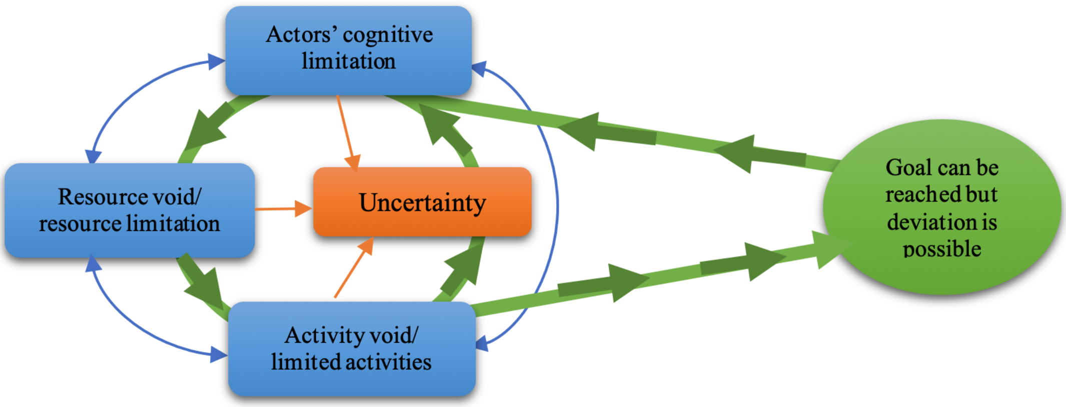

Fig. 2. How uncertainty emerged in the innovation process of e-Safe and SRHYWS (based on the analysis)

7 Conclusion

Uncertainty emerges in the innovation process of e-Safe and SRHYWV seeds because of actors' limited cognition, resource void and activity void, and the interaction among these three interdependent aspects. Actors are limited in cognition because they do not always have access to complete knowledge or information about what kinds of activities to be undertaken or what resources to be utilized, that is, actors always experience a resource void. Yet the actors can be unduly optimistic; considering they have adequate knowledge to handle certain activities. Unduly optimistic actors tend to disregard important information necessary for resource development and create further resource void in the process. When resource void appears due to unavailability of certain resources, the activities which demand those resources cannot be undertaken and coordinated thus, resource void creates activity void in the process and disturbs the activity chain. Alternately, when activity void appears, no desirable resources can be produced to undertake the next activity in the sequence thus activity void creates further resource void. Under such circumstances actors experience further cognitive limitation, as their existing understanding of how to eliminate the resource void by gaining access to the right resources or to eliminate the activity void by means of undertaking the right activities falls short. Actors with limited cognition can act in two ways; (1) they can prefer to be boundedly rational therefore can decide to forgo the expectation of filling up the voids by undertaking the planned activities with the desirable resources. The cost of such act of compromise is that the process may take a different trajectory than anticipated thereby can produce an undesirable outcome. (2) They can consider being rational therefore can decide to try to fill up the voids by undertaking the planned activities with the desirable resources. The cost of not compromising is that the process may take a longer time to reach the final outcome thus can have difficulties penetrating the market before the competitors. Here is a dilemma that an actor faces during the innovation process and this creates further limitation in actors' cognition to steer the process. Thus, uncertainty emerges in the innovation process in a cycle of interaction among resource void, activity void and actors' limited cognition.

The idea of being risk averse (Cyert and March, 1963) completely fails when it comes to the innovation process because uncertainties are embedded in the innovation process thus unavoidable. This paper suggests that a manger who is undertaking an innovation process should be willing to face this unavoidable and deal with it. The innovation process calls managers to be proactive risk takers instead of being risk averse and passive. Furthermore, the managers have to accept that they cannot act in completely rational manner but rather they have to be boundedly rational; act with certain extent of compromises when needed. Being too rational in the innovation process may lead to conflict with other actors as well as can delay the market entry by delaying the undertaking of the development activities. Therefore, managers are suggested to make necessary compromises to avoid falling into the activity void. Innovation projects are often so resource consuming that falling into the activity void can be common, though not an ideal situation. The paper further suggests that managers should look at the priority list and forgo achieving the overarching goal which may cost a fortune if fails, especially when resources are not promised. Nevertheless, the aim of the compromises should be achieving the best possible outcome from the best possible combination of resource combination by coordinating activities in the best possible way under the limited condition of resources. Although being compromising is motivated from the idea of being boundedly rational it is in fact motivated by a rational judgement.

While the paper attempts to contribute to the innovation management literature by integrating theoretical insights from the IMP perspectives, it questions the basic assumption of this perspective; resources are available, if not in the house at least through relationship development. The paper shows that gaining access to resources is not always possible even though relationship development is desired and embarked on. Furthermore, relationship development is not always preferable, even though lack of access to resources from potential partner can cost a great deal. Sometimes protecting one resource becomes so important that actors can forgo the opportunity of gaining other resources through relationship development. The IMP perspective cannot also explain a condition when activity cannot be linked or coordinated due to lack of resources. Although the IMP scholars argue that their approach enables investigation of the innovation process because of its ability to explain how resources are accessed and leveraged by partners (Gadde and Lind, 2016), this paper argues that they need to discuss the issue of resource unavailability which they have not touched upon so far. Since activity void has a significant impact on the innovation process, the paper suggests the IMP scholars to explain the implications of resource unavailability for activities in the innovation process so that our understanding of the innovation process can be improved.

To sum up, innovation process is interactive and moreover a boundary crossing interactive process (Waluszewski, et al., 2017). Firms interact with other firms across borders to acquire resources as well as to outsource activities. However, it is not always easy to acquire resources across border because there are significant differences among counties in terms of institutional policies supporting resource transfer (Luthfa, 2017). A firm's ability to acquire resources and to undertake the resource recombination activities become subject to the influence of the institutional differences across borders. Therefore, it is important to understand how firms from different institutional settings interact with one another for the purpose of novelty creation and how their interactions are affected by the institutional differences so that suggestions can be made for policy improvement.

The paper is limited in explaining how uncertainties emerge in the service sector innovation and open innovation sector. The study of the open innovation process could possibly enable us to understand how to eliminate resource void as well as activity void in the innovation process as firms are able to exploit the ideas and knowledge outside of their boundaries (Chesbrough, 2003). Therefore, it would be interesting to study open innovation process in relation to how to reduce activity void. Since activity void can have a serious impact on the innovation process as it hinders the undertaking and linking of the activities it would be useful to investigate this aspect in future research. Then again, since the activity void and resource void are interconnected one cannot separate their studies. The studies of activity-resource voids would contribute to the field of innovation operation management. The paper did not study innovation process undertaken by the start-up companies. Both companies were established and had enough resources to deal with the processes. Start-up companies face more difficulties than the established firms as they often lack financial resources (Muller, 2013). Financing difficulties are a common type of uncertainty in the innovation process for small start-up firms as a result many promising ideas fail to be realized (Luthfa, 2017). Future studies can also look into how uncertainties emerge in the start-up phases in the innovation process and how they can be managed efficiently.

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Design Thinking in Leading European Companies - Organizational and Spatial Issues

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Abstract. In the last decade, design thinking has been discussed as a new paradigm for dealing with complex business problems. The implementation of design thinking is linked with substantial changes in the organizational culture and becomes visible in new approaches to designing office and learning spaces. To analyze proponents' perspectives on the implementation process, we adapted Schein's (1990, 2017) approach of different layers of an organizational culture. In general, two layers in an organization are addressed, namely visible artifacts and behaviors, as well as basic principles to think about approaches to deal with business problems (mindset). In total, eight semi-structured expert interviews were conducted with proponents to learn more about the implementation of design thinking and the architecture of related office spaces. The findings suggest that design thinking addresses both aspects—the provision and inner design of physical space as well as a change of mindset.

Keywords. Design Thinking, Designerly Thinking, Office Space, Innovation.

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1 Introduction

Design thinking is seen as a new paradigm and strategic tool for dealing with complex (business) problems (Kotler and Rath, 1984; Brown, 2008, 2009; Camillus, 2008; Cooper et al., 2009; Johansson and Woodilla, 2009; Dorst, 2011; Wattanasupachoke, 2012; Johansson-Sköldberg et al., 2013; Liedtka, 2015; Carlgren et al., 2016a, 2016b; Elsbach and Stigliani, 2018). It is outlined as a required skill for management executives and therefore relevant for management education (Dunne and Martin, 2006). Scholars recommend the use of design thinking in different fields such as health care (Uehira and Kay, 2009), the law (Szabo, 2010), and human resources (Birchall-Spencer, 2010). With a special focus on service organizations, service design thinking represents a different body of research (Holmlid and Evenson, 2008; Kimbell, 2011, 2012; Stickdorn and Schneider, 2011). In management, design thinking influences the work in strategic management (Fraser, 2007) and organizational development (Sato et al., 2010), and it offers a toolbox for managers (Liedtka and Ogilvie, 2011; Stickdorn and Schneider, 2011). Nowadays, design thinking has been implemented in many large organizations, but of course it is not a "miracle cure," and more research on design thinking in organizational settings is needed (Carlgren et al., 2016b, p.39).

In its essence, design thinking refers to a reflective practice, a problem-solving activity, and a practice-based activity toward design as the creation of meaning (Buchanan, 1992; Kimbell, 2011, 2012; Johansson-Sköldberg et al., 2013; Carlgren et al., 2016a; 2016b; Prud'homme van Reine, 2017). The idea is to bring design practice and competence into the managerial and/or learning context and find new ways to deal with a complex reality (Johansson-Sköldberg et al., 2013). Hereby, human-centeredness is a core issue. This is reflected in the concept of human-centered design, which "has gradually developed into a field of expertise of its own" (van der Bijl-Brouwer and Dorst, 2017, p.1).

Carlgren and her colleagues (2016a, 2016b) identified five core elements of design thinking, namely user focus, problem framing, visualization, experimentation, and diversity. Innovation and design thinking are closely intertwined so that enterprises use the design thinking approach as a key lever for improvement (Brown, 2008). Successful design thinking implementations come along with substantial organizational changes. To implement design thinking successfully, organizations have not only to provide settings and working spaces that fit the design thinking purpose, but also have to rethink their traditional values and norms. Against this background, the objective of this paper is to learn more about the implementation of design thinking in general and the role of spatial issues in particular. To do this, we adapted Schein's (1990, 2017) approach of different layers of an organizational culture (artifacts and behaviors, observable values, and basic assumptions).[1] In a rough outline, the implementation of design thinking addresses two layers: visible artifacts and behaviors (office spaces, design thinking activities such as prototyping), and basic principles to think about business problems (design thinking as a change of mindset) (Hassi and Laakso, 2011; Carlgren et al., 2016a, 2016b). This paper addresses both—the design of office spaces as well as the need to change the mindset while implementing design thinking.

[1] In alignment with this, Argyris and Schön (1996) stated that the visibility of a culture can be assigned to two different theories of action: the espoused theory and the theory-in-use.

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The paper is structured as follows: First, we give a brief overview of the research on design thinking (Chapter 2.1). Next, spatial issues are outlined (Chapter 2.2). The research question and method are addressed in Chapter 3; we focus on the identification of spatial and organizational issues while implementing design thinking. For that reason, expert interviews with design thinking experts (managers in large multi-business organizations) were conducted. The findings of the interview study are reported in Chapter 4. Finally, implications and limitations of the research are discussed (Chapter 5).

2 Design thinking

2.1 Designerly thinking and design thinking

There is an extensive body of literature on design thinking. Kimbell (2011) reviewed the origins of the term "design thinking" and identified three main accounts, namely design thinking as (1) a cognitive style (the focus is on experts and their problem-solving activities in traditional design disciplines; design problems are ill-structured); (2) a general theory of design (the focus is on design as a discipline; design's purpose is taming wicked problems); and (3) a resource for organizations (the focus is on innovation; organizational problems are design problems). More generally, Johansson-Sköldberg et al. (2013; see also Carlgren et al., 2016b, and Elsbach and Stigliani, 2018) identified two strands, namely an academic and a practitioner-oriented perspective: designerly thinking and design thinking.

Designerly thinking is rooted in design and closely related to disciplines such as architecture, planning, art, or design history. It aims at understanding students' education, e.g., in mechanical engineering, and refers to the "academic construction of the professional designer's practice (practical skills and competence) and theoretical reflections around how to interpret and characterize this non-verbal competence of the designers" (Johansson-Sköldberg et al., 2013, p.123). Johansson-Sköldberg et al. (2013) identified five strands of the designerly way of thinking, namely design and designerly thinking as (1) the creation of artifacts (Simon, 1969), (2) reflexive practice (Schön, 1983), (3) problem-solving activity (Buchanan, 1992), (4) practice-based activity and way of making (Cross, 2006; Lawson, 2006), and (5) the creation of meaning (Krippendorff, 2006) and innovation (Verganti, 2009). Against this background, one can state that there is a rich, theoretically underpinned discussion on the nature of designerly thinking (Carlgren et al., 2016b). However, this is not fully true for the discussion on design thinking within the management discourse—it is "less thoughtful and robust than contributions to the designerly thinking discourse" (Johansson-Sköldberg et al., 2013, p.127). Design thinking refers to the use of design practice and competence in the managerial context. It can be seen as (1) a way of working, (2) a way of dealing with organizational problems and therefore a crucial skill for managers, or (3) a part of management theory. The starting point was the need to think about creativity to be successful in saturated markets (Ward et al., 2009; Stevens and Moultrie, 2011), and design thinking has become a strategic tool (Kotler and Rath, 1984). The need for innovation and creativity as well as new ways to think about complex business problems are the main reasons for the popularity of design thinking in management (Johansson and Woodilla, 2009; Johansson-Sköldberg et al., 2013).

While discussing the relationship between design and designerly thinking, Johansson-Sköldberg et al. (2013, p.131) stated that "design thinking can be seen as a translation of designerly thinking into a popularized, management version" (for differences between business thinking and design thinking see Liedtka, 2010). Meinel and Leifer (2010, p.xiv) postulated that design thinking "creates a vibrant interactive environment that promotes learning through rapid conceptual prototyping." By analyzing common approaches, definitions, and toolboxes of design thinking, the following key issues of design thinking seem to be noteworthy (Carlgren et al., 2016a, 2016b; Matthews and Wrigley, 2017):

Innovation and *customer centricity* are seen as central factors behind the implementation of design thinking. The induction of design competence into the management context has an effect on innovation and can lead to competitive advantages (Brown, 2008; Johansson-Sköldberg et al., 2013; Carlgren et al., 2016b; Prud'homme van Reine, 2017). Martin (2009, p.38) argued that design thinking "enables leaders to innovate along the path of the knowledge funnel (mystery, heuristic, algorithm) and the firms that master it can gain long-term business advantages." Innovations should meet customer needs and therefore be user-centered. Furthermore, Elsbach and Stigliani (2018) highlighted the relevance of empathy with users. In this context, approaches such as user-centered or human-centered design are discussed; both are closely related to design thinking. Norman and Verganti (2014) discussed the potentials of human-centered design for creating innovations critically. They stated that companies have to overcome the traditional methods of human-centered design (observations, ideation, rapid prototype, and testing; for an overview on methods to support human-centered design see Maguiere, 2001). In fact, companies have to think about fundamental changes of technology and meaning (e.g., by motivating design teams to work simultaneously in multiple directions) when they want to create radical and not just incremental innovation (Norman and Verganti, 2014). In response to this criticism, van der Bijl-Brouwer and Dorst (2017) emphasized the importance of human-centered design. They stated that nowadays human-centered design provides deeper insights about human beings' needs and aspirations, and simultaneously design innovation is becoming more human-centric. They introduced a transdisciplinary four-layer model of human needs and aspirations for application in a design and innovation process (NADI) and distinguished four levels of needs and aspirations: (1) solutions: what people want and need; (2) scenarios: how people want to interact with a solution in a specific context of use; (3) goals: what people want to achieve within the context of a certain design problem; and (4) themes: the underlying structures, meanings, and values outside the direct context of the problem.

Furthermore, design thinking is related to *problem solving*. Buchanan (1992; see also Kimbell, 2011) described design thinking as a general approach to deal with wicked problems, and Kimbell (2011, p.287), as well as Carlgren et al. (2016b, p.39), defined design thinking as a "human-centered approach to problem solving." In this sense, design thinking activities are often described as problem-solving processes. Liedtka (2015) named three phases of the design thinking process, namely (1) data gathering to identify user needs and define the problem to be solved, (2) idea generation, and (3) prototyping and testing. Elsbach and Stigliani (2018) identified—based on the framework of Seidel and Fixson (2013)—three categories of design thinking tools: (1) need-finding tools (i.e., ethnographic observations, in-depth contextual interviews, and customer journeys used to empathize with and understand customers' needs), (2) idea-generation tools (i.e., brainstorming, cocreation/codesign), and (3) idea-testing tools (i.e., rapid prototyping and experimentation). Dorst (2011; see also Lawson and Dorst, 2009, or Paton and Dorst, 2011) identified two paradigms to describe design thinking, namely the 'rational problem-solving' (Simon) and the 'reflection-in-action' (Schön) approach (see above). Based on the work of Peirce (1931-35) on the logic of reasoning, the need of abduction-2 to deal with complex problems is highlighted. This means that designers have to create a product or a service *and* in parallel have to develop new ways of working to create value for the customers. He suggested working backwards, starting with the value the designer wants to create, then developing or adopting a standpoint from which the problem can be tackled, and finally moving to abduction-1 and creating the product or service. Furthermore, barriers or cognitive biases hindering the problem-solving process were outlined. Liedtka (2015) identified cognitive biases (e.g., the hypothesis confirmation bias or the gap between saying and doing) that are linked with negative consequences in decision making. Paton and Dorst (2011) also depicted enablers (using metaphors and analogies, contextual engagement through research, conjecture) and barriers (fixation on initial ideas, unfavorable mental models of design, resistance to journey) to reframe a given situation in a new one (for the impact of team cognition on problem reframing see also Kress and Sadler, 2014).

Creativity is derived as an essential objective for design thinking implementations (Dorst, 2011). Creativity and knowledge resources are positively associated with newly designed products (Jiang and Zhang, 2014). Design thinking is characterized as "an analytic and creative process" that generates opportunities to experiment, to prototype, and to gather feedback for redesign (Razzouk and Shute, 2012, p.330). This notion can also be found in the work of Meinel and Leifer (2010, p.xiv), by describing design thinking as the "creation of, as well as adaptive use of a body of behaviors and values."

Change issues are also part of design thinking. Against this background, it is obvious that the discussion on design thinking is intertwined with organizational culture issues. We follow the understanding of culture as "beliefs, ideologies, and values, and the ways these are transmitted through symbols, languages, narratives, and practices" (Schneider et al., 2011, p.373). In summary, culture can be defined as (group) patterns of behavior and actions learned during a specific time period to achieve external adaptation and resolve internal integration problems (Schein, 1990, 2017).[2] Hassi and Laakso (2011) evaluated how design thinking skills can be beneficial for dealing with continuous change, while Burdick and Willis (2011) investigated the bias toward action as a major change enabler for organizational development.

Finally, a comprehensive *evaluation* of the success of design thinking initiatives is needed in order to derive change measures for improvement. This could be done in various ways (i.e., number of prototypes, satisfaction of customers, product usability).

2.2 Spatial issues: Learning environments and working spaces

A learning environment is seen as "a place where people can draw upon resources to make sense

[2] Sometimes culture and climate are seen as equivalents. In brief, one can state that climate researchers focus more on practices, procedures, and behaviors, whereas research on culture is more on a macro level and targets values and beliefs (for a differentiation between organizational culture and organizational climate see Schneider et al., 2011).

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out of things and construct meaningful solutions to problems" (Wilson 1996, p. 4); it is a setting "wherein the learner acts, using tools and devices, collecting and interpreting information, interacting perhaps with others" (Wilson, 1996, p.6). Physical proximity and face-to-face communication foster learning and knowledge transfer in enterprises (Nonaka and Takeuchi, 1995; Cook and Brown, 1999) as well as in universities (Cox, 2018; Thoring et al., 2018). A learning environment is characterized by the particular quality of the current learning situation in terms of time, space, and social and cultural context. The terms "space" (locations without social connections for employees) and "place" (locations with meaning and values created by human experiences; see Saar and Palang, 2009) are of importance in describing an environment (for the architecture of university buildings see Cox, 2018). With regard to workplaces, Lindahl (2004) also differentiated between space and place and highlighted the relationship between spatial and organizational issues of workplaces for the development of organizations. Leifer and Steinert (2011, p.157) also emphasized the design of working spaces as a key factor for performing change: by adapting the physical environment, "organizations are able to lower hierarchical boundaries, enhance ideation and creativity, foster and accelerate prototyping and generally increase the rate of learning and change." Flexibility in terms of adaptive as well as agile working places is outlined as a crucial component of the spatial setting.

Thoring et al. (2018) presented a typology of creative-learning spaces with regard to the working and learning processes of designers. Based on an extensive literature review, they distinguished among five types of creative spaces: (1) personal space for working alone, (2) collaboration space for working together with others, (3) presentation space for giving presentations, (4) making space in which people experiment and try things out, and (5) an intermission space for transition and recreation (e.g., cafeterias). They further distinguished among five different spatial qualities (each space type comprises all spatial qualities): space can (a) be a knowledge processor (e.g., provides access to knowledge); (b) be an indicator of organizational culture (e.g., indicates privacy); (c) be a process enabler (by providing an appropriate infrastructure); (d) have a social dimension (e.g., reduces or facilitates social interactions); and (e) be a source of stimulation (e.g., provides external stimulation). By linking the space types with the spatial qualities, they were able to describe spatial concepts in organizations and universities.

In design thinking research, flexibility in terms of adaptive as well as agile working places is outlined as a crucial component of the spatial setting. The space makes allowance for and even can arouse ideation and prototyping actions. Stanford's Center for Design Research (d.school) identified some important issues: (1) flexible room separators instead of fixed walls, (2) movable and modular furniture, (3) furniture should enhance creativity and lower barriers to ideation, (4) the use of minimum commitment prototypes to facilitate rapid redesign and learning, and (5) furniture and support infrastructure should be customized for the needs of project teams (Leifer and Steinert, 2011). Against this background and with regard to the learning theories based on the context of situated learning (Brown et al., 1989; Collins et al., 1989), the following elements of physical spaces are discussed to foster design thinking activities (e.g., Herrington and Oliver, 2000):

- Design thinking requires physical space that is different from the usual offices, and a physical environment that fosters creative thinking. The space should enable a thorough investigation from different perspectives. Among other aspects, this includes a prototyping environment that reflects the usage of knowledge in real-world scenarios (making space). Writable walls and easily movable furniture are also often mentioned. Moreover, spaces should provide possibilities for transition and recreation (intermission space) to facilitate social interactions.

- Design thinking needs room for teamwork (collaboration space). Collaboration and cocreation refer to core elements of design thinking. Ill-defined problems are tackled by a project team, and complex tasks are better addressed within a group than by individuals (Resnick, 1987; Collins et al., 1989; Hooper, 1992) in order to get an all-embracing perception of a problem. Furthermore, the exploration of problem settings from various perspectives is of importance (Collins et al., 1989; Lave and Wenger, 1991).
- Finally, spaces should provide access to knowledge and expertise. Ways to make tacit knowledge explicit and to get access to expert knowledge are needed. Access to expert thinking is necessary to deepen the knowledge in ill-defined problem areas. This is particularly true for the initial project phase in which the team has to immerse itself in the subject matter to deeply understand the problem field.

3 Interview study

The main objective of the interview study was to explicate spatial issues (the design of office spaces) and organizational issues (design thinking in relation to changing the mindset) in design thinking initiatives in selected European companies. In doing so, we conducted an interview study. Eight interviewees (proponents who are entrusted with design thinking in their companies) were identified and addressed for scheduling the interviews. During the correspondence for the appointments, the interviewees confirmed the challenge of implementing design thinking initiatives in the last few years as well as the relevance and the challenges associated with designing an appropriate office space. The interviews were conducted to explore the firm-specific conditions of implementing design thinking and to learn more about the office space. In this context, we were particularly interested in the relationship between spatial aspects and the understanding of design thinking as a change of mindset (in the sense of a change of the organizational culture). In other words: Are design thinking tools and workspaces seen as a trigger to change the mindset or has a change of mindset influenced the design of office spaces according to the principles of design thinking? With regard to Schein's (1990, 2017) layers: Do the interviewees stress the underlying norms, values, and assumptions more or do they highlight visible artifacts and behaviors? We asked questions on the following aspects: (1) What was the main reason for implementing design thinking? (2) How did the introduction of design thinking take place? (3) How are the design thinking offices designed? (4) How is the success of design thinking measured? (5) Finally, we wanted to learn more about the understanding of design thinking (is design thinking seen as a tool/method or is it more about a change of mindset?). After running a content analysis of the individual interview transcripts, a cross-organizational analysis was used to find patterns in the collected data.

By using the criteria of organization size (defined in terms of sales volume and number of employees) and industry segments, eight interviewees were selected with a theoretical sampling

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strategy (Eisenhardt, 1989). Enterprises with different characteristics were incorporated (from different industries) to cover different perspectives. Each of them faces serious competition with regard to quality—cost leadership is not an option. Consequently, there is a strong need for innovation, creativity, and change. The consideration of different organizations with diverse industry backgrounds offers a more holistic view of design thinking. The organizational culture and the business models differ considerably among the companies, and design thinking initiatives are deployed in different corporate functions such as innovation management, research and development, corporate venturing, information technology, and consulting. This ambiguity is also reflected in the job descriptions of the interviewees.

We used a semi-structured interview guideline, and the interviews were conducted in April and May 2016 in person or via phone. The interviews lasted between 22 and 59 minutes. In order to retain the data from the interviews, the interviews were recorded. After the interview sessions, the interview transcripts were submitted to the interviewees for control and approval. The final interview reports were used for the analysis. In order to generate a holistic view of the interviewed organization, the interview results were linked with publicly available information from corporate websites and information service providers such as Bloomberg. Table 1 shows the profiles of the interviewees.

Table 1. Profiles of the interviewees

Case	Sector	Employees > 20k	Turnover € > 20 billion	Interviewee	Interviews
ALPHA	Industrial	√	√	Manager, Innovation	1
BETA	Technology	√	√	Senior Consultant	1
GAMMA	Utilities	√	√	Director, Corporate Ventures	2
				Senior Vice President, Technology	
DELTA	Health Care	√	√	Director, Innovation	1
EPSILON	Industrial	√	---	Director, Technology	1
ZETA	Industrial	√	√	Manager, Innovation	1
ETA	Consulting	---	---	Senior Consultant	1

4 Findings

4.1 Design thinking in different organizations

To contextualize the findings, we first present brief information on the companies that outlines different ways of implementing and using design thinking. Table 2 gives an overview of the key findings of the interviews.

4.1.1 ALPHA

Context information: ALPHA is a multinational industrial company with corporate headquarters in Europe. The product, service, and solution portfolio covers a broad range of technologies, and ALPHA is the market leader in different markets. Key markets are located abroad, while product development and design reside in Europe. Novel products, services, and solutions are rolled out globally without specific tailoring to customers' demands or cultures. One key issue is that ALPHA's products are very complex and often do not meet customers' needs. The main challenges are dealing with market dynamics and innovative, customer-tailored solutions.

Design thinking in the organization: A few years ago, design thinking was implemented as a method for topics burdened with wicked problems (especially to develop more innovative products). At ALPHA, design thinking is primarily seen as one instrument (among others) designed to support innovation and to find out what the customer needs. The interviewee also mentioned the relevance of design thinking as a tool to support the change of mindset, but top management support is not strongly noticeable. ALPHA's design thinking comprises recursive loops in the ideation phase using arts and crafts materials. In this context, the aim is to find a solution that works on the basis of a prototype and delivers value to the customers. The interviewee stated that "design thinking revealed that users actually had very different needs than originally anticipated by the business unit and engineers." While implementing the design thinking method, the implementation team cooperated, among others, with IDEO (a global design company), and members were trained and coached through external consultants. At ALPHA, no specific measurement tools to assess the success of design thinking have been established. Qualitative indicators such as the perceived benefit of projects have been used instead.

Office space: For ALPHA's design thinking initiative, rooms and labs were set up in order to be flexible. The rooms were equipped with movable furniture, and foamboards were used (e.g., as visualization platform and prototyping space). An advanced machine shop with additive manufacturing technologies (e.g., 3D printing devices), as well as a computerized numerical control laser cutter, both of which make prototyping more professional, were deployed. The interviewees highlighted that new spaces do not automatically solve the problems of ALPHA but help to break up certain rules and assumptions. In this sense, the design thinking office spaces were seen as a tool to support the change of mindset.

4.1.2 BETA

Context information: BETA is a large technology and software vendor that supplies all relevant markets in the support and automation of customer resource planning, manufacturing execution, customer relationship management, supply chain and supplier management, and business analytics. BETA is headquartered in Europe but has worldwide user designs, research and development, and sales offices. After years of organic growth, BETA now tends to focus on acquisitions more to attract new customer segments and to come up with innovations. Technological disruptions in this branch are currently initiated by other market players (e.g., Silicon Valley start-ups).

Design thinking in the organization: BETA has had a long tradition of design thinking practices for more than twenty years. In recent years, design thinking has been rolled out and established on a global scale. Design thinking is understood as a global mindset, and it is supported by top management in many ways. In daily operations, the processes and routines focus on the methodical point of view of design thinking. While implementing design thinking, BETA utilized different steps, namely the use of (1) external design thinking coaches, (2) qualifying internal coaches, and (3) project-based development of design thinking skills. Often employees with design thinking expertise perform an ambivalent role in the project team. They are both coaches and project workers. Balancing these needs turns out to be challenging. Another challenge is to balance creativity and large-scale project requirements. The approach is to cooperate with partners that provide physical space and infrastructure to take the team out of its daily business and enable cooperation and co-creation across organizational boundaries. The interviewee stated that BETA has managed the design thinking institutionalization successfully. Drivers were the support of the board of directors as well as the intrinsic motivation of employees to spread design thinking within the organization. Customer feedback is used to assess the success of design thinking.

Office space: The physical learning environment constitutes both internal and external locations. For external locations, BETA uses facilities with a craftsmanship background or loft buildings that are located nearby. Temporarily moving to external locations helps to get out of the daily work routine and to rethink traditional views. Each of BETA's internal buildings incorporates at least one design thinking space in proximity to break rooms and restrooms to ensure convenient access. All rooms have been designed individually. The furniture, sofas, movable walls, bar chairs, and bar tables are equipped with casters so that the room becomes flexible and can be tailored to different needs. Tools and materials for prototyping such as polystyrene beads, cardboard boxes, construction paper, glue, LEGO bricks, and modeling clay are available. Most of the design thinking spaces are based on redesigned meeting rooms. Walls have been repositioned to create spacious and light-filled rooms. The comfortable furniture and colored design items offer cozy corners and seating areas that make people stay in the office after work. As the interviewee stated, the well-equipped office spaces can be seen as an indicator of how much the top management supports the implementation of design thinking as a mindset.

4.1.3 GAMMA

Context information: GAMMA is one of the major European enterprises in the untility industry. In recent years, the organization has been restructured and has suffered from governmental-initiated turnaround in energy policy. The organization is split into two parts: a more conventional large-scale system provisioning business and a new business unit that designs and implements decentralized and customer-tailored energy solutions. Two company representatives were interviewed to reflect both views.

Design thinking in the organization: Against the background of game-changing market dynamics in the energy crisis, GAMMA's management decided to give strategic significance to innovation and new business models. In this context, design thinking found its way into GAMMA. First, external coaches conducted workshops with the entire senior management team. As articulated by one of the interviewees, GAMMA wants "to realize more innovation and a change in the enterprise culture. A lean and rapid approach of testing new business models in the market is preferable toward thoroughness and perfectionism." Following this notion, an innovation hub was launched. The innovation hub is organized in several sections that present the current topics of interest (e.g., smart home, big-data management, and digitalization). Design thinking, so far seen more as a tool, plays an essential role in transforming the traditional mindset nowadays, and several corporate initiatives have been started to overcome risk aversion and to open up for new ideas. To learn more about the success of design thinking, GAMMA analyzed a number of projects that found their way to the market.

Office space: In the past, more and more rooms were designed especially for design thinking. Movable furniture and writable walls were key requirements for the interior design as well as sticky notes and movable walls. The aim was to create an entirely agile environment to support the changing needs in a project. Being a pioneer for GAMMA, this trend was adopted rapidly by other business units. After some initial resistance, people recognized the advantages of such an environment, in terms of a contrast to the usual office spaces. In this sense, the new designed office spaces trigger the change of mindset. As described by the innovation manager after facilitating some design thinking workshops, "if you look at someone working in the finance area, and drop him in a design thinking room for the first time, where you can write on walls and have LEGO bricks for prototyping, he probably thinks he is in pre-school. But after going through the design thinking process and looking at tangible prototypes, they quickly are convinced."

4.1.4 DELTA

Context information: DELTA is a multinational health-care company, and innovation plays a key role. The company opened an innovation center to give employees the possibility to work on new ideas and projects in a creativity-enabling environment. An important element of the innovation center is an "Innovator Academy," where employees have access to trainings or workshops including topics such as design thinking, user-centered design, and creativity techniques.

Design thinking in the organization: To push cross-divisional innovations, design thinking is a tool to foster collaboration within the company. In the past, things were explored in one area, mostly in laboratories, and in this area they were brought to market maturity without a prototyping phase or a customer requirement analysis. Design thinking should help to overcome this problem. The innovation center is seen as a melting pot of ideas and offers space for working in interdisciplinary teams, and the building complex has been constructed to represent the management's cultural change of mindset. While implementing design thinking, external coaches were hired. The success of design thinking is analyzed by indicators such as participation rates at design thinking events.

Office space: Openness is the main guiding principle behind the architecture of the innovation center. It is divided into two areas: one where staff and visitors have access and a second one that is reserved for project teams. Here, employees and external partners work together in interdisciplinary projects. There are no fixed office rooms but flexible working spaces instead, and everything is easily movable. The finished modules as part of the building are grouped around a spacious courtyard. For the manager of the innovation center, a key factor for productive work is the atmosphere. For a feel-good factor, a kitchen was incorporated into the work area. As the innovation center has been built to represent the management's cultural change of mindset, visible artifacts can be seen as a tool to change the values and norms.

4.1.5 EPSILON

Context information: EPSILON is a leading industrial provider of maintenance services for the transportation sector. EPSILON faces some serious challenges that can be traced to game-changing market shifts. Original equipment manufacturers are looking for new business models since they are suffering from shrinking margins, international competition, and service-demanding customers. Another challenge is the intense competition for EPSILON's customers. Both factors weaken the market position and lead to considerable cost pressure for EPSILON.

Design thinking in the organization: Design thinking was brought to EPSILON a few years ago and is seen as a tool to promote innovation. Until then, there had been no internal trainings available, but when an employee now wishes to gain experience, this is seen in line with his or her personnel development and thus is supported by EPSILON. Against this background, the implementation of design thinking is still in a rather early stage. The interviewee reported being quite satisfied with the result of the new way to work after EPSILON implemented a structural reorganization of the IT department. Along with some other units, his team is seen as one area for change and the usage of innovative and creative methods for their daily work. Particularly in the IT sector, rapid prototyping and other agile approaches are of importance. Through the reorganization, his team had the chance to rethink the established processes and culture. They became a grass root movement, and slowly more and more units explored the advantages of design thinking. In this sense, the new designed office spaces are seen as a measure to support change. After initial hesitation, the support of the top management is also emerging now. To learn more about the effects of design thinking, EPSILON used data from employee surveys.

Office space: At EPSILON, employees can create flexible working spaces for design thinking issues. These rooms have writable walls, and while some are furnished with couches, others have high tables and stools. Moreover, conference rooms and libraries are provided for the team, if the employees want to work in concentrated silence. Before the implementation, employee surveys showed the need for this. But the libraries were not frequented as expected, and therefore the library space has already been transformed into a team room. The rooms are supplemented by a "market place," which is an open, cozy area with sofas, tables, and comfortable chairs. Further, EPSILON's manager clearly emphasized the benefits of writable and accessible glass partitions in meeting rooms and office spaces. However, he acknowledged budget restrictions. Especially for the prototyping phase, serious LEGO play is of importance. A 3D printing lab was also installed to create prototypes quickly. Especially for the manufacturing unit, this device is seen as advantageous.

4.1.6 ZETA

Context information: ZETA is a traditional engineering-minded European organization and constructs resource-, knowledge-, and capital-intensive investment goods. As the final assembler that brings complex systems together, ZETA heads a large production network. One of the main challenges lies in the consolidation of ZETA's business customers. As a consequence, ZETA started extensive cost-saving programs that look for all costs in the business and accordingly approach suppliers to renegotiate prior agreements to reduce the product price. Due to financial constraints, the equipment operators cannot afford the huge investments anymore.

Design thinking in the organization: Design thinking started a few years ago. Several managers attended workshops and brought the notion into the company. Nowadays, design thinking is part of the corporate innovation program. There are awareness workshops to inform ZETA's technicians and engineers about the design thinking paradigm. However, the management has understood that the benefits of design thinking go far beyond a collaborative working mode in workshops. The corporate innovation team aims at developing user-centered innovations and thereby altering the maturity of design thinking usage. The idea today is to implement design thinking extensively as an innovation method. However, the spread of design thinking within the company is still limited. There is no top management support that drives a design thinking program, provides budget, or controls the success of design thinking. At ZETA, currently, no specific measurement tools/key performance indicators have been established to measure the success of design thinking.

Office space: There are physical rooms that have been tailored for innovation projects, but ZETA has no dedicated room for the exclusive use of teaching or applying design thinking. The interviewee explained that "the needs of such a room differ considerably." At ZETA, there are pop-up spaces to bring internationally distributed teams physically together. Moreover, the design thinking space has to facilitate the prototyping activities. This includes prototyping on paper, but also an environment for testing the prototypes. For a pop-up space, the team can use existing spaces and reshape them. The basic notion is to make those spaces flexible and scalable. This includes modular walls and different zones, such as meeting zones and focus zones. The resources that are still required are projection spaces, interaction spaces with projectors and smartboards, and a videoconference system for remote collaboration.

4.1.7 ETA

Context information: The interviewee is a management consultant with eight years of experience in design thinking. He consults, among others, with clients in the financial service industry. This industry faces different game-changing problems and is characterized by hierarchical grown structures and thinking in terms of status.

Design thinking in the organization: The interviewee's bank client has started with a bottom-up approach. The middle management, responsible for aligning business and technology strategy, wanted to improve the cooperation mode. A program was set up to initiate design thinking projects on the operative level. At this time, the operative project managers realized that customer solutions (e.g., banking apps, online banking) were outdated. So design thinking was used to get access to customer needs in direct interaction with customers. They started with small project teams that were coached by external consultants. Further, they built an innovation community that diffuses design thinking within the corporation. This had an enabling effect on the working culture. Nevertheless, the implementation teaches management executives that the learning curve cannot be shortened. As outlined by the interviewee, "although design thinking is simple and feasible, this does not imply that it can be implemented at once. All organizations have to pass the hermeneutic circle of learning." For the implementation of design thinking, support by top management is advantageous. Even a sound bottom-up strategy that supports the needs of project teams is essential. Against sceptics and doubters, this is the best solution when both parties are aligned and cooperate. When it comes to approaches to measure the success of design thinking, the interviewee stated that the deployment of adequate controlling instruments and key performance indicators will take a long time and is a challenging task.

Office space: The learning environment starts with the appropriate physical location. Lessons learned from the financial service provider refer to a hosting role for the design space. This person ensures usage in terms of the intended purpose and takes care that the required material is available and stocked. The room should be located centrally to enable good access and allow drop-by situations from other curious employees. Openness, transparency, and daylight offer further features. Comfortable and cozy furniture as well as writable and flexible walls, all equipped with “movable casters”, complement the interior of the design space. By referring to one of his previous mentors from Stanford University, the management consultant stated that “each point in the room has to be accessible within a seven-second reach, since this is precisely the time period that a person can keep a prototyping idea in mind.” This presents an appropriate size indication without mentioning a number in square meters. In addition, the atmosphere should be inviting and cozy to make people stay in the room, even for leisure activities. Further, the behavioral rules should allow making results visible and exposing prototypes for several days or weeks. For instance, there is a well-recognized best practice to preserve stakeholders’ profiles such as personas for the entire design thinking project along all phases. This measure helps to keep the assessment of all project ideas and outputs against the desired customer and user centricity criteria in mind.

4.2 Summary of the findings of the interviews

4.2.1 Implementing design thinking

First of all, it is of interest to know whether design thinking is merely seen as a method/toolbox or as a way of thinking about business problems. BETA shows the highest maturity in this concern: design thinking is implemented comprehensively, and it is understood as a mindset. At GAMMA, the interviewee also reported that nowadays there is a more comprehensive understanding and the shift from the tool to the mindset perspective is noticeable. The interviewees from ALPHA, DELTA, EPSILON, and ZETA merely stressed the tool perspective. Particularly in these cases, the crucial success factor to implement design thinking is the strategic alignment of design thinking within the company. The findings from the interviews indicate that a bottom-up movement as well as top management support are both of importance. In the interviews, different positions were mentioned. BETA and DELTA both have top management support, budget for buildings, design rooms, and training programs. At ALPHA and ZETA, design thinking is a supportive staff division. At EPSILON, the IT division design team came up with an initiative due to its understanding of the need for prototyping—and the efforts of the employees let the design initiative grow. The interviewed consultant (ETA) additionally stated that “top management support is an evergreen. But that’s not the only possibility. You also need people from bottom-up who have pressure; when they are supported by the management, that’s the best case. Once there is a main unit that is convinced and also top management support is given, then a cultural change can occur."

Furthermore, the interviewees mentioned the important role of design thinking coaches. But in the end, the key issue is that the organizational culture fits design thinking. This is especially relevant in the prototyping phase when all restrictions and limitations are set aside and possible prototypes occur that are not aligned with the business strategy or company portfolio. At ALPHA and ZETA, design thinking initiatives don't integrate well with the traditional organizational structure and management leadership style. Accordingly, their impact remains limited to the administrative departments they report to, e.g., ALPHA's corporate innovation department. Similar thinking applies to ZETA, where the innovation manager emphasized that the product divisions have to be convinced by his unit to allow active participation and coaching. ETA's senior consultant brought forward organizational readiness as one of the key differentiators between those organizations that formally pretend to conduct design thinking and those that have achieved the readiness to take radical innovation ideas seriously (as done for example in BETA).

Closely linked to the implementation of design thinking is the question of how the success of design thinking is evaluated. Currently, the companies did not have customized key indicators at hand, but the development and establishment of measurement tools is seen as an important task for the future. ALPHA's innovation manager stated that "if you measure design thinking projects in terms of market entry as part of a strict definition of innovation, then we have not succeeded." BETA used customer feedback in some cases, but BETA's senior consultant acknowledged that the opportunity costs of not having used design thinking for ideation to innovate product development cannot be calculated. GAMMA analyzed the funnel from the project idea to the market, but the interviewee stressed that it is hard to identify the crucial triggers for market success. At DELTA, an evaluation based on key performance indicators is also quite difficult. DELTA offers voluntary participation events with design themes in the evenings and measures the participation rate as an indicator for the acceptance of design thinking. EPSILON does not apply specific measures for design thinking projects, and at ZETA the conception is prevalent that classical quantitative measuring instruments do not fit the design thinking approach. One can state that the success of design thinking is not measured based on hard facts on a regular basis. The companies used mostly weak indicators such as employee participation in design thinking projects or employee satisfaction with regard to design thinking. ETA's senior consultant acknowledged that the deployment of adequate controlling instruments will take a long time, but he saw the potential for the following performance indicators: employees using the method, diversity and interdisciplinary representation in the design team, number of generated prototypes, and number of ideas that achieved market readiness.

4.2.2 Office space and architecture

All interviewees highlighted the relevance of the architecture of office space. BETA's senior consultant outlined that the architectural style is crucial for learning and innovation. The interviewee differentiated between the reuse of existing office space and the acquisition of external buildings that serve exclusively as design space. Small changes, e.g., different routes to external locations, can make a first contribution to getting the employees out of their daily routines.

However, both types of space share specific design features, i.e., writable glass walls or movable furniture. As reported by the interviewee from GAMMA, it is very advantageous to have a space that can be perfectly transformed to individual needs. ZETA's innovation manager thought that an appropriate workshop room needs one thing above all: flexible walls with space. The design space creates an enabling role for the selected collaboration mode within the team but should also serve as separated units for breakout sessions. Besides this, all interviewees declared themselves in favor of having a spacious room equipped with writable walls, easily movable furniture, and all sorts of prototyping materials. ALPHA's favorite tools to document results were foamboards with sticky notes because they are easily storable between creative sessions. Flexible walls with sticky notes were the preferred alternative for BETA, DELTA, and GAMMA. There, the results are secured through smartphone pictures if they can't remain on the wall until the next meeting. The director of corporate ventures of GAMMA outlined that an effective learning environment for design thinking "cannot be drawn back to a singular board or a glass panel; instead, the opportunity for self-expressionism should be given. The space in which you can let your ideas flow is important."

Another strand addressed the atmosphere of the environment. GAMMA's director of corporate ventures postulated that the office spaces for design thinking "should be so spacious and inviting that people say, let's stay for a group session." For him, it was essential that people feel comfortable and that everything is located next to the room or in the room so that a "bonfire atmosphere" can arise. The senior vice president for technology at GAMMA supplemented this with the following statement: "An indirect effect is caused by a different environment. If the environment changes, the people have to change." He continued by saying that "through furnishings and equipment, a controversial, but nice atmosphere, as compared to the corporate standard environment, should be created." The senior consultant at BETA said that the aim is "pulling someone into another world". DELTA's director was sure that the "atmosphere is always transferred to people," while ZETA's innovation manager outlined that he wants to support a start-up-like atmosphere. GAMMA's senior director for corporate ventures said that the design space refers to a place that people enjoy with bright and flexible rooms. This forms an atmosphere that encourages employees to stay and ensures that creativity flows. The investment for large organizations such as GAMMA pays off if the project team spends more time on the project than in the usual office spaces. In the evening, the company occasionally organizes public viewings for sport events and includes drinks and food to make employees feel comfortable. At the same time, those employees are still engaged and can discuss projects after work.

To sum up, all the interviewees emphasized the meaning of design thinking in the sense of changing the mindset and with regard to architecture and office space issues. All interviewees addressed the importance of organizational readiness. Especially at ALPHA and ZETA, the design thinking approach does not integrate well with the traditional organizational structure and management leadership style. When it comes to the measurement of the success of design thinking, all interviewees stressed that prevailing instruments and key performance indicators are not appropriate and have to be adapted.

4.3 Discussion of the findings

As Lindahl (2004, p.253) stated: "Often in situations when changes of work and the organi-

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Table 2. Overview of the findings of the interviews

Case	Cue to implement design thinking	Implementation of design thinking	Design of office spaces	Performance measurement	Design thinking as a change of mindset
ALPHA	Competitive markets, need to identify customer requirements, and develop product and process innovations	In the last few years, in cooperation with IDEO, external consultants acted as coaches	Flexible space concepts, movable furniture, foamboards, as well as 3D printers, and other devices used for prototyping	No specific measurement tools/key performance indicators established; approaches to measure the benefit of projects for internal customers are used	DT as an instrument designed to support innovation, furthermore as a tool to trigger the change of mindset, and new office spaces serve as an indicator for the new way of thinking (and to break up traditional rules)
BETA	Competitive markets, growth by own success (and not only by acquisitions), product and process innovations	For more than 20 years; in the last years DT has been rolled out globally, in steps: (1) hiring external coaches, (2) qualifying internal coaches, and (3) developing DT skills	Internal and external locations, facilities with craftsmanship backgrounds, loft buildings; external locations to break daily routines; lounge/bar atmosphere, movable walls and furniture; LEGO and other materials for prototyping	No specific measurement tools/key performance indicators established; customer feedback is used to learn more about the effects of DT	DT as a global mindset for the whole company; DT office spaces are seen as an investment to support new ways of working and to show the top management support
GAMMA	Competitive and highly regulated dynamic markets, innovation, and new business models	In the last few years, launch of an "innovation hub"	Movable furniture, writable walls, movable walls; different materials for prototyping	No specific measurement tools/key performance indicators established; analyzing the number of projects that find their way to the market	DT as a tool to support innovation and an approach to transform the traditional mindset

Note. DT = Design thinking

Table 2. Overview of the findings of the interviews (cont.)

Case	Cue to implement design thinking	Implementation of design thinking	Design of office spaces	Performance measurement	Design thinking as a change of mindset
DELTA	Innovation through collaboration and interdisciplinary teams	In the last few years, hiring external coaches	Innovation center, flexible spaces, and movable furniture; different materials for prototyping	No specific measurement tools/key performance indicators established; analyzing participation rates at DT events	DT as a tool to foster collaboration within the company; cultural mindset change would be supported by design thinking tools
EPSILON	Game-changing market shifts, competitive markets, market power of customers	In the last few years, based on the initiative of individuals; no internal trainings, but development of DT skills as a result of individual engagement	Flexible working spaces, writable walls, lounge atmosphere, dismantling of rooms that are suitable for work in silence; LEGO play and 3D printers used for prototyping	No specific measurement tools/key performance indicators established; employee surveys are used to learn more about the effects of DT	DT as a grassroots movement to change the mindset
ZETA	Shrinking margins, cost-saving programs, price competition, innovation	In the last few years, based on the initiative of managers who brought DT knowledge into the company; currently no top management support	Some (pop-up) spaces with modular walls to meet DT needs, but no dedicated rooms for exclusive DT use; different materials for prototyping	No specific measurement tools/key performance indicators established	DT as an approach to implement user-centered innovations
ETA	Process and product innovation, competitive markets	Implementing DT in many different ways (e.g., bottom up); top management support as crucial factor	Spaces are essential; openness, transparency, daylight; writable and flexible walls, cozy atmosphere; comfortable furniture; inviting atmosphere; different materials for prototyping	Development of key performance indicators as a long-term undertaking, e.g., employees using DT, composition of DT teams, number of prototypes, number of ideas ready for market	DT as an approach to overcome traditional structures and thinking in terms of status; DT to foster creativity and innovation

Note. DT = Design thinking

sation of it are underway, workspace issues are discussed". But one question is which kind of workplace will support the implementation of design thinking in the most effective way. The more challenging question, however, is to what extent office space is seen as an instrument to support mindset change. Regarding the first question, all interviewees showed great agreement and mentioned the importance of key features of design thinking spaces (writable walls, movable walls and furniture, cozy atmosphere, and so on). Regarding the latter question, we found that the use of design thinking tools and new designed office spaces had an effect on the change of the mindset in the sense of the underlying norms, values, and assumptions (Schein, 1990, 2017). All interviewees indicated that this relationship exists. But a comprehensive alignment between the organizational culture and visible artifacts and behaviors (office spaces and design thinking tools) was only clearly visible at BETA. Against this background, one can assume that the openness and readiness to organizational change is of importance for a comprehensive implementation of design thinking.

Against this background, the results from our interview study are partly in line with key findings on design thinking. In their extensive literature review (86 empirical articles: 79 articles used case-study methodology, but only seven used survey or interview methods) on the relationship between design thinking and organizational culture, Elsbach and Stigliani (2018) showed that specific design thinking tools support the development of specific aspects of the organizational culture (33 articles) and vice versa (25 articles), and they stressed the idea that there is a recursive relationship between the tools and the culture. They also reported that the use of design thinking tools produced physical artifacts (e.g., drawings, prototypes, design spaces) as well as emotional experiences (e.g., the experience of empathy) (22 articles).

More specifically, our findings confirm the results from an interview study conducted by Carlgren and colleagues (2016a, 2016b). They interviewed 36 respondents from five large firms that all had had only a few years of experience of using design thinking to learn more about the common understanding of design thinking. They used a framework that included the categories of principles/mindset, practices, and techniques and identified different strands (user focus, problem framing, visualization, experimentation, and diversity). The main use of design thinking was often to foster innovation, and design thinking was mainly understood as a process or as a set of principles on an organizational level. Aims of using design thinking were the wish to develop innovative solutions and to effect cultural change/mindset change. Both perspectives were highlighted in our interviews as well. With regard to the integration of design thinking within the company, Carlgren and colleagues identified different approaches (e.g., integration in existing structures, use of workshop formats to support projects, the use of design thinking as a special innovation function). As main challenges linked to the use of design thinking, they named, among others, a misfit with existing processes and structures as well as with the existing organizational culture, and they highlighted the need for "balancing between doing things differently with not alienating people in the organization" (Carlgren et al., 2016a, p.353). This holds true for our study, too.

Furthermore, approaches to measure the success of design thinking were addressed in our study. All interviewees stated that they do not have customized key performance indicators but use common indicators instead. This could be seen as an indicator that design thinking is not yet fully integrated into the organizational culture. Based on Kirkpatrick's framework of evaluation

(Kirkpatrick, 1994; Kirkpatrick and Kaiser Kirkpatrick, 2016) one can state that a change of mindset can be measured on four levels, namely reaction (level 1: the degree to which employees perceive design thinking as favorable and relevant for their jobs), learning (level 2: the degree to which employees acquire design thinking knowledge, skills, attitudes, and so on), behavior (level 3: the degree to which employees apply design thinking knowledge and skills during their jobs), and results (level 4: outcomes for the organization). Usually, self-reports (surveying employees), surveys with customers and other stakeholders, as well as assessments and observations at the workplace, are used to measure the effects on levels 1 to 3. Since many factors can impact effects on level 4, it is hard to isolate the direct link to organizational cultural issues, and therefore it is understandable that companies do not have a sophisticated framework for measuring design thinking performance yet.

Our findings are in line with results from a survey done by Schmiedgen et al. (2016). They surveyed about 400 design thinking practitioners from mostly larger companies. The respondents stated—generally speaking—that it is not possible to measure design thinking as a single concept. Carlgren et al. (2016a) also mentioned the difficulty of assessing the success of design thinking initiatives. Besides this, Rauth et al. (2014) worked out some strategies to legitimize design thinking, e.g., demonstrating its usefulness. More generally, one can differentiate an input perspective (e.g., sum of costs), a process perspective (e.g., team engagement), and an output perspective (e.g., number of projects ready to market, number of prototypes), as well as an internal (e.g., employee satisfaction), and external (e.g., customer satisfaction) view, and create key performance indicators for the design thinking process as well as the outcomes. Liedtka (2017), for instance, described the design thinking impact on innovation outcomes as follows: design thinking leads to higher-quality solutions, helps to reduce the risk and cost of failure, improves the likelihood of implementation of ideas, improves organizational adaptability, and supports the creation of local skills and competencies. Based on these five assumptions, key performance indicators to measure the success of design thinking could be developed. It is evident that the usefulness of different key performance indicators depends on the organizational context (e.g., industry or the mature level in design thinking utilization) (Rauth et al., 2014; Björklund et al., 2018).

5 Conclusions

This study sought to analyze the implementation of design thinking in Europe-based companies. The starting point of the implementation of design thinking was that all of the companies wanted to have a better understanding of customers' needs and become more user-centric (see also the results from case studies done by Seidel and Fixson, 2013; Liedtka, 2014; or Rau et al., 2017), because all are players in global competitive markets. The interviewees were convinced that design thinking is about mindset change and that office space—in the sense of visible artifacts—is an important tool to push the new way to work on business problems. Based on the results from the expert interviews, we identified different issues that are crucial for design thinking in organizations, namely physical space (flexible office design and space equipment), atmosphere, organizational readiness (see Weiner et al., 2008, for an overview how organizational readiness for change can be defined and measured), and top management support. Most importantly, design thinking tools and artifacts have to be aligned with issues of organizational culture. All interviewees pointed out that the development of customized measurement tools is a desideratum.

Our research addresses the empirical understanding of how design thinking is implemented and practiced in companies. Nowadays, there is a large body of empirical research on design thinking, and several review articles are available (for an overview see Elsbach and Stigliani, 2018), and—in sum—positive implications of design thinking were emphasized. All of our interviewees stated that it is not trivial to assess the success of design thinking. Most of them implemented design thinking successfully, but they could not calculate the opportunity costs of not using design thinking.

From a research perspective, it would be very interesting to compare entities with or without design thinking in comparable settings to learn more about the potential and the effects of design thinking (e.g., in an experimental setting using experimental and control groups). The development of a valid system of indicators is of interest from a research perspective as well as a managerial perspective. Furthermore, additional research on the potential of design thinking in small- and mid-sized companies is needed. Besides this, the relationship between the professional qualifications as well as the attitudes, beliefs, and emotions of the employees and the success of design thinking should be analyzed in greater detail. In this context, Elsbach and Stigliani (2018, p.2300) mentioned the important role of empathy (representing an important issue of design thinking; empathy can be interpreted as "an important signal of cultural values of collaboration and user focus in the organization") for a better understanding of the effectiveness of design thinking processes. Finally, research on the possibilities and constraints of the implementation of design thinking in higher education (e.g., linking design thinking to topics such as entrepreneurship; see Garbuio et al., 2018) is of interest.

Our study comes with several limitations. The use of interviews implies certain validity restrictions. We used a convenience sample but payed attention to the careful selection of the interviewees. The sample was limited to eight individual expert interviews from a certain number of organizations and selected industry sectors. Each expert represented an individual perspective, which may not necessarily have corresponded with the espoused theory of the company. The phenomenon of interest was initiated by different innovation stakeholders ranging from the cofounder to executive managers and departmental managers in technical development and IT to management consultants. In accordance with these different roles in the organization, the interviewees showed considerably different backgrounds, resided on different hierarchy levels, and belonged to different corporate functions. This, in turn, exposes another limitation for generalizing the cross-interview findings, as in most cases only a singular representative of the organization was interviewed. The given information reflects a specific perspective on design thinking implementation, e.g., from the corporate innovation department, IT, or a new-venture unit. Moreover, the data sampling relied on large and Europe-based companies. This imposed a traditional and engineering-focused culture but made those organizations that implement design thinking interesting subjects of investigation. Small- and mid-sized organizations do not have the resources to roll out design thinking in this way. Against this background, we have to be aware of selection bias (all interviewees were entrusted with design thinking issues and therefore could be biased) and we have to question whether the results are transferable to other organizations and/or industries. To increase the reliability, we compared the interviews with freely accessible company information from the corporate websites and information service providers such as Bloomberg.

From a managerial perspective, the alignment of tools and organizational culture is the key issue to implement design thinking successfully. There are many barriers to the implementation of design thinking (Carlgren et al., 2016a), and top management support as well as highly qualified and motivated employees are of importance. However, the interviews also showed that the extent to which design thinking is integrated into organizational culture varies. It ranges from a rather early stage to a comprehensive implementation in the sense of linking design thinking tools and cultural values.

Besides this, key performance indicators with a focus on design thinking issues are needed. Research shows that companies lack appropriate tools, especially when it comes to effects on the organizational level. Furthermore, design thinking needs highly qualified and intrinsically motivated employees. This is closely linked to learning and education. Companies as well as universities should think about new ways to qualify professionals for the challenge of dealing with complex business problems. This is about collaborative knowledge construction in groups, multiple perspectives, coaching and scaffolding, and authentic assessment (Herrington and Oliver, 2000). Technical knowledge is of importance, but we have to "equip students with meta competences going beyond cognitive knowledge" (Scheer et al., 2012, p.8). Universities and other institutions often struggle with this challenge. Against this background, strong efforts to foster workplace learning are needed. Furthermore, managers should be aware that design thinking comes along with some limitations. If design thinking processes mainly focus on customer needs, companies run the risk of losing balance and failing to sufficiently take other perspectives and stakeholder needs into account. Finally, not all kinds of problems (e.g., routine tasks) are suitable for design thinking.

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Identifying enablers of innovation in developed economies: A National Innovation Systems approach

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Abstract. It has been recognized that innovation drives the long-run economic growth of nations and increasingly governments are placing innovation at the center of their economic growth strategies. International variation in the investment on innovation presents an opportunity to examine key enablers of innovation-driving policy choices. Countries find themselves at different stages of economic development and innovation performance and so their relative levels of innovation inputs and outputs are likely to be different. In this study we employ a systems of innovation approach to examine what enables improvements in innovation potential among developed countries. Using data from the 2017 Global Innovation Index (GII) Report, we subjected 770 data measures to an analysis of 242 relationships involving changes in the GII's innovation inputs/outputs scores and overall innovation potential of 35 OECD countries over a five year period (2012 to 2016). Our findings suggest that instituting policies that improve access to open and competitive markets is the most significant enabler for raising a developed country's innovation potential.

Keywords. Innovation Enablers, Innovation Policy, OECD, Developed Economies, National Innovation Systems.

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1. Introduction

Countries increasingly recognize that innovation drives long-run economic growth and governments are putting innovation at the center of their growth strategies (INSEAD, 2017). Investment in innovation is an important contributor to productivity and the growth of an economy (Hassan and Tucci, 2009; Roberts, 1998; Chen, 2009; Chol, 1990). The extant literature on innovation's role on economic growth is voluminous (Mansfield, 1980; Romer, 1986; Griliches and Mairesse, 1986; Stokey, 1995; Fagerberg, 1994; Kirchoff, 1994; Wennekers, 1999; Audretsch, 1995; Abiad et. al., 1989). Growing attention to the Schumpterian theory of economic growth has drawn attention to the role that technological change and innovation play in achieving economic growth (Watkins et. al., 2015). This has attracted considerable research interest in the enablers of the innovation process itself (Crespo and Crespo, 2016; Furman, Porter and Stern, 2002; Lui and Buck, 2007; Grossman and Helpman, 1991). International variation in the investment on innovation presents an opportunity to examine key enablers of innovation-driving policy choices. Countries find themselves at different stages of economic development and innovation performance and so their relative levels of innovation inputs and outputs are likely to be different (Vivarelli, 2014; Watkins et. al., 2015; Crespo and Crespo, 2016). For innovation policy makers in developed countries the driver for improving their innovation potential is premised on the realization that while innovation (particularly that of a process orientation) can reduce employment, improving a country's potential to innovate will result in increased investment in capital goods, lower prices to drive consumption, new products and higher average wages (Vivarelli, 2014). A comprehensive review of the general literature dealing with innovation enablement was undertaken to determine a suitable conceptual framework and provide empirical support for the relationship within inputs and outputs of innovation (predicator variables) and with the Global Innovation Index (GII), (criterion variable). An analysis of the rankings of indices helps policymakers and governments, particularly in industrialized countries, to identify paths for future development and design innovation policies (Balzat and Hanusch, 2004; Mahroum and Al-Saleh, 2013). The principal research question driving this study is: What enables improvements in innovation potential among developed countries?

In total, 770 data measures were subjected to an analysis of 242 relationships involving changes in the GII's innovation inputs/outputs scores and overall innovation potential of 35 OECD countries over a five year period (2012 to 2016). This study adopted an indicators method of national innovation performance and considered the following characteristics (Grupp and Schubert, 2010): the indicators are of comparable importance as measures of the concept under study, the indicators are based on reliable statistics; the indicators hold their value over time; and the indicators are relevant to medium and long-term policy issues (Carayannis and Grigoroudis, 2014). To understand the key determinants that drive innovation, this study used Pearson correlation coefficients and stepwise linear regression modeling to observe the relationships among these determinants that might inform innovation policy-makers. This follows a "systems of innovation approach" (NIS) in terms of enablers of, or factors influencing, innovation. This approach includes economic, social, political organizational, institutional and other factors that influence the diffusion and use of innovation (Edquist, 1997b; Nelson, 1993, Lundvall, 1992).

We have organized our article by starting with a general discussion regarding innovation competitiveness and globalization. This is followed by some background regarding the concept of national innovation systems and then a description of what is involved in the GII framework. The next section describes the methodology we employed in our study followed by our results and discussion. We conclude with a discussion of the implications of our findings and identify some of the limitations of our study.

2. Innovation Competitiveness

Technology entrepreneurs often compete in dynamic and fierce environments (D'Aeni, 1994) and need to develop and commercialize new products in order to exploit promising market opportunities, generate cash flows and make a profit (Haeussler et. al., 2012). A knowledge-based global economy emphasizes the need of a country to develop its innovative potential, given that the competitive performance of a national economy depends on the formation of intellectual capital and the society's capacity to innovate (Carayannis and Grigoroudis 2014). Yet, developing, testing and commercializing innovations can be a costly and time consuming process and financial outcomes risky. In order to decrease the risks of innovation and achieve the benefits of innovativeness, it is important to understand the key enablers. One of the most important stimuli of innovativeness is public policy support (Wojnicka-Syez and Syez, 2016). The role of public policy in Schumpeterian economics generally reflects the importance of entrepreneurial start-ups in generating innovation, economic growth and competitiveness in globally linked markets (Ferreira et. al., 2017; Audretsch et. al., 2012). Researchers have sought to explain the determinants of innovation, from a micro perspective, by identifying a number of critical success factors of innovation such as the firm's size (Fritsch and Meschede, 2001), strategy and social capital (Balachandra and Friar, 1997). Other research has shown innovation determinates from a macro perspective, mainly from the research and development (R&D) function, patents and governance (Fagerberg and Srholec, 2008; Becheikh at al., 2006a). According to an OECD survey on a sample of 20 OCED countries over the period 1982-2001, the main determinants of countries innovativeness appear to be the availability of scientist and engineers, research conducted in the public sector, business-academic links, the degree of product-market competition and the a high level of financial development and access to foreign inventions (OECD, 2005: 33).

The link between R&D and other macro functions is of great interest to governments (MacPherson, 1997). Governments formulate policies and offer services destined to promote and support technological innovation, with the hope that it will translate into higher levels of innovation, growth and internationalization of firms (Raymond and St. Pierre, 2010; Ouellet and Raoub, 2006). Ultimately this strategy leads to innovation as a competitive advantage. Porter's seminal work developed this linkage when he identifiedtwo existing models that make a country and organization competitive: the first model uses efficiency as the source of competitive advantage and is mainly operated by multinationals; the second model is based on innovation and growth to meet the individualized needs of the consumer (Porter, 1991). This environment emphasizes technological progress powered by entrepreneurship and innovation and leads to the creation of product and process innovations. Later work by the Global Entrepreneurship Monitor (2016) described this type of environment as "innovation driven" and found within advanced global economies. These economies have the ability to produce innovative products and services at the global technological frontier using the most advanced methods and are the dominant source of competitive advantage. At this stage, the national business environment is characterized by the presence of deep clusters. Clusters become critical motors not only in generating productivity but encouraging innovation at the world frontier. Institutions and incentives supporting innovation are also well developed, increasing the efficiency of cluster interaction. Companies compete with unique strategies that are often global in scope, and invest strongly in advanced skills, the latest technology, and innovative capacity (Delgado et. al., 2012). Therefore, innovation-driven competitiveness is critical for a country's long run economic performance (Carayannis and Grigoroudis, 2014).

3. A Systems Approach to Innovation

The concept of National innovation systems (NIS) have its origin in the influential work of Joseph Schumpeter. He recognized that innovation and ultimately economic growth is not autonomous, being dependent on factors outside of it. Since these factors are many, no one-factor can ever be satisfactory (Schumpeter, 1947). Schumpeter's insight was further supported by research introduced in the late 1980s (Freeman, 1987; Dosi et. al., 1988) and expounded upon in subsequent years (Lundvall, 1992; Nelson, 1993; Edquist, 1997). Furman et al., (2002) defined NIS as the ability of a country – as both a political and economic entity- to produce and commercialize a flow of new-to-the world technologies over the long term and Oglobina et al. (2002) and Godin (2007) found that such ability relies on a larger system composed of national institutional sectors and their environments. Lunval (2007) identified two schools of thought in the literature about NIS. The first, tends to define innovation in a narrow sense by focusing on science and technology policy, and mostly analyzes the systemic relationships between R&D efforts in firms. The other school of thought looks at innovation in a broader sense and defines innovation as a continuous cumulative process involving not only radical and incremental innovation, but also the diffusion, absorption and use of innovation, beside science (Nasierowski, 2009). The framework also emphasized the relationships between the components or sectors as the "cause" explaining the performance of innovation systems (Godin, 2007). In short, a national innovation system can be perceived as a historically grown subsystem of the national economy in which various organizations and institutions interact with and influence one another in the carrying out of innovative activity (Balzat and Hanusch, 2004). The systemic approach to innovation is based on the notion of non-linear and multidisciplinary innovation processes. Interactions on the organizational level as well as the interplay between organizations and institutions are given central significance (Nelson, 1993). This in turn is consistent with the dynamics capabilities concept of strategy, that sees a firm's ability to deploy and exploit resources as critical to its competitiveness (Amit and Schoemaker,1993; Teece et. al., 1997). For firms engaged in innovation commercialization within fast-changing environments, a Schumpeterian approach to innovation is likely to be more important (Lim et al., 2013). Ultimately, the NIS approach not only contributes to innovation, but is almost totally defined in terms of, and dedicated to, innovation as commercialization of technological invention (Godin, 2006a).

Connecting the level of NIS development with the level of economic advancement along structural and institutional development is critical in order to avoid defining pathways that are impossible to achieve (Gu, 1999, Watkins et al. 2015). High income and low income countries demonstrate different paradigms of economic development, and as such, the dimensions that support their innovation performance should be distinct (Watkins et. al., 2015; Crespo and Crespo, 2016).

3.1 GII Innovation Framework

Since the late 1990s, the most collective approach to compare the performances of different innovation systems is the use of indices and rankings. The appeal of indices and rankings is based on political and operational importance for decision-making. An analysis of the rankings of these indices helps policymakers and governments throughout the world, particularly in industrialized countries, to identify paths for future development and design innovation policies (Sonorexa and Moodie, 2013). In 2007, the INSEAD Business School, Cornell University, and the World Intellectual Property Organization (WIPO) developed the GII to evaluate the level of innovative potential in national socioeconomic systems and to support the development of policies and practices that stimulate innovation. The use of this particular index as a measure of national innovation capability has been recognized in the recent innovation literature (Al-Sudairi et al., 2014; Crespo & Crespo, 2016; Jackson et al., 2016; Sohn et al., 2016; Prim et al., 2017). The GII depends on two sub-indices, each one developed on several enablers. Over time, this index has improved, and by 2015 included 79 indicators divided into 5 input enablers (institutions, human capital and research, infrastructure, market sophistication and business sophistication and two output enablers, knowledge and technology outputs and creative outputs.

4. Methodology

Each of the innovation inputs and innovation outputs contained within the GII framework are measured for each country by using a number of metrics that are combined to provide their respective scores. The input/output scores are then aggregated to provide an overall innovation potential score for each country in the study. The measures included in the GII framework are described in the Appendix. For the purpose of further analysis we have created a conceptual model as shown in Figure 1. The authors (Dutta et al. 2016, pg. 49) of the GII recognize that it is not a tool that can provide *"the ultimate and definitive ranking of economies with respect to innovation"* but they support their framework by stating that *"The rich metrics can be used – on the level of the index, the sub-indices, or the actual raw data of individual indicators – to monitor performance over time and to benchmark developments against countries in the same region or of the same income category."*

With that observation in mind, and the empirical evidence within the literature that supports isolating high income from low income countries when using the GII for analysis (Crespo and Crespo, 2016), we have chosen to focus on the GII data associated with OECD member countries. Accordingly our principal research question that we seek to address is "what enables improvements in innovation potential among developed countries"?

To measure improvement or deterioration in a country's innovation potential we have chosen to compare the change in a country's GII score with changes in both innovation inputs and outputs over a five year period (2012-2016) relying on data published annually by Cornell University, Insead and the World Intellectual Property Organization in their Global Innovation Index report. Our sample is comprised of 35 country members of the Organisation for Economic Co-operation and Development as listed in Table 1. Given the continuous nature of the scoring data, a Pearson correlation was run to determine if there were any significant relationships between increases or decreases in a country's GII score over that five year period when compared to any increases or decreases in a country's scores for each of the innovation inputs and outputs, Upon determining statistically significant relationships, and in order to explore for any predictive variables, stepwise linear regression modelling was undertaken. Our sample of developed countries are missing only three of the total number of developed economies as identified by the United Nations; Bulgaria, Croatia and Cyprus.[1]

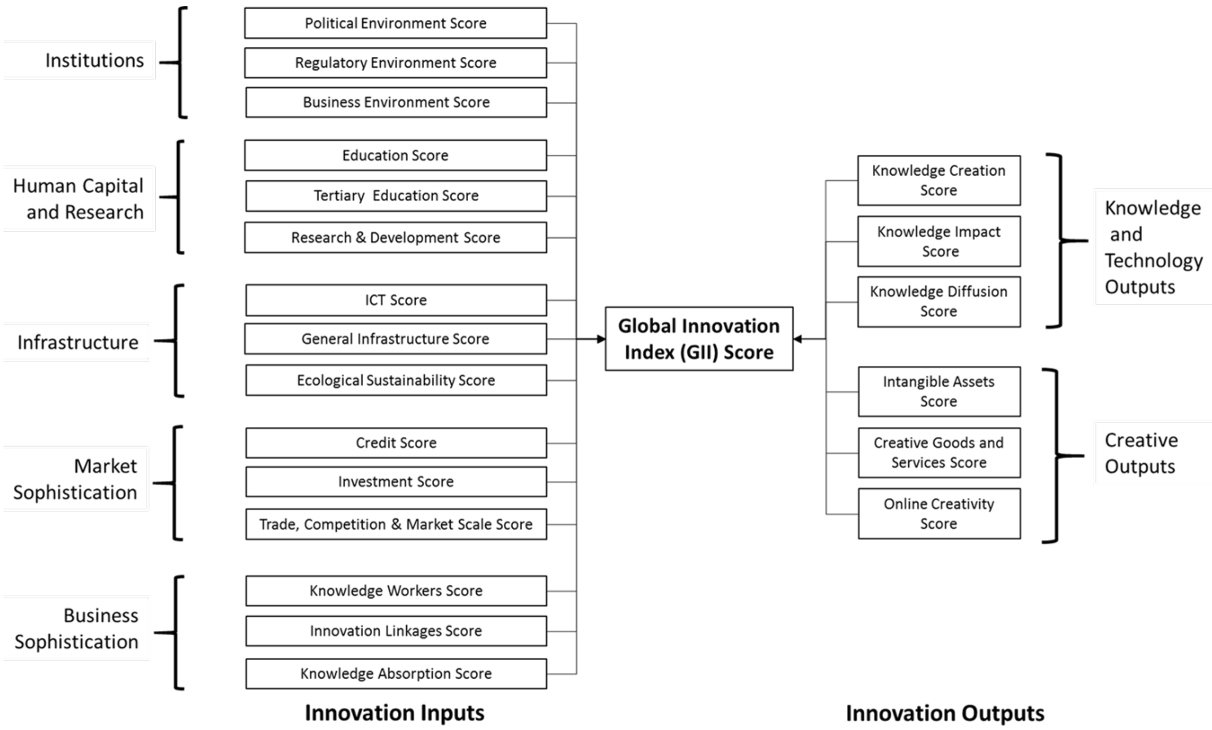

Fig. 1. Drivers of Innovation Research Model after Dutta et al. 2016

The change in GII score is the dependent variable and changes in those innovation inputs or outputs that were statistically significantly correlated to GII are the independent variables. In addition, we wish to further examine any innovation inputs or outputs that might influence the predictive variables by identifying any statistically significant correlations between them. As the GII score is determined using the respective country's innovation inputs and output scores we are watchful for any collinearities that might exist in the data. Accordingly we will test for multi-collinearity between variables by calculating the variance inflation factor (VIF) in our regressions and employ the Durbin-Watson test on any regression models.

[1] http://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

5. Results and Discussion

In total, 770 data measures were subjected to an analysis of 242 relationships. Table 2 provides the results of the Pearson correlations between the 5 year change in GII score and the corresponding changes in scores for innovation inputs. A statistically significant and strongly positive relationship (R=.515, p = .002) was found between a change in a country's Trade, Competition and Market Scale (Trade et al) score and the change in its GII score. This result is not surprising given that improving the market conditions for trade, encouraging competition that might stimulate innovation among market participants, and increasing the scale of the domestic market and its innovation capacity could positively impact a country's ability to advance its innovation potential. Our result also finds support in the literature. Baldwin and Gu (2004) in their empirical study of trade liberalization and increased export capacity in Canada found that improving access to export markets increased the innovative capacity of firms. In a literature review on the relationship of market scale and innovation, Dubois et al. (2015) found that for large industries like the pharmaceutical industry, the larger the market the greater the amount of innovation and while Stagni et al. (2017) found that increased competition can limit the type of innovation they also discovered that competition increases firm diversification and innovation exploration. A more moderate, yet statistically significant, positive relationship was found to exist between the change in a country's GII score and its knowledge absorption score.

Table 1. OECD sample countries

Country	Gross Domestic Product (GDP) (2016) in US$ billions[1]	GII Income Group	GII Region
Australia	1,256.6	High Income	SE Asia, East Asia, and Oceania
Austria	387.3	High Income	Europe
Belgium	470.2	High Income	Europe
Canada	1,532.3	High Income	Northern America
Chile	234.9	High Income	Latin America and the Caribbean
Czech Republic	193.5	High Income	Europe
Denmark	302.6	High Income	Europe
Estonia	23.5	High Income	Europe
Finland	239.2	High Income	Europe
France	2,488.3	High Income	Europe
Germany	3,494.9	High Income	Europe
Greece	195.9	High Income	Europe
Hungary	117.1	High Income	Europe
Iceland	19.4	High Income	Europe
Ireland	307.9	High Income	Europe
Israel	311.7	High Income	Northern Africa and Western Asia
Italy	1,852.5	High Income	Europe

Country	Gross Domestic Product (GDP) (2016) in US$ billions[1]	GII Income Group	GII Region
Japan	4,730.3	High Income	SE Asia, East Asia, and Oceania
Korea, Republic of	1,404.4	High Income	SE Asia, East Asia, and Oceania
Latvia	27.9	High Income	Europe
Luxembourg	61.0	High Income	Europe
Mexico	1,063.6	Upper-Middle Income	Latin America and the Caribbean
Netherlands	769.9	High Income	Europe
New Zealand	179.4	High Income	SE Asia, East Asia, and Oceania
Norway	376.3	High Income	Europe
Poland	467.4	High Income	Europe
Portugal	205.9	High Income	Europe
Slovakia	90.3	High Income	Europe
Slovenia	44.1	High Income	Europe
Spain	1,252.2	High Income	Europe
Sweden	517.4	High Income	Europe
Switzerland	662.5	High Income	Europe
Turkey	735.7	Upper-Middle Income	Northern Africa and Western Asia
United Kingdom	2,649.9	High Income	Europe
United States	18,561.9	High Income	Northern America

[1] As reported by GII

The GII measures knowledge absorption principally through the ability of a country's high tech sector to acquire information and information technology related to innovation, to encourage inflows of foreign investment that will allow domestic firms to be exposed to global innovation, and the measure of local professionals engaged in acquiring intellectual property. To find in the data a positive relationship between greater knowledge absorption and a county's improved GII score is also reasonable and is consistent with the work of Forés and Camisón (2016) who found that the absorptive capacity of firms has a significant positive effect on innovation performance.

Table 3 contains the results of the Pearson correlations between the 5 year change in GII score and the corresponding changes in scores for innovation outputs. Moderate and statistically significant relationships exist between the increase in a country's overall innovation score and its ability to improve knowledge creation capabilities (R=.475, p = .004) and the ability to diffuse that knowledge (R=.386, p = .022). The latter result is interesting because the GII framework is designed so that knowledge diffusion output measures are a "mirror" of the knowledge absorption

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input measures (Dutta et al. 2016, p.55). As opposed to the ability to acquire information as a benefit for enhancing innovation, the diffusion output measures the value received (royalties and fees, technology exports, foreign direct investment) for being able to disseminate the knowledge derived from innovation activities. Given the framework design, to find similar results for both as significant contributors to a country's overall innovation potential is therefore not unsurprising. Furthermore, these results are consistent with the description by Zanello et al. (2016) that the innovation process is one where investments are made in knowledge building activities that support the creation, diffusion and absorption of innovation. Finally, a moderate relationship exists between that the intangible assets associated specifically with creative outputs and the overall growth in a nation's innovation standing (R=.486, $p = .004$). The output measures include national trademark and design applications as well as the use of ICT within the businesses and organizations of the country. The literature continues to support these measures as contributors to improving regional or national innovation potential and support our findings here (Billon et al. 2017; Khedhaouria and Thurik, 2017).

Having identified some significant relationships between improvements in specific inputs and outputs and overall improvement of a country's innovation standing we now focus on their predictive capabilities. Stepwise regression was employed to determine the relative predictive contribution of each

Table 2. Correlations – Change in Innovation Inputs Score with Change in Global Innovation Index Score (n=35)

Human Capital and Research			
	Education	Tertiary Education	Research and Development
Pearson Corr.	.008	.063	.231
Sig.	.963	.720	.181

Infrastructure			
	Information Communication Technology (ICT)	General Infrastructure	Ecological Sustainability
Pearson Corr.	.080	.214	-.297
Sig.	.648	.217	.083

Market Sophistication			
	Credit	Investment	Trade, Competition & Market Scale
Pearson Corr.	-.157	-.135	.515**
Sig.	.367	.438	.002

	Business Sophistication		
	Knowledge Workers	Innovation Linkages	Knowledge Absorption
Pearson Corr.	.208	.262	.410*
Sig.	.230	.129	.014

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlations – Change in Innovation Outputs Score with Change in Global Innovation Index Score (N=35)

	Knowledge and Technology			**Creative Outputs**		
	Knowledge Creation	Knowledge Impact	Knowledge Diffusion	Intangible Assets	Creative Goods and Services	Online Creativity
Pearson Corr.	.475**	.223	.386*	.486**	.271	.317
Sig.	.004	.198	.022	.003	.115	.063

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

to multi-variate regression models. Table 4 provides the results of the regressions with Trade et al, Knowledge Diffusion and Intangible Assets being included in the predictive models and Knowledge Absorption and Knowledge Creation being excluded. Model 3 combined all three predictive variables improving the total correlation co-efficient or strength of association (R=.714) and resulting in a relatively high explanation of variance (R^2= .549). The validity of Model 3 was examined by firstly adjusting the R^2 for the number of independent variables included in the model. The result indicating that the model continues to explain or predict over half of the variability of the increase in the GII score (Adjusted R^2 = .505). A Durbin-Watson test was conducted to identify if any autocorrelation or non-independence exists within the variables and the test outcome approaches 2 (1.984) confirming the independence of the data. Finally, multicollinearity within the data was analyzed to determine if the variance of the co-efficient estimate was being influenced by any collinearity between the predictor variables. Both the Tolerance and VIF tests approach 1 suggesting little multicollinearity. We rely on the work of Knofczynski and Mundfrom (2008) to confirm whether the level of predictive strength given the sample size of 35 is appropriate. With an R^2 of 0.549 and three predictor variables in our model, their sample size recommendation for a "good prediction level" (pg. 438, Table 1) lies between 33 and 39.

Table 4. Predictive model (stepwise regression) for GII improvement

Model	**R**	$\mathbf{R^2}$	**Adjusted** $\mathbf{R^2}$	**R Square Change**	**Durbin-Watson**
1	.515[a]	0.265	0.243	0.265	
2	.695[b]	0.484	0.451	0.218	

Model	R	R^2	Adjusted R^2	R Square Change	Durbin-Watson
3	.741[c]	0.549	0.505	0.065	1.984

a. Predictors: (Constant), Trade

b. Predictors: (Constant), Trade, Knowledge Diffusion

c. Predictors: (Constant), Trade, Knowledge Diffusion, Intangible Assets

d. Dependent Variable: GII

Excluded Variables

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1		.269[b]	1.752	0.089	0.296	0.890	1.123	0.890
	Knowledge Creation	.344[b]	2.320	0.027	0.379	0.894	1.118	0.894
	Knowledge Diffusion	.472[b]	3.679	0.001	0.545	0.978	1.022	0.978
	Intangible Assets	.286[b]	1.611	0.117	0.274	0.676	1.480	0.676
2	Knowledge Absorption	.114[c]	0.789	0.436	0.140	0.788	1.270	0.788
	Knowledge Creation	.226[c]	1.660	0.107	0.286	0.827	1.209	0.827
	Intangible Assets	.311[c]	2.117	0.042	0.355	0.674	1.483	0.669
3	Knowledge Absorption	.088[d]	0.640	0.527	0.116	0.781	1.280	0.614
	Knowledge Creation	.168[d]	1.242	0.224	0.221	0.780	1.282	0.636

a. Dependent Variable: GII

b. Predictors in the Model: (Constant), Trade

c. Predictors in the Model: (Constant), Trade, KnowDiffusion

d. Predictors in the Model: (Constant), Trade, KnowDiffusion, IntangibleAss

The strongest singular predictive variable; Trade et al., is moderately and positively (R= .489 p = .003) associated with the Research and Development score. This association was also found by Silaghi et al. (2014) in their economic study of eastern and central European countries where they found that increases in research and development by businesses in those countries were linked to economies that encouraged more trade and competitive (open) markets. Furthermore, scores for both Trade et al. and Research and Development

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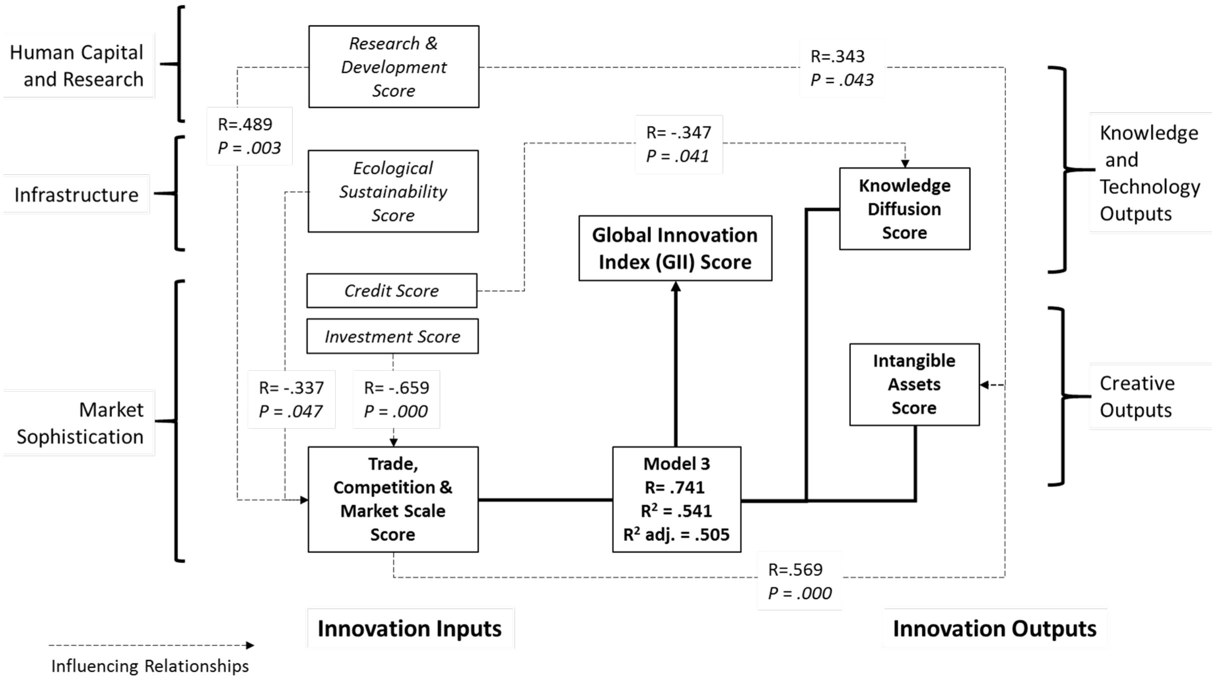

Fig. 2. Innovation drivers influencing predictive Model 3.

were also found to have moderate positive relationships (R= .569 p = .000 and R= .343 p = .043 respectively)with improvement in the Intangible Assets score, another of Model 3's predictive variables. The association of trademark applications, industrial design applications, and ICT with (Intangible Assets measures) the measures of Research and Development (R&D expenditures) would seem logical as they are recognized outputs of the R&D process. More significant is the relatively strong relationship with greater trade, more competitive markets and increased market scale, further confirming the collective role they have in promoting growth in innovation.

There are a three negative associations that have arisen from our analysis and they are worth discussing here. The strongest and most statistically significant is the inverse relationship between the change in a country's Trade et al. score and its Investment score (R= -.659 p = .000). This result suggests that those countries who increased trade and market competition experienced decreased levels of domestic investment in publicly-traded companies. With increased competition at home, domestic investors might wish to seek opportunities elsewhere to invest their capital especially if external markets are opened as a result of the introduction of open trade policies. We found another more moderate negative correlation (R= -.347 p = .041) between a country's Credit score and its Knowledge Diffusion score. As countries improved the ability to borrow they saw a decline, in some combination of high-tech and ICT exports, related royalty and licence fees, and net outflows of FDI as a percentage of their gross domestic product (GDP). It is likely the effect is due to the latter, rather than the former, as improving domestic borrowing capacity should encourage domestic lenders to loan capital at home and perhaps limit their investment in external economies, thus reducing the FDI outflows. With the former, increased access to capital should support the ability to fund, and therefore increase, exports. Our final negative association was also a moderate one and was observed between the Trade et al. and Ecological

Sustainability innovation inputs (R= -.337 p = .047). From our finding it could be argued that even in developed countries the improving of trade, competition and market scale results in a reduction of some combination of energy efficiency, and environmental performance and compliance. This observation is consistent with the literature in finding that increased open trade and market scale led to greater negative environmental footprints (Al-Mulali and Ozturk, 2015), even specifically within OECD countries (Shafiei and Salim, 2014).

6. Conclusion and Limitations

The principal research question driving this study was: What enables improvements in innovation potential among developed countries? Developing economies can no longer rely on labour-intensive industries for economic growth and job creation as those industries have moved to developing countries with lower wages and lower costs of operation. In developed countries, policy innovation should remain focused on encouraging inputs and outputs that improve a nation's potential to innovate. This study explored innovation enablers that have a relationship with high innovation performance using an NIS approach. We relied on correlations and regression to identify the specific enablers that contribute to improving a country's innovation potential. By using GII data, we have attempted to understand what NIS' key elements may be more relevant to designing policy for enhancing innovation performance. In this study, we subjected 770 data measures to an analysis of 242 relationships between GII's innovation inputs, outputs and overall innovation potential among 35 OECD countries resulting in the identification of statistically significant relationships between the improvement of certain input/output scores and a nation's total GII score. We used those relationships to produce a predictive regression model that could inform policy on improving a country's innovation capacity. Before stating our conclusions we need to be clear that we are not suggesting that policies to promote innovation within developed countries should exclude any of the many inputs and outputs identified in the GII. Rather, we have attempted to isolate those input/outputs that policy makers may wish to focus on when considering innovation policy.

In terms of our results, we were surprised to find that, with the large number of innovation inputs and outputs contained within the GII framework, there were such few statistically significant relationships found when comparing changes in input/output scores with changes in the total GII score over a recent five year period. However, we find the aggregate predictive model that did emerge is significant in its strength and fit. Therefore we conclude that for the developed nation, the initial focus might be on policies that promote open, competitive markets and the enabling of hi-tech and ICT exports. Furthermore, policy support for continued creative outputs and the development and use of ICT might also be considered. As discussed in our results, there are important relationships with other innovation inputs and outputs that must be considered when structuring policy as suggested. Certainly, the resulting positive association between open, competitive markets that encourage trade, competition and increase in market scale and increased research and development and creative output would be seen by policy makers as beneficial to increased innovation capacity.

However, caution must be taken as some moderate to strong negative associations may exist when focusing policy on the results of our predictive model. The most significant may be the potential for decreased investment in domestic capital markets as policies for expanding open-trade and increased competition might encourage domestic investment to seek opportunities externally, especially if reciprocal open market agreements provides access to external markets. The other is the potential environmental impact arising from policies that stimulate economic growth such as easing trade and opening markets. Policy makers may need to consider the importance of balance between innovation and economic need with protection of the environment. Perhaps more importantly, policy that continues to support environmental innovation can be integrated into open market policies in order to mitigate some of the potential harm that may arise.

There are some limitations with our study. We have relied on the integrity of the data presented within the GII report and would recommend that readers review the methodology contained within that report in order to assist in understanding why we have chosen to use this data. Furthermore, we have chosen the scores for each of the inputs and outputs identified by the GII for our statistical measures but we recognize that each input/output is an aggregation of a number of measures that make up the score. Further research might look into specific correlations and regressions within this larger data set. We have also limited ourselves to the most recent five year period and the changes in score of each input/output for the 35 OECD countries to generalize on innovation policy for developed nations. The statistical significance of the correlations and the prediction level of our model may be reasonable but we must rely on the fact that our sample represents almost all of the countries currently defined as developed countries by the United Nations in order for us to make our generalizations.

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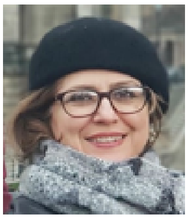

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