Running an Innovation Engine in High-Tech Product Business

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Abstract
Vaisala is a Finnish stock-listed technology company founded in the 1930s. The company has a successful innovation track record, and its Industrial Measurements business unit has performed financially successfully over the past years. However, its innovation practices are conservative with respect to the literature and practices in more dynamic business environments. Because financial impact of innovation show with a delay and the innovation practices in Industrial Measurements have not been thoroughly benchmarked earlier, this thesis examined the key enablers for an Innovation Engine in such a high-technology hardware product business context. This qualitative research was based primarily on five internal and twelve benchmark interviews, and as a result, I propose managerial implications for five identified development areas for the case company. According to my analysis, the business unit needs to adopt a wider exposure to external knowledge, and it needs to create an innovation strategy that defines how and where innovation is sought. Moreover, a systematic process for validated learning that is shared for all initiatives needs to be adopted in the business unit. Then, through the implemented strategic guidance, systematic validation process and leadership, a more focused portfolio and shorter projects with a rapid cadence need to be achieved in initiatives. Finally, for an optimized performance in each innovation initiative, Industrial Measurements need to adopt diverse cross-functional teams with integrated market and customer need understanding and strive for a more holistic approach for business cases.

Keywords Innovation Strategy, Technology Management, Collaborative Capability, Corporate Entrepreneurship

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Tiivistelmä

Vaisala on suomalainen pörssilistattu teknologiayritys, joka perustettiin 1930-luvulla. Yrityksellä on menestyksekäs innovaatiohistoria, ja sen teollisten mittausten liiketoiminta-alueen taloudellinen menestys on viime vuosina ollut erinomaista. Sen innovaatiokäytännöt ovat kuitenkin kirjallisuuteen ja dynaamisempiin liiketoimintaympäristöihin verrattuna varsin konservatiivisia. Koska innovaatioiden taloudelliset vaikutukset näkyvät viiveellä ja koska liiketoiminta-alueen innovaatiokäytäntöjä ei ole aiemmin kokonaisvaltaisesti verrattu muihin toimijoihin, tämä opinnäytetyö selvitti, mitkä ovat avaintekijät innovaatiokoneelle tällaisessa korkean teknologian tuoteliiketoiminnassa. Tämä kvalitatiivinen tutkimus perustui pääasiassa viiteen sisäiseen ja kahteentoista ulkoiseen haastatteluun, ja tuloksena esitän johdolle suosituksia viiteen tunnistettuun kehitysalueeseen. Analyysini perusteella teollisten mittausten liiketoiminta-alueen tulisi altistua laajemmin ulkopuoliselle tiedolle ja luoda innovaatiostrategia joka määrittelee, miten ja mistä innovaatiota etsitään. Lisäksi liiketoiminta-alueen tulisi ottaa käyttöön järjestelmällinen prosessi validoidulle oppimiselle jota sovelletaan kaikkiin innovaatiohankkeisiin. Innovaatiostrategian ja järjestelmällisen validointiprosessin sekä oikeanlaisen johtamisen tulee johtaa rajatumpaan projektiportfolioon sekä lyhytkestoisempiin ja nopeatahtisempiin hankkeisiin. Monialaiset tiimit, joihin sisältyy markkinoiden ja asiakastarpeiden ymmärrys, sekä kokonaisvaltaisempi lähestymistapa uusien liiketoimintavaltausten suhteen auttavat yritystä saavuttamaan paremman suorituskyvyn innovaation suhteen.

Avainsanat Innovaatiostrategia, Teknologiajohtaminen, Yhteistyökyvykkyys, Sisäinen yrittäjyys

Preface

Writing this thesis has been an exciting journey. I am thankful that I could work with a topic that combined my interests in both deep technology but also commercial and strategic viewpoints on innovation.

Having worked in Vaisala since the summer 2015, I have seen different viewpoints on innovation. In earlier scientist roles I learned how broad and deep the world of external technology outside Vaisala is, and how entrepreneurial practices can be adopted on new product development. In my current role as Business Development Manager in the Liquid Measurements product area, I work more closely with identifying customer needs, linking those into technological capabilities and validating business cases from a commercial and holistic perspective.

At the same time, because my studies in the School of Business were conveniently nearing the completion, this thesis was a perfect opportunity for me to revise my thoughts from work experience and deepen further into the innovation management theme.

First and foremost, I would like to thank my advisor, Hannu Talvitie, for making this possible, for his support and for the enthusiastic chats that ranged from broad strategic themes to technical nitty-gritty. It was a great pleasure to work with you and I learned plenty from you. I want to thank my supervisor, Jutta Hakkarainen, who not only allowed me to flexibly use a small work time allocation on my thesis alongside with my role, but also providing great insights in an interview. I would also like to express my gratitude to my supervisor, professor Henri Schildt, for his sharp thinking, tips and guidance on theory and writing topics.

Finally, I warmly thank all the interviewees who took the time from their busy schedules to discuss innovation and share their valuable insights. It was enlightening to learn viewpoints from innovative companies other than Vaisala on how innovation is and should be done.

I hope this thesis not only initiates discussion and action for better innovation within Vaisala, but also shares fruitful theoretical and practical insights for other managers in a similar context.

Espoo, 28.8.2023

Markus Huuhtanen

Contents

Abbreviations

AMMONICAP	Vaisala's capacitive ammonia sensing technology (®)
BAROCAP	Vaisala's capacitive pressure sensing technology (®)
CARBOCAP	Vaisala's optical gas sensing technology (®)
DRYCAP	Vaisala's capacitive dew point sensing technology (®)
DGA	Dissolved Gas Analysis
FPI	Fabry-Perot Interferometer
FTIR	Fourier-Transform Infrared
HUMICAP	Vaisala's capacitive humidity sensing technology (®)
HVAC	Heating, Ventilation and Air Conditioning
IP	Intellectual property
KPI	Key Performance Indicator
MEMS	Micro-Electro-Mechanical System
MGP261	Vaisala Methane, Carbon Dioxide and Humidity Multigas Probe
MVP	Minimum Viable Product
OPT100	Vaisala Optimus™DGA Monitor
R&D	Research and Development
SAFe	The Scaled Agile Framework
SPECTRACAP	Vaisala's optical oxygen sensing technology (®)
TRIZ	Theory of Inventive Problem Solving framework
VIM	Vaisala Industrial Measurements business unit
VTT	Technical Research Center of Finland
WXT	Vaisala's Compact Weather transmitter product series

1 Introduction

1.1 Background

Vaisala is a Finnish stock-listed company serving customers globally with measurements in two business areas: Weather and Environment (WEA) and Industrial Measurements (VIM). Professor Vilho Väisälä was enthusiastic in solving the problem of weather forecasting, from both theoretical and practical perspectives. He founded the company Vaisala in the 1930s after having found a Soviet radiosonde and the realization it could be made better (Michelsen, 2006). Radiosonde is a battery-powered device that is sent up to stratosphere with a weather balloon, measuring and transmitting weather data.

Until the 1970s, reliable humidity measurements in radiosondes had been an unresolved problem (Vaisala, 2020d). The next step for better soundings and weather prediction required development of a humidity sensor for extreme conditions. Firstly, measurement needed to be fast, as during the weather balloon fly up to dozens of kilometers, it needs to measure as many data points as possible. Moreover, the sensor needed to be highly robust to tolerate the harsh environment such as extreme temperature variations and condensed water in clouds. The task was not simple, but through collaboration with Technical Research Center of Finland VTT (Puurunen, 2014), the company assimilated the HUMICAP humidity sensor technology, which strengthened Vaisala's position as the market leader in weather and environmental measurements.

Having been successful in its initial sounding application, it was noticed that the HUMICAP humidity sensor technology had more potential. This was the start of the business area that today is known as Industrial Measurements. Over the years and through product leadership strategy, Vaisala has been able to achieve a winning position in selected niche industrial applications in industrial humidity and dew point measurements. Today, the sensor technology is utilized in greenhouses, bakeries, construction sites, warehouses, kilns and museums (Vaisala, 2020d).

The history from over eight decades proves that the company has indeed been able to both invent and acquire new technologies as well as commercially benefit from them. The VIM business area has been able to expand and grow from humidity to many new parameters. By continuing to heavily invest in research and development and collaboration with VTT (Vaisala, 2020b), the company has extended its technology capabilities into micro-electro-mechanical (MEMS) based components manufactured in the company's own cleanroom, such as the optical gas sensors, known as CARBOCAP technology, as well as pressure sensors, known as BAROCAP technology. Moreover, the company has expanded into new markets through acquisitions, such as continuous monitoring systems through the Veriteq acquisition (Vaisala, 2010b) and in-line liquid measurements through the K-Patents acquisition (Vaisala, 2018).

Industrial customers are typically rather conservative, and change cycles in the market are slow. Sugar is refined, salad is grown, cookies are baked, concrete is casted and pharmaceuticals are stored in relatively same way as it has been done for a long time already. Still, the business environment today is different today than it was a few decades ago. Although cycles are slow, new openings in terms of measurement technologies or competitors have risen in the scene. Moreover, the whole world has become more volatile, uncertain, complex and ambiguous, also referred to as VUCA (Bennett & Lemoine, 2014). Not only the growth imperative (Christensen & Raynor, 2004) continues to force companies in seeking continuous economic growth and constantly exceed expectation of shareholders, but also significance of ecological, social and governmental sustainability has risen in the current discourse. What's more, the COVID-19 pandemic forced many knowledge workers to homes working remotely, limiting interaction and ideation potential for further innovation.

Moreover, the paradigm in technology and innovation management has changed. Whereas earlier focus in high technology companies was in development of in-house technologies in Research and Development (R&D) *fortresses* and protecting the technologies by tight appropriability regimes (Teece, 1986), today Open Innovation (Chesbrough, 2003), organizational linkages and Ambidexterity (Felin & Zenger, 2014; Taylor & Helfat, 2009) and orchestrating innovation networks (Dhanaraj & Parkhe, 2006) are emphasized much more. Companies that are able to value, assimilate and apply new knowledge faster than competitors, win (Zahra & George, 2002).

During the past few decades, startups and growth companies have revolutionized many industries such as the fintech, health, logistics, retail and hotels. The Lean Startup methodology developed by Ries (2011) and Design Thinking (T. Brown, 2008) have become dominant frameworks to boost time-to-market and ensure product-market fit through validated learning and customer interaction. Whereas software startups have been as the basis of both Design thinking (T. Brown, 2008) and Lean Startup (Ries, 2011), it has become apparent that also hardware-based businesses have much to learn. Moreover, not only startups, but also big corporations such as General Electric have adopted the methodology and intrapreneurial mindset.

In this thesis I investigate what are the key building blocks of an Innovation Engine in a slowly changing high-technology hardware product-based business, using VIM as a case study. Current innovation practices in VIM appear relatively conservative when we compare them to the evolving landscape of innovation in the world, other businesses or literature. Despite the fact that the business unit exhibited strong financial performance over the past 8 years, it is crucial to discover and implement essential innovation practices now because financial outcomes of such practices show with a delay in the slowly changing industrial business environment. Furthermore, thorough analyses or benchmarks of innovation practices have not been conducted previously in VIM.

1.2 Definitions

Adapting from Bekkers and De Stobbeleir (2011) and Hackett et al. (2008), I define technology as the application of scientific understanding into practical purposes. It can be considered as the practical implementation of knowledge from a variety of scientific field such as mathematics, engineering, biotechnology, material science and information technology.

With invention I mean creation of a component, product or system that has not existed before (Drucker, 2014). Novelty is what differentiates invention from other products. In the context of this thesis, I consider that an invention needs to involve utilizing a technology in a new way but also it needs to be something that can solve a particular problem or satisfy a need.

I define innovation as a technological invention that has substantial commercial potential. This adds to the aforementioned definitions of technology and invention the crucial component of commercial success. The definition is adapted from Drucker (2014), who argues that not only inventing new technologies and products are crucial, but implementing and commercializing them successfully to the market is equally important.

By Innovation Engine, then, I mean the company's capability to systematically and repeatedly generate, develop and implement innovative ideas. The definition is adapted from Chesbrough et al. (2006). A well-oiled Innovation Engine is a system that allows continuous growth through repeatedly creating successful new products. The abstract term includes all relevant practices and processes in the organization that fuel innovation performance and therefore contribute to the company growth and competitiveness.

1.3 Research question

My research question in this thesis is:

> *What are the key enablers for an Innovation Engine for in a high-technology hardware product based business context such as the Vaisala Industrial Measurements (VIM)?*

This broad research question includes the fact that those key enablers were previously unknown for VIM. The question is framed for high-technology hardware product business, scoping out for example digital innovation where practices and processes for an Innovation Engine could be very different due to the more dynamic business environment. Furthermore, through the definition of innovation and including the words *hardware product* in the research question, I elaborate that the thesis focuses on studying practices and processes that lead to product innovation and not, for example, business model innovation or process innovation.

Based on the literature review, chosen research method and my analysis based on the internal interviews, the research question is further divided into five development areas that I identified as themes where the case company, VIM, should improve:

Development area 1: Identification of new business opportunities

Development area 2: Strategic guidance for innovation

Development area 3: Process and Validated Learning for new initiatives

Development area 4: Portfolio resourcing and focus

Development area 5: Organizational structure and culture to support innovation

This breakdown of the abstract research question into five areas allows then providing practical and applicable implications for managers. The proposals on each of the development area allow VIM to make targeted improvements in its practices to achieve a better-running Innovation Engine.

1.4 Thesis structure

This thesis is divided into six chapters. In chapter 2 I review the relevant literature regarding the innovation performance topic, including different innovation types, technology management, Open Innovation, product development processes, entrepreneurial practices and strategic views. Chapter 3 explains how I did internal and external benchmark interviews and how I applied the chosen qualitative research methodology. In chapter 4 I first analyze VIM with respect to past innovations and the current state and identify the development areas, and then provide results from analysis of the external benchmark interviews. Chapter 5 merges theory, VIM current state and benchmark interview insights into discussion and managerial implications that answer the research question. Finally, chapter 6 concludes the thesis.

2 Theory

Over multiple decades academic research has sought to find theories, frameworks and models that lead into innovation and commercial success. However, all frameworks have their specific context and limitations. A conceptual and abstract model lacks in giving practical and tangible guidance, whereas applied frameworks rarely fully work outside their initial context in a different time. Although no single theory will guarantee success, companies that achieve alignment by successfully adopting appropriate management theories can provide a competitive advantage (Powell, 1992).

In this chapter I cover essential and topical innovation, technology and venturing management theories and themes that are relevant in today's high technology innovation context. First, I start with describing what drives companies to pursue innovation and what kind of different innovation types exist. Then, I utilize a technology management framework as a map where further topics, such as Open Innovation, product development frameworks and entrepreneurial practices link. That is followed by considerations on what organizational capabilities and cultural aspects promote innovative performance, and finally, I conclude the chapter with strategic level insights on what literature suggests is needed for an Innovation Engine.

2.1 Innovation types

Growth imperative is a term that refers to the need of economic growth, which still today remains a necessity for many firms (Richters & Siemoneit, 2019). Because investors evaluate firms based on the current and discounted future value, owners' value only increase if the expectation of future value is exceeded (Christensen & Raynor, 2004). For the firm, this means constant need for innovation.

In addition to monetary value, the importance of sustainability has recently come to the forefront in innovation discourse. Sustainability means meeting the present needs while not compromising needs of future generations (UN, 1987). The 2018 Nobelists in Economic Sciences, William Nordhaus and Paul Romer have argued how innovation plays a crucial role in achieving sustainable development. Nordhaus (2019) has emphasized the need to incentivize innovation of clean low-, zero- or even negative-carbon technologies whereas Romer (2019) highlights the importance of knowledge spillovers and international flows of technology to promote sustainable development in poor countries. Sustainability-focused innovation is not only a necessity for future generations, but also presents business opportunities today.

As defined in Chapter 1, and following Christensen and Raynor (2004), I define innovation as a technical invention that has proven commercial success, but this success can be achieved from different perspectives. To help a company to find an appropriate approach, it is fruitful to identify the four innovation categories, summarized in Figure 1. From an external customer's perspective, innovation can be divided into sustaining innovation and disruptive innovation. Christensen and

Raynor (2004) define sustaining innovation to be targeted towards demanding high-end customers with better performance, whereas disruptive innovation targets to provide not-as-good products but from a simpler, more convenient or affordable way compared to existing offering. The rate of improvement that customers can fully utilize plays a key role in how sustaining or disruptive innovation generate competitive advantage — disruption often occurs when performance of sustaining innovation exceeds beyond what customers can absorb (Christensen & Raynor, 2004).

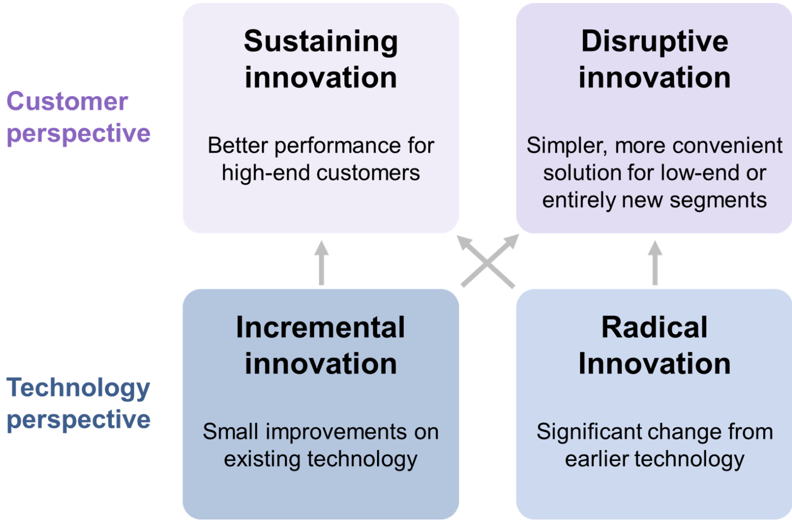

Figure 1: Innovation terminology used in this thesis, divided into customer and technology perspectives. Adopter from Christensen and Raynor (2004), Tushman and Anderson (1987) and Hopp et al. (2018).

Sustaining innovation is often dominated by established players in the market, as they have the best position to hear the existing customers and improve performance of the existing offering. Winning more market share or profits through sustaining innovation can happen through incremental development steps, a leapfrog over competitors' performance, or a technological breakthrough that lifts performance considerably. (Christensen & Raynor, 2004) Apple or BMW can be considered as examples of sustaining innovators who aim at serving most demanding high-end customer segments of their markets with better performance and profits.

New value through disruptive innovation can be created in two ways: new market or low-end. New market disruption means that the existing market is disrupted and existing products become obsolete through an innovation that serves a different customer segment more affordably and in a simpler way. Typically new market disruption targets non-consumption, as in offering something to customers who previously did not have access to such product, at a lower price and lower performance than the existing product base. (Christensen & Raynor, 2004) For example, in the 21st century smartphones brought many functions such as internet or digital photography capabilities to consumers' pockets, disrupting the personal computer and camera businesses. Low-end disruption, on the other hand, aims to offer *good enough* quality for the low-end customer segment within the market who do not need and are not ready to pay for performance (Christensen & Raynor, 2004). For example, the Seat Mii disrupts the electric car market by bringing an affordable model to the market otherwise dominated by high-end brands such as Tesla.

Innovation can also be categorized from a technology perspective: the technological innovation can be incremental or radical. Incremental innovation refers to small improvements or modifications to an existing product (Tushman & Anderson, 1987), and radical innovation means that in a new product a significant change and a departure from earlier technology is done (Christensen, 1997). Whereas disruptive and sustaining innovation look from the perspective of customer needs, incremental and radical innovation refer to internal capabilities within the incumbent (Hopp et al., 2018).

With innovation categories, it is important to distinguish the differences of the technology (what technologically is under the hood of the product) and customer (how customers see the product) perspectives. Regardless of how minor advancement or radical the technological leap is under the hood of a new product, it does not always determine how it is seen from the external perspective. Therefore, incremental or radical improvements can both lead to either sustaining or disruptive innovation in customer's eyes, depending on which customer segments it is marketed to.

It also is important to remind about the definition of innovation: technological invention that has substantial commercial potential. Therefore, those technological inventions that lack the commercial potential are outside the categories in Figure 1. This notion is important and easily forgot if one focuses solely on technology and the invention. It may be tempting to call a technologically sophisticated invention an innovation. However, that should not be done without or before proof of how customers experience the product or how it performs commercially. No matter how fancy a prototype is, without commercial success it does not help the company to pursue its growth imperative or sustainability goals. Thus, here, even in the technology perspective, an incremental or radical innovation already entails the commercial potential dimension.

No category is worse than the other per se — through any innovation type a company can reach commercial success and growth. Many want to consider and define themselves as disruptive or radical innovators. Radical innovations may lead to technological competitive advantage that is difficult to imitate, and disrupting a market could bring a reputation of the pioneer of an industry. In reality, however, most technological steps are incremental in the industry (Christensen, 1997) and are often less risky than radical technological leaps (Tushman & Anderson, 1987). In fact, often a fast follower strategy can lead to reduced technical and business risks due to learning from experiences from first movers and needing less resources for technology development (Teece, 1986).

Innovation has much to do with context and timing. The cyclical model of technological development by Anderson and Tushman (1990) divides technology development into four phases. The first phase is the technological discontinuity where a technological breakthrough innovation significantly increases the performance frontier over existing design (Anderson & Tushman, 1990). I consider that also disruptive innovation elements such as considerably more affordable or simpler designs are included in this definition. The second phase is the era of ferment, where novel design competes with the existing ones and starts substituting them. The third phase is when the new breakthrough technology emerges as the dominant design in the market, and this is followed by the fourth phase, the era of incremental change, where sustaining innovation and stabilization of the dominant design happens, until a next radical discontinuity disrupts the market. (Anderson & Tushman, 1990)

The competitive environment as well as the challenges organizations are facing differ greatly in the different phases and the pace of the cycles depends greatly on the context and industry. Organizations must develop diverse competences to shape, deal with and survive in the technological evolution. They need to be able to respond rapidly to technological breakthroughs, as the discontinuity can be competence-destroying meaning that earlier know-how becomes obsolete, which can be challenging for existing players and opens the door for new ones. During the era of ferment and emerging of dominant design, the organization needs to be able to combine capabilities and influence the development of industry standard. Finally, in the era of incremental change, the company needs to both remain competitive in sustaining innovation, but also develop competencies for further technological breakthroughs. (Anderson & Tushman, 1990)

Digital innovation can be defined as combining digital and physical components to create novel products. This innovation expansion to the digital world has happened because of technology development in the recent decades, such as microchips, telecommunication and power management becoming more and more affordable, available and miniaturized. (Yoo et al., 2010) Not only established corporations such as Apple or Amazon have been able to reach superior economic performance over multiple decades, but born global startups such as Uber have been able to disrupt the market within just a few years through digital innovation. Creating digitized products with standard interfaces, generic components and fluid product boundary meanings (Yoo et al., 2010) may enable scalable business growth opportunities also for Vaisala. For example, standard interfaces and free interchangeability of Vaisala smart probes were implemented in the Indigo series industrial transmitters and the company recently launched Xweather which combines intelligent hardware and software technologies such as artificial intelligence and machine learning to provide customers real-time and hyperlocal weather and environmental data.

Despite the opportunities in digital innovation, I scope my thesis to innovation in the hardware layer. Competitive advantage in industrial instrumentation still today is in providing reliable and robust hardware products and digital features play more often a complementary role in a measurement instrument. Digitalization plays a bigger role in the layer where measurement data is used, however measurement and industrial automation firms compete in different games.

In addition to innovation categories and terminology covered so far, it is important to acknowledge that there are many other types of innovation that can make companies competitive and successful. In framework by Keeley et al. (2013), innovation is divided into ten different types. Firstly, it can relate to innermost configuration of the company, such as (1) profit model, (2) networking with other organizations, (3) structure and alignment of talent and assets, or (4) superior processes for doing work. Secondly, innovation be about offering, such as (5) product performance, features, or functionality or (6) product systems that involve complementary products or services. Lastly, innovation can be about customer experience, such as (7) service innovation, (8) channel, (9) brand and identity or (10) customer engagement and interaction. (Keeley et al., 2013)

In this thesis with innovation I mean particularly product innovation and categories (5) and (6) by Keeley et al. (2013). However, with the mission to create and run an Innovation Engine that repeatedly produces such product innovation, in this thesis I do not focus on making product innovation as such but study *how* innovation should be done. In a way the analysis and managerial implications of this thesis could be considered for example as (4) process innovation. However, because commercializing innovation processes is not in the scope of interest here and to avoid confusion, I do not refer to categories (1...4) or (7...10) as innovation.

2.2 Technology management

Because my definition of innovation includes the word *technological*, technology management plays a crucial part in how innovation is created. Technology management can be described with a framework such as the one in Figure 2 by Phaal et al. (2001). The basis of the model is in the technological base, where the company's technological competence and capabilities are. Around the base, five technology management processes are run to maintain and strengthen the competitive advantage: identification, selection, acquisition, exploitation and protection. The identification process relates to probing technologies that are not yet contained in the base, but might become useful later. Selection refers to choosing the technologies that are needed for future products or technologies, through for example portfolio management. Acquisition relates to obtaining the selected technologies through, for example, R&D activities, licensing or acquiring a firm. Exploitation means seeking commercial benefit from the acquired technologies through incorporating it into products, services, or licensing the technology. Finally, the protection process is related to preventing competition from gaining access to the competitive advantage of the technology. (Phaal et al., 2001)

The framework in Figure 2 emphasizes that technology management must not happen in isolation, but should be strongly linked to the three core business processes of strategy, innovation and operations to provide productive and sustainable results for the company. Moreover, dynamic knowledge flows and collaboration between technological and commercial perspectives are highlighted. It is important to have a suitable balance between emphasis on market pull (requirements and customer need) and the technology push (capabilities) mechanisms. (Phaal et al., 2001)

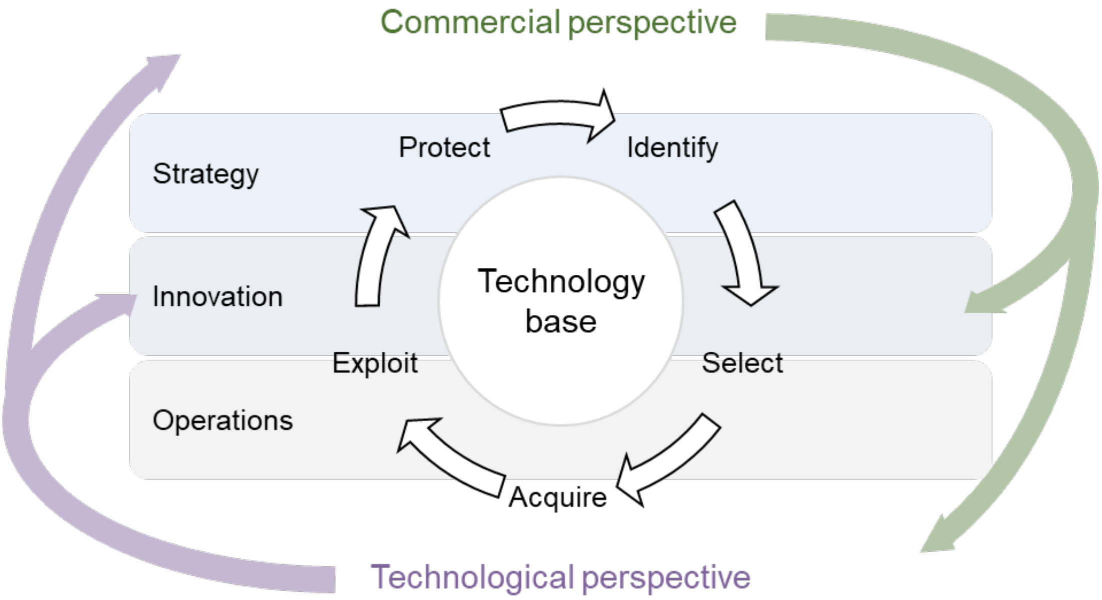

Figure 2: Technology management framework adapted from Phaal et al. (2001)

Effective management of the five technology processes is difficult and the specific issues depend on context, such as internal infrastructure, organizational structure and culture, as well as external business environment and challenges. Moreover, time plays a key role as these internal and external factors are dynamic (Phaal et al., 2001). Particular attention to the governance is needed particularly when the market is disrupted by a technological discontinuity and company's position changes due to its assets (for example, specialized manufacturing or distribution channel) either retain or lose their usefulness Taylor and Helfat (2009).

Taylor and Helfat (2009) argue that in technological change, Ambidexterity is needed in the organization to effectively manage the knowledge flows and collaboration between technological and commercial perspectives. An Ambidextrous organization effectively finds, creates and benefits from linkages between new core technology and needed complementary assets, whether they pre-existed within the company or need to be acquired externally. Middle managers play a crucial role in the Ambidexterity of the organization, as they often build the intra- and interorganizational linkages and ensure communication and coordination of actors from different organizational units. It is important to support this through proper economical incentives and social recognition and visibility of middle managers, but also through creating organizational structure and cognition that allows linking knowledge, planning and procedures between interdependent sub-units. (Taylor & Helfat, 2009)

The Three Horizons Model by Baghai et al. (2000) is used to effectively manage a portfolio and allocate resources with respect to time and value creation potential. The model divides strategic initiatives into three horizons: Horizon 1 focuses on incremental innovation in existing business, Horizon 2 explores adjacent opportunities and Horizon 3 explores entirely new and disruptive opportunities for the organization.

The model emphasizes effective management of the present business while selectively ramping down outdated practices and products. Appropriate balance in resourcing is needed to achieve adequate short-term performance, near-term growth and long-term transformation, but the balance always depends on context. If core business is growing attractively, more focus in Horizon 1 is reasonable as it has the lowest risks, whereas when existing business is not growing, the firm is forced to explore more risky adjacent and new markets. (Baghai et al., 2000)

Protection of technology can be considered through the term appropriability regime, which refers to firm's mechanisms to secure a monetary return of their investments in innovation and technology, which encompasses various approaches such as patents, copyrights, trade secrets, trademarks and contractual agreements. In protection of intellectual property (IP) a firm can take a tight or loose appropriability approach. In a tight appropriability regime a firm relies on formal legal protection such as patents to create barriers for imitation, whereas in a loose appropriability regime firms rely more on keeping the key core technological knowledge tacit or codified, and aiming for faster time-to-market through quick development and commercialization and the use of complementary assets such as specialized equipment, unique distributor channels or a network of strategic partnerships. (Teece, 1986)

In the scope of this thesis, portfolio management and IP protection are addressed only in a superficial manner and they could each be thoroughly examined in separate theses. My work focuses on the effective and repetitive generation of innovation, which is fundamentally a strategic theme. Portfolio management, although contributing to innovation performance in an organization, is subordinated to this strategic theme. It serves as a means of implementing strategy rather than being a primary driver of innovation. Similarly, IP protection is primarily concerned with safeguarding revenue and competitive position by securing already invented and possibly exploited intellectual property in the market. Hence, within the context of this thesis, these topics play a secondary role.

2.3 Open Innovation

Open Innovation refers to combining ideas from within and outside the company to advance new technologies, offering fruitful thinking particularly for the early-phase identification, selection and acquisition processes in the technology management framework by Phaal et al. (2001). The key thought in Open Innovation paradigm is that not all good ideas are formed within the company's boundaries and not all ideas should be developed within the company. This can be illustrated with a funnel such as in Figure 3. Open Innovation is opposed to closed innovation paradigm, which refers to a traditional way to develop technology in the 20th century. In a closed innovation paradigm the thinking is that the smartest people already work in the company and new technologies must be discovered, developed, productized and strictly protected within the company. (Chesbrough, 2003)

Chesbrough (2003) uses the Xerox Palo Alto Research Center as an example of

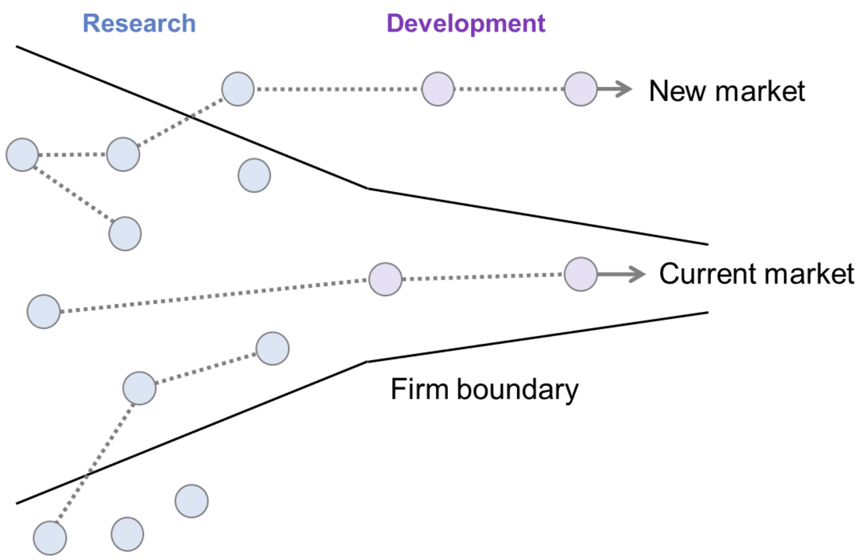

Figure 3: An innovation funnel of research and development projects with respect to the firm's boundary. In Open Innovation paradigm not everything happens in-house but ideas from outside firm boundary can be developed into products for current markets, and internal initiatives can be divested.

the closed innovation paradigm, where considerable investments in internal resources were used to develop breakthrough technologies such as Graphical User Interface, Ethernet and Laser Printing. However, Xerox failed to commercialize its technologies effectively and missed out on the significant growth opportunities. Xerox lacked strategic alignment and the company strictly focused on its core busniess of copiers and printers, whereas its developed technologies had considerable strategic value in other markets. The company didn't have the new business development capabilities to seize this potential, nor did it effectively monetize their technologies through, for example, licensing. (Chesbrough, 2003)

Closed innovation paradigm is no longer relevant in the competitive environment due to several factors. Firstly, the accelerated pace of innovation has made technology more and more complex, making it hard for one company to maintain necessary expertise to develop further breakthrough technologies on its own. Secondly, globalization and interconnectedness of he world have expanded and scattered the pool of knowledge and expertise. Mobility and availability of highly educated people has increased dramatically. Such people changing their jobs generates knowledge flows and results in broad knowledge existing outside R&D departments of large companies. Thirdly, the norm and expectation for development process has become more open and possibilities for collaboration across firm boundary have increased. For example, external knowledge and technology can be utilized through licensing agreements. Suppliers and customers expect to get to participate in the innovation process, and co-creation and collaborative approach are known to lead to better customer satisfaction and product-market fit. (Chesbrough, 2003)

A key Open Innovation paradigm takeaway is that a firm should tap into external knowledge and expertise and foster collaboration and partnerships (Chesbrough, 2003). Similar thinking repeats in a number of scientific publications. S. L. Brown and Eisenhardt (1997) propose that regarding the identification and selection processes of technology the focal firm should have low-cost probes for potential technologies in future products. Felin and Zenger (2014) argue that networking is a mandatory component in global competitiveness, and argue that more linkages and breadth of external knowledge sources is connected to better innovation performance. Dhanaraj and Parkhe (2006) introduce the concept of orchestrating innovation networks, which are loosely coupled systems of autonomous firms and where innovation is generated through interaction. A hub firm needs to hold a central position in the network and pull together necessary dispersed resources and capabilities. It is important to design the members, structure and the firm's position in the network, as well as knowledge mobility so that the hub firm learns more and faster than the partners. (Dhanaraj & Parkhe, 2006)

When companies need to address different innovation problems, categorization into two key attributes becomes helpful: hidden knowledge and problem complexity. Hidden knowledge refers to whether sources of knowledge are known and available with practical amounts of search for the firm. Complex problems have a number of interdependent elements and choices, and creativity and theory-based approach is needed for a solution, whereas simple problems have less interdependency between the elements and are more easily solved through trial and error. (Felin & Zenger, 2014)

Choosing a right governance choice to approach each innovation problem can be done based on the categorization. For example, only low hidden knowledge problems can be solved easily within the company, whereas hidden knowledge always introduces the need for a more open governance approach. If knowledge is hidden from the focal firm but it is known who possesses it, the firm should consider strategic alliances or requests for proposal to distribute to those selected firms. If the level of hidden knowledge is very high, innovation contests, or user- and community-directed approaches should be used. (Felin & Zenger, 2014)

In terms of protecting IP, the Open Innovation paradigm (Chesbrough, 2003) favors more the principles of loose than tight appropriability regimes (Teece, 1986). The focal firm should profit from others using their IP and they should buy external IP whenever it is relevant (Chesbrough, 2003). Too much focus in protection of IP can waste resources as in the accelerated pace of innovation it is more about who runs fastest in the game of commercializing novel ideas rather than who protects best their existing ones. However, in open collaboration and managing innovation networks it is still important to secure the strategic secrets and sharing selectively (Dhanaraj & Parkhe, 2006).

2.4 Product development processes

Cooper (1990) introduced the Stage-Gate model which is widely recognized and used model for managing innovation in various businesses, which in the Phaal et al. (2001) framework is most relevant for the technology exploitation process. The Stage-Gate is a structured product development approach that divides the process into different stages and gates between the stages. Each stage is a step in the product development process, such as preliminary assessment, business case definition, product development, validation and commercialization (Cooper, 1990). Each gate represents a decision point where the project is evaluated and either rejected or approved for the next stage (Cooper, 2001). The power of the model is in emphasis on clear goals and providing rigid structure for the product development process.

Even though emphasis on customer needs, as well as effective communication are encouraged (Cooper, 2001), the Stage-Gate model lacks in flexibility and responding to changing market conditions because following stages rely on the previous stages and there is no iteration involved in the linear process.

For commercial success in new product development time-to-market is crucial. A study by Vesey (1991) showed that in the high-technology product context, projects that were on budget but launched the product to market six months late earned 33 percent less during a 5-year period than an on-time launch, and being on-time with market entry with 50 percent spend-over-budget only reduced profitability by 4 percent. A delayed project leads to missing on revenue. Lengthy product development projects often come with waste of resources into peripheral activities and features. (Eisenhardt & Tabrizi, 1995)

Opposing a strict Stage-Gate model, Eisenhardt and Tabrizi (1995) propose an adaptive process where overlapping of different product development phases and fast strategic decision-making are preferred over progressing linearly through each gate and wasting time in extensive and detailed product requirements planning in early phase. Multifunctional teams and fast, improvisational real-time learning through design iterations can be much more efficient in rapid product development. The authors also emphasize the importance of senior management support and early supplier involvement in new product introduction. (Eisenhardt & Tabrizi, 1995)

However, the adaptive product development process does not a mean fully chaotic approach. Eisenhardt and Tabrizi (1995) propose to combine the iterative mindset with a focus and discipline on well-defined milestones. S. L. Brown and Eisenhardt (1997) refer to this as Semistructures, which are organizations where while some responsibilities and priorities are well determined, some other aspects such as role boundaries are not as strict. In such setting, the key for successful innovation is a balance between rigid planning and ad hoc reaction to market needs. It is important to have extensive communication and improvisational design freedom that allow frequent new ideas, new ways of thinking and a continuously changing organization, but on the contrary, enough structure is needed to avoid a full chaos. (S. L. Brown & Eisenhardt, 1997)

Cooper himself has recognized the need for a more agile and adaptable approach to product development, and introduced the Agile-Stage-Gate Hybrid Model which combines features from the Agile Software Development (Beck et al., 2001) into the Stage-Gate model of hardware product development. The Hybrid Model recognizes that the business case may evolve and change over time, and therefore a more iterative and adaptive process is needed. Similar to sprints in the Agile Software Development, shorter and more frequent feedback loops and checkpoints are needed to respond to changes and build the product on voice-of-customer. (Cooper & Sommer, 2016) The adaptive and iterative approach adds value most value for new product development, where uncertainty is high, particularly when the initiatives land in Horizons 2 or 3.

2.5 Entrepreneurial practices and business validation

Traditionally business management and models such as the Stage-Gate (Cooper, 1990) have been based on creating and implementing a solid business plan and strategy based on market research. This kind of management based on planning and forecasting is possible for initiatives in Horizon 1 and sustaining innovation and where the company has a long history and a stable business environment. However, these boundary conditions are not present for startups. Even for established businesses, exploring adjacent or new markets and creating disruptive innovation, excessive business planning can be considered a waste of time because forecasting unknowns is next to impossible and such business plans usually don't survive their first contact with a customer (Blank, 2013). In the other end of the spectrum are the *just do it* type of entrepreneurs, where instead of managing, the business is pursued with a chaotic approach. Ries (2011) argues that neither work in order to create disruptive innovation, and proposes the Lean Startup methodology which is a systematic way for entrepreneurs to manage building new business initiatives. (Ries, 2011)

The Lean Startup is a systematic process to navigate through uncertainty by Validated Learning, which means testing hypotheses through practical experimentation to gather evidence and insights to steer the development of a product (Ries, 2011). This offers a solution to linking both commercial and technological perspectives in the Phaal et al. (2001) technology management framework.

The goal of Lean Startup methodology is to maximize learning and as quickly as possible to discover the right kind of product that customers are willing to pay for. Instead of building a thorough business plan in the beginning as in Stage-Gate model, the starting point is a vision and a business model with assumptions of different aspects such as the value proposition, customer segments and competition. Then, key is in systematical validation of those assumptions through getting out of the building, implementing experiments and repeating a Build-Measure-Learn loop. The time spent in learning cycles should be minimized, and Validated Learning should be done with Minimum Viable Product (MVP) designs, which have just enough complexity and effort that is valid for testing the hypotheses. In the high uncertainty environment, it is expected that some of the hypotheses fail, in which case the team needs to make small adjustments as design iterations, or sometimes pivot entirely away from ideas that don't work. (Ries, 2011)

Felin et al. (2019) take a critical view on Lean Startup by claiming that customer feedback is overstated. To avoid myopia and traps, customers should not be trusted as such, but a mechanism is needed for filtering the feedback. This phenomenon is well described by the example of Henry Ford: if he had literally taken customer feedback, he would have developed a faster horse rather than a car. Moreover, Steve Jobs has argued that it is not the customer's job to know what they want. (Felin et al., 2019)

To overcome this criticism and to add to Lean Startup methodology, the Mom Test by Fitzpatrick (2013) provides insights and practical guidance, which I personally have found very valuable in business case validation of new product initiatives. The key message of the book is similar to what Felin et al. (2019) had identified: people have a temptation to lie and provide biased answers, and therefore their words should not be taken objectively. The phenomenon is illustrated by an imaginary event where an entrepreneur presents a business idea to their mom, asking for feedback. A mother would of course want to compliment the business idea to avoid hurting the presenters' feelings — and interestingly, similar mechanism exists in the business world. (Fitzpatrick, 2013)

Fitzpatrick (2013) calls fake compliments *fluff*, which easily blurs or biases an objective vision to the business case. Exposing one's business idea or presenting guiding questions easily leads to fluff: the interviewee leans into complimenting the idea and confirming the entrepreneur's assumptions, regardless of what they truly think. The key to avoid biased answers is to ask open-ended and neutral questions, which encourage customers to tell about their true needs, problems, experiences and opinions. Moreover, focus should be in understanding the customers' problem rather than asking an abstract question of what the customer needs. This can be done by asking of a concrete example of the last time a problem occurred, why did it happen or what impacts it had may provide a more objective understanding of the customer need. An entrepreneur should seek for commitment to buy instead of compliments. (Fitzpatrick, 2013)

Fitzpatrick (2013) also encourage observing customers' behaviors and actions rather than solely relying on their words or feedback. When possible, it is good to meet customers in the natural setting or environment, allowing more realistic observations. One should seek concrete evidence of customer behavior that supports their claims: for example, if a customer says they would want to buy a product, it is good to try to find out what kind of existing alternatives they use and why. (Fitzpatrick, 2013)

Felin et al. (2019) consider Lean Startup to put too much emphasis into rushing to testing MVPs compared to planning of hypotheses and creating the business plan. The authors also criticize the emphasis for the Business Model Canvas (Osterwalder & Pigneur, 2010) in Lean Startup methodology: often the devil is in the details when it comes to reasons why a startup fails, but ironically, the more details one introduces in Business Model Canvas, it becomes more complicated and less useful in providing strategic guidance (Felin et al., 2019). I agree that detailed understanding of what is behind the Business Model Canvas must never be undermined among the decision-makers, and it should not be considered anything more than a top-level summary. However, opposed to the view by Felin et al. (2019) I do not interpret that Lean Startup methodology suggests disregarding the important part of business planning per se, but the key point is not to take the assumptions as knowns. In my experience thorough formulation and prioritization assumptions and knowledge gaps are very important in the beginning to guide a new product initiative towards right kind of experiments. Camuffo et al. (2020) argue for a similar point: careful framing of problem and formulating hypotheses that are truly falsifiable.

One needs to be mindful in how the methodology is applied in terms of validating assumptions. Camuffo et al. (2020) argue that rigorous experiments can be effective in reducing false positives and avoiding pursuing bad venture initiatives for too long. However, experimentation not always needs an MVP. For example, seeking for social proof for the idea can be very fruitful first approach in validating whether the business case makes sense (Felin et al., 2019). In a startup context such social proof could mean, for example, someone willing to quit a lucrative job to join the startup. However, it comes to testing MVPs, I agree with Felin et al. (2019) that launching a beta product and rapid user testing can be done much faster in software context where Ries (2011) comes from, compared to the high technology hardware context of this thesis.

The threshold for pivot is another much discussed topic around Lean Startup. Felin et al. (2019) interpret Lean Startup methodology and low-cost experiments encourage for too erratic changes in the course of action, and they argue that impactful startup activity often requires significant commitment in one direction at a time. S. L. Brown and Eisenhardt (1997) discussed this theme and proposed Semistructures, which provide just enough structure to ensure focus, but also flexible and a slightly chaotic approach that allows adapting to changing market needs. I believe this is a question of balance where a theoretical approach can't provide an unambiguous answer, but the correct way to apply a methodology needs to be considered in the particular context and business environment.

Bocken and Snihur (2020) provide an important notion regarding the balance between pivots and focus: the Lean Startup methodology is not a panacea for all entrepreneurial challenges, but it is a systematic way to validate an idea. The point can be seen from Figure 4. Lean Startup, experimentation and Build-Measure-Learn loop provide help for validation, but in fact, the methodology offers little guidance for ideation phase, generating unique hypotheses and what to look for in the first place. This needs to come from understanding of the particular business environment. Design iterations in the hypothesis generation and testing are the bread-and-butter of the methodology, and when necessary, the innovation or product idea needs to be changed. However, the point of Lean Startup is not to constantly squirrel around with the vision or values of the company. (Bocken & Snihur, 2020)

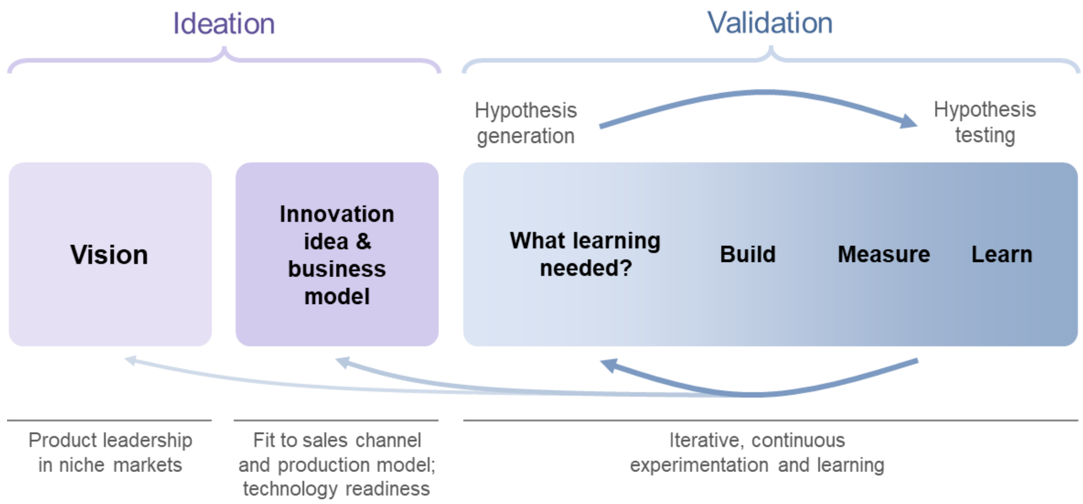

Figure 4: Business model development process adapted from Bocken and Snihur (2020).

Felin et al. (2019) argue that the term *Lean* is mistakenly used in the startup context where focus should be on creating something novel, because the word stems from Lean Manufacturing where the approach is to make something already-existing better, through addressing operational issues such as inventory management, just-in-time deliveries and waste reduction. I think here it is important to remember the point by Bocken and Snihur (2020): the point never was in providing all-encompassing guidance. One should not outsource the creation of best novel, radical or disruptive ideas to a methodology, but the ideas are always created by competent people. How I then interpret *Lean* in this context is related to how the product-market fit and validity of the brilliant idea are ensured, and this validation part should actually be rather operational and systematical, regardless of the idea.

Design Thinking is another methodology that similarly emphasizes customer need and prototyping like the Lean Startup. Traditionally design has been thought of as a downstream step in the product development process, and the designers' task has been to make an already-developed idea more attractive and appealing to customers. However, in Design Thinking the role shifts to a more strategic one: creating ideas that better meet customer need in the very beginning. Key is to take a human-centered approach together with the business and technological aspects, and introduce iterative cycles of prototypes, tests and refinement. The process is all about looping back and forth between inspiration (circumstances or customer problem), ideation (search for solution) and implementation (path to market). Although design is often thought to be, and also is, about aesthetics, with this methodology can lead into better product-market fit and more valuable products. (T. Brown, 2008)

Sarasvathy (2001) introduced a framework for entrepreneurs that outlines five Effectuation principles to help navigating with decision-making in uncertain and ambiguous market environment. The framework has not only helped entrepreneurs but is also proposed to be equally important as early-phase business opportunity guidelines in large corporations (Svensrud & Åsvoll, 2012). Firstly, the Bird-in-Land principle states that one should start with what one has readily available, leveraging personal skills, knowledge and networks. Secondly, the Affordable Loss principle states that the startup should invest only amounts that it can afford to lose. Thirdly, the Crazy Quilt principle emphasizes forming partnerships and leveraging relationships to co-create mutually beneficial outcomes. Fourthly, the Lemonade principle highlights the ability to adapt and pivot based on unexpected outcomes, transforming setbacks into opportunities. Fifthly, the Pilot-in-Plane principle emphasizes that the entrepreneur must proactively be in control of his or her action and strategic direction of the company.

Strong connection to the outer world is of utmost importance. Linking with the Crazy Quilt principle (Sarasvathy, 2001), Bocken and Snihur (2020) argue that Lean Startup type of business experimentation allows collaborative new business model creation with stakeholders such as customers or suppliers. Moreover, McDonald and Eisenhardt (2020) argue that it is risky to avoid imitating peers as keeping to oneself can lead to wasting resources and features that do not provide value for customers. McDonald and Eisenhardt (2020) propose a strategy of Parallel Play, which is a common phenomenon where preschoolers who mostly play alone but near each other start to take interest in and mimicking their peers. Key takeaway in Parallel Play is that while focus is in self and the hands-on building in the sandbox, acknowledging what peers do and seeking for uniqueness leads to competitive advantage. It is also important to be able to pause and reflect before continuing every now and then. Borrowing from an established peer company mindfully allows quick learning with rough business model ideas. While the focus in Parallel Play is similarly in testing assumptions, iterations and rapid prototyping as in Lean Startup, McDonald and Eisenhardt (2020) also emphasize focusing attention and resources on a single business model and template at a time. Moreover, the best innovators need not to only follow peers, but also be aware of firms in adjacent markets (Horizon 2). (McDonald & Eisenhardt, 2020)

2.6 Organizational capabilities and culture

Organization's Dynamic Capabilities play a crucial role in enhancing innovation performance. The concept of Dynamic Capabilities refers to the firm's ability to flexibly build, integrate, reconfigure and strategically reposition competencies in the organization to dynamically respond to a changing business environment. This means, that the paradigm has to change from operative, governing and administrative approach to more dynamic learning, sensing, filtering and shaping of opportunities. (Teece et al., 1997)

Absorptive Capacity refers to the organization's capability of valuing, assimilating and applying new knowledge (Zahra & George, 2002) and is an essential component of Dynamic Capabilities. Key in mastering Absorptive Capacity is in maximizing realized absorbed capabilities, which requires focus on three entities. Firstly, a firm's opportunities increase if it is widely exposed to diverse and complementary external knowledge sources. Secondly, it needs to acquire and assimilate the available knowledge through interpretation, comprehension and learning competencies. Thirdly, the potential is only realized when the knowledge has been transformed into functional assets. Mastering only one of these dimensions, such as wide exposure to complementary knowledge, is not enough. Emphasis is needed in all three, and the firm only benefits from capabilities that are fully absorbed and exploited for profit generation and absorption of further capabilities. (Zahra & George, 2002)

Implementation of Dynamic Capabilities and Absorptive Capacity requires appropriate organizational structures and cultural aspects that foster collaboration and knowledge sharing. One effective approach is cross-functional product teams, which bring together individuals from diverse disciplines to collaborate on product development and innovation (Eisenhardt & Martin, 2000). In the team design it is important to address factors such as leadership style and task characteristics (Ancona & Caldwell, 1992). Henard and Szymanski (2001) argue that functional fixedness in terms of tasks, as well as lack of consensus among parties, disagreement in leadership and biased managerial perceptions can be highly detrimental for product performance and therefore must be avoided.

Team composition plays a crucial role in successful cross-functional product teams. Inclusion of different functional backgrounds can bring broader viewpoints in generation of ideas and managing new product initiatives (Henard & Szymanski, 2001), and diversity is a recognized source for team creativity and innovation capability (Bassett-Jones, 2005). van Gelderen (2017) has divided diversity into three dimension: Variety, Separation and Disparity. The first dimension, Variety, means the distribution of information and what team members know that is unique from others (van Gelderen, 2017), which links well with the discussion around diversity and innovation. A high Variety is of essence for complementing the skillset and knowledge among the team. A team with high Variety has a broader cognitive repertoire in the form of variety of information, knowledge and social networks to face innovation problems (van Gelderen, 2017).

However, diversity as such does not yield successful products (Henard & Szymanski, 2001). The second diversity dimension, Separation, means the distribution of where team members are in regard to their values, beliefs and attitudes (van Gelderen, 2017). The link between Separation and innovation is ambiguous. A high Separation may actually bring leadership challenges in terms of misunderstandings, suspicion and conflict (Henard & Szymanski, 2001), but on the other hand van Gelderen (2017) argues it can be managed with team trust and psychological safety. The third dimension, Disparity, reflects how much distribution there is in power, status or resources between the team members. While in some settings a moderate Disparity is needed for clear leadership, a high Disparity can pose challenges for the team performance as it drives less powerful members to withdraw and limit their contributions. (van Gelderen, 2017)

Still, a firm avoiding diversity risks loss of competitiveness in the global business environment (Henard & Szymanski, 2001). I consider this a particularly important notion for this thesis where the case company headquartered in Finland. As a small economy, specialized competencies and social networks among native Finns and within the country are limited.

Boundary Spanning is a key activity for cross-functional teams in realizing the Absorptive Capacity. Boundary Spanning means the team activities to connect across boundaries between the team and its external environment such as suppliers and customers, allowing the team to tap into valuable external expertise and resources and gain diverse perspectives (Ancona & Caldwell, 1992). This cross-boundary integration need to be actualized in selected contexts to ensure productive idea generation and communication (Henard & Szymanski, 2001). Boundary Spanning goes well in hand with other topics discussed in the thesis. I consider it a team-level implementation of the Open Innovation paradigm (Chesbrough, 2003) and the entrepreneurial thinking that heavily relies on external feedback.

To successfully apply the entrepreneurial principles and behavior in cross-functional teams in the established organization of VIM, an intrapreneurial culture needs to be created. Although the initial focus of Lean Startup was in startups, Ries (2011) defines entrepreneurship as any institution that seeks to create new products and services in extreme uncertainty, which does not exclude corporations. Large companies that are able to embrace and implement the methodology successfully are to gain the biggest payoffs, and therefore many companies such as General Electric, Qualcomm and Intuit have implemented a Lean Startup methodology (Blank, 2013). The intrapreneur teams must adopt an entrepreneurial mindset, proactive and opportunity-driven problem-solving and focus on learning. Moreover, the team must be empowered and autonomous for integrated decision-making. Bureaucratic barriers must be removed and rather the organization must support and reward the entrepreneurial initiatives. (Mason & Rohner, 2002)

Linking with the theme of Validated Learning (Ries, 2011), Senge (2006) introduced the concept of Learning Organization, which means an organizational system that fosters continuous learning, adaptability, and collective problem-solving to achieve sustainable success in a dynamic environment. Unlike traditional approaches that focus solely on maximizing short-term output or results, a Learning Organization emphasizes the importance of maximizing learning throughout the organization's processes, encouraging employees to embrace experimentation, knowledge-sharing, and iterative improvement for long-term growth and innovation. (Senge, 2006)

2.7 What makes an Innovation Engine

Innovation engine means the company's capability to systematically and repeatedly produce successful innovation. The Innovation Engine inputs ideas, runs with the company's processes and practices, and outputs commercial success. According to Heim (2017) bringing innovative products to the market again and again is challenging, even if the company can afford to spend considerable investments in R&D and collaborate with external parties and acquisitions of intellectual property. The multi-faceted issue is captured well on an abstract level by Teece et al. (1997) according to whom a global market-leader must *"demonstrate timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competences."* Only a small share of large companies can steadily grow through innovation year after year, but those companies that do have something in common (McGrath, 2000).

Bringing more tangible guidance, Treacy and Wiersema (1993) argue successful companies focus on delivering superior customer value by focusing on one of three strategies: Operational Excellence, Customer Intimacy or Product Leadership. In Operational Excellence strategy the focus is in making production lean: minimizing overhead cost, eliminating intermediate production steps and waste and optimizing business processes across the organization. The company must deliver products to customers at competitive price and with minimal inconvenience. Customer intimacy strategy focuses to continuously tailoring the offering for specific customer needs, which comes at an expense but is done to build long-term customer loyalty. In Product Leadership strategy where focus is in producing a continuous stream of state-of-the-art products. While a certain professional standard is required in all three dimensions, it is difficult to at the same time pursue multiple of these goals: for example price competition is often in conflict with customizability or state-of-the-art performance. It is advisable to focus to master one, and only few market leaders have successfully been able to master two of the three strategies. (Treacy & Wiersema, 1993) Tesla is a book example of a company with clear Product Leadership focus complemented by Operational Excellency that supports the business, while purposefully keeping the product options to a minimum.

A well-oiled Innovation Engine is a necessity particularly for the Product Leadership strategy. In Product leadership strategy firstly, the company needs to be creative and embrace ideas from outside the company, which is where Open Innovation paradigm (Chesbrough, 2003) and Design Thinking (T. Brown, 2008) come into play. Secondly, according to McGrath (2000) successful innovative companies are fast: they repeatedly enter markets before competitors. Time-to-market is also emphasized by Vesey (1991) and Eisenhardt and Tabrizi (1995). In such organization, the business and management processes have to be designed for speed (Treacy & Wiersema, 1993). Thirdly, a product leader that pursues sustaining innovation should replace their own offering: If anyone is to make existing products obsolete a product leader company should do it themselves (Treacy & Wiersema, 1993).

Along the lines of adaptive process (Eisenhardt & Tabrizi, 1995) and Lean startup (Ries, 2011), McGrath (2000) underlines for an adaptive and flexible approach with new product initiatives. She covers many points familiar from entrepreneurial thinking: successful innovators are good at experimentation, in the organization everyone is held accountable for new ideas and the teams are able to change focus swiftly. According to Heim (2017) innovative organizations need to adopt a culture that recognizes the value of failure, and are both able to learn from mistakes and switch direction in good time to avoid or minimize wasted effort for bad initiatives.

On the contrary, not everything in the organization should change focus swiftly. According to Heim (2017) and McGrath (2000) a stable, long-term strategic direction and a detailed roadmap are key building blocks of an Innovation Engine. Bocken and Snihur (2020) brought up a similar argument in the context of Lean Startup and threshold for pivots: the innovation idea may sometimes need to be pivoted based on Validated Learning, but the vision and company identity should not be erratic. McGrath (2000) identified that innovative growth outlier companies often have had consistent strategic and organizational structure for long periods, a strong and unchanging corporate culture and executive managers that have a history within the company.

For such stability, technology management frameworks such as the one proposed by Phaal et al. (2001) or observing the environment from the Three Horizons (Baghai et al., 2000) perspective can be beneficial in the strategy work. In my experience, a strong connection between strategic, market and technology understanding is crucial. Formulating a fruitful strategic direction requires meticulous examination and coupling of both technological and commercial perspectives. A too abstract level strategic vision lacks in giving practical guidance for strategy implementation, and if the vision is detached from the technological and commercial realities, innovation initiatives end up to erratic pivots and lack of focus as they do not endure meeting with the reality.

Heim (2017) argues there should be entirely different management and leadership approaches for upstream and downstream R&D activities. The right approach has to do much with how uncertainty the market is for the focal company. A model such as Stage-Gate (Cooper, 1990) may be suitable for a downstream productization phase initiative, and for a long-term investments and direction are recommended for a working Horizon 1 business. However, Horizons 2 and 3 need entirely different Key Performance Indicators (KPI), as it is impossible to provide net present values for initiatives for adjacent and new markets with similar precision as in Horizon 1. Typical KPIs in a Stage-Gate model such as market share growth, revenue targets, or product profitability leave little room for high risk innovation. Instead, the evaluation should be more qualitative regarding how the project aligns with innovation strategy. (Heim, 2017)

Chesbrough (2003) used the analogy of chess and poker to compare suitable approaches for existing and new businesses. He uses Xerox as an example for the chess approach: the company chose a calculated game and a strict focus in existing copier business (Horizon 1). I was listening to Sivaram (2022) in SEMICON West 2022 about the flash memory market, which I think is another perfect example of a *chess market*: The technology evolution is heavily in the era of ferment, and no breakthrough technologies are expected anytime soon. A few players compete in the market through striving to integrate more and more layers in the chip to increase the flash memory capacity. Very simply, the company that integrates most giga- and terabytes most cost-effectively wins in the market.

A poker strategy (Chesbrough, 2003), on the other hand, is needed when entering uncertain markets (Horizons 2 and 3): one can't exactly predict what will happen, but focus should be whether one has a winning hand (team, capabilities) and to win, one needs to take risks, make rapid decisions based on limited information and be adaptive to changes in the market learnings, trends and opportunities. According to Chesbrough (2003) Silicon Valley venture capitalists do exactly this. A linear and calculative model does not work, because the business case can't be evaluated at an early stage and in isolation from product development.

While managing the initiatives in different Horizons with two different leadership approaches, research and development should never be in isolation. Heim (2017) emphasizes the need to collaborate within the different initiatives to mitigate the risk of misalignment. This is easier said than done. To my experience such misalignment can easily happen not only with one initiative proceeding from upstream to downstream in the R&D funnel, but also between strategy, market and technology understanding. With this, I would re-emphasize the importance of middle managers, Ambidexterity, intra- and interorganizational linkages (Felin & Zenger, 2014; Taylor & Helfat, 2009).

To conclude, Figure 5 entails some of the key theoretical themes I covered in this chapter. While no single framework is all-encompassing, a mindful adoption of these perspectives will help a company for better innovation performance.

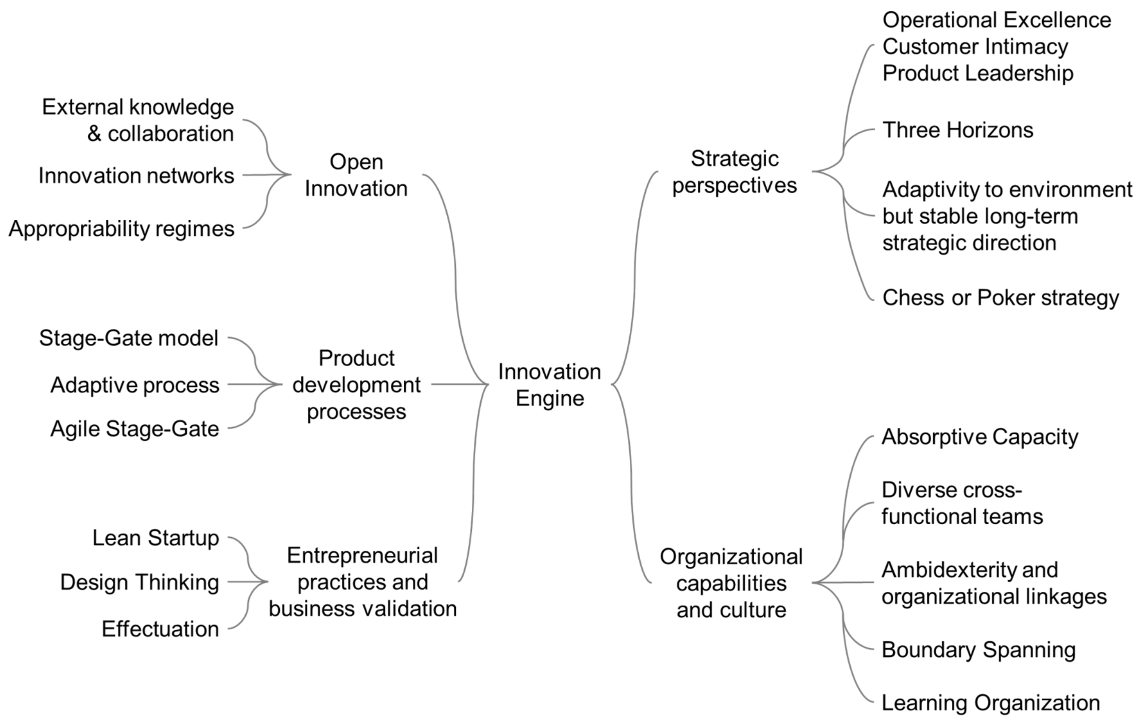

Figure 5: Key themes linked to Innovation Engine in a mindmap scheme.

3 Methodology

To restate the research question, in this thesis I investigate what are the key enablers for an Innovation Engine for in a high-technology hardware product based business. While this is a case study of VIM business area, the results are applicable to any business in a similar context.

This is a qualitative research that forms a holistic view of the phenomenon as well as managerial implications for VIM. I chose qualitative research method due to the nature of the research question; the purpose was not to validate whether a specific hypothesis is true or not but to understand, explore and interpret the phenomenon to find patterns and explanations to what leads to better innovation performance. In this study I took a social constructionist approach, because people within the company and innovative teams themselves are those who have the best visibility to what makes a good innovator. I did not have access to the necessary data that would be needed to demonstrate causality from a different companies' themes or focus areas to innovation performance from an objective perspective. The chosen social constructionist approach utilizes subjective stakeholder perspectives and meanings, draws those into theoretical abstractions and reflects the results with the theoretical background.

The research utilizes interviews as primary data, which was collected for two different purposes. Firstly, I collected data from VIM organization to form a clear understanding of past examples of innovation as well as the current state with respect to the reviewed theory and framing of this thesis. As primary data I interviewed five people within the organization. I also utilized my personal experience in the company. I have several years' experience in R&D including chief scientist, project manager responsibilities in different projects, and my current role as Business Development Manager entails leading new product initiatives in terms of business validation.

Secondly, 12 people were interviewed from people outside Vaisala to gain a broad understanding of different practices and perspectives from successful innovators. These benchmark interviews were selected based on known good innovative performance of the companies, and I focused on interviewing people in roles that are at the core of innovation activities in the firm. Selection of interviewees and companies favored those established businesses in high technology hardware context. However, for a comprehensive view, four of the interviews were from growth companies with less than a hundred employees. Publicly available online data was utilized as a secondary source, when it was necessary to complement interview data. For example, financial performance of stock-listed companies and different acknowledgements of innovativeness were useful pieces of information to supplement the analysis.

The interviews follow an inductive logic and were conducted as semi-structured as shown in Appendix A. Firstly, in part 1 the goal is to understand the company context similarities and differences with respect to the case company, Vaisala. Regarding the actual interview insights regarding innovation focus areas, it was important to understand from which kind of context it came from. Even though both may provide useful insights for the analysis, a startup or growth company focused on components for consumer products and a multinational corporation serving industrial customers may have very reasons to highlight different areas.

Secondly, in part 2 the goal was to gain interviewees' subjective views on the focus areas for innovative performance in their context. For that, open-ended questions were the most fruitful way to start: the first question *What are the key enablers for innovation in your company/team?* allowed conversation to start, and loose structure with follow-up questions on the most important topics allowed to shift focus where the interviewee resonated the most. However, when feasible and within time constraint of the interview, leading questions were presented to interviewees to discover interviewees' reflection on four themes: (1) organizational responsibilities, (2) innovation process, (3) entrepreneurial practices and (4) external innovation. The themes were selected based on theoretical review and identified development areas for VIM.

Each interview was recorded, and I wrote an initial memorandum on key points was written during or soon after each interview. I then utilized the recording to complete the memorandum and ensure no important points from the conversation were missed from the memo. I use pseudonyms of interviewees and companies due to research ethics and to mitigate bias and to promote interviewees' courage to give honest views. Inspired of the 2023 World Snooker Championship, I chose to use top snooker player names as pseudonyms. Not using full anonymity allowed utilizing role and company context information of interviewees in the analysis. It makes a difference whether a comment is from an innovation manager of a multinational company or a Chief Executive of a startup. On the other hand, to ensure pseudonymity, I do take certain precautions in the analysis of this thesis. Any association or resemblance in terms of gender, age, or other characteristics between the interviewee and the pseudonym snooker player is purely coincidental. Moreover, I intentionally omit the connection between a piece of information and its source if revealing it would compromise the identities of the interviewees.

I made the analysis of the primary research data, the completed memos, based on the Gioia methodology (Gioia et al., 2013), which is a widely used approach in qualitative research for systematic analysis of interview data. However, as Locke et al. (2022) propose, and adopting an entrepreneurial spirit (Ries, 2011) also to research work, I took a more iterative approach instead of strict step-by-step process (Gioia et al., 2013). Simultaneously with the interview data collection and organization, I moved iteratively back and forth between coding, data interpretation, theme identification and reviewing the relevance and linkages to literature to fine-tune the focus of this thesis towards the research question. After a number of iterations, I synthesized the identified themes and literature review into conclusions and managerial implications for the case study.

4 Analysis

In this chapter I first analyze the historical evolution and current state of the case company, VIM, in terms of innovation. This historical context reveals certain strengths, but more importantly, allowed to identify areas for development for a better innovation performance. Finally, I present key findings from the innovation benchmark interviews from external companies related to the research question and identified key development areas.

4.1 Vaisala Industrial Measurements

VIM runs a high-mix low-volume business with hundreds of product families and thousands of different products to meet the needs in different niche industrial measurement applications. Annual production volumes of typical VIM products range from hundreds to up to tens of thousands, and similarly, sales prices range from hundreds to up to few tens of thousands. Due to the broadness of the product portfolio I limited the extent of analysis from the customer point-of-view into only a few key examples. However, there are only a handful of core measurement technologies and the competitive advantages they enable are somewhat similar in different measurement instruments and applications. Therefore, I chose measurement technologies as another angle to analyze VIM's innovation performance.

Table 1 summarizes the internal interviewees I utilized in the analysis for VIM business. Many of the interviewees have been in the company for a long time and multiple different roles ranging from technology to business, giving a good overview on the innovation performance. In addition to the internal interviews, I used my own experience in the company for the analysis, as I have experience from both technical and commercial sides of VIM since 2016.

Table 1: Vaisala-internal interviews done in this thesis

Name	Role	Business Unit
Hannu Talvitie	Director, Technology Strategy	VIM
Kaisa Lehmus	Head of Technology	VIM
Jutta Hakkarainen	Director, Liquid Measurements	VIM
Tommi Roman	Director, Strategy and Business Development	VIM
Samuli Laukkanen	Head of Technology	WEA

4.1.1 Technology-driven value creation

Before expansion to industrial measurements, the foundation of Vaisala was in weather and environmental measurements. That business has yielded many technological milestones over eight decades' history, and still today represents the majority (56%) of revenue for the company (Vaisala, 2022).

The development of Vaisala's first product, the radiosonde is a book example of sustaining innovation. Radiosonde is a battery-powered measurement instrument carried by a weather balloon, which plays a crucial role in atmospheric measurements for meteorological applications. The disruption from earlier dominant design (manual and surface weather observations) into upper air soundings had already happened before Vaisala was founded. However, through Vilho Väisälä's first Vaisala radiosonde design in the 1930s (Michelsen, 2006) Vaisala was able to enter the market. During eight decades Vaisala has been able to become and maintain its position as soundings market leader through different incremental, but also radical technological innovation under the hood. From external point-of-view all development for radiosondes has been sustaining: through superior access to the existing meteorological customer segment, Vaisala has been able to identify, add and enhance necessary features in the radiosonde product. Although development in performance has been dramatic when comparing the today's 4th generation radiosondes to the original design, the device still serves the same measurement application for the same customer segment.

The invention of HUMICAP, the world's first thin-film capacitive humidity sensor is an example of a radical innovation that needs to be emphasized from the radiosonde development path. Until the 1970s the dominant technology for humidity measurements was hair hygrometers, and a better solution was needed to satisfy the need of soundings (Vaisala, 2020d). Not only better response time, accuracy, linearity and hysteresis attributes were needed, but the sensor needed to tolerate the harsh temperature and pressure variations from earth's surface up to the stratosphere. Moreover, the sensor needed to recover from water condensation from the clouds and survive exposure to solar rays and electric outbursts (Michelsen, 2006). The revolutionary HUMICAP sensor was able to fulfill those needs with a simpler and more convenient solid-state structure, making it a disruptive innovation.

HUMICAP is truly an innovation as it has proven to be commercially very valuable for the company. As a spin-off from its usage in the radiosonde application, it has opened an entirely new business area of industrial humidity measurements for Vaisala. The HUMICAP sensors not only have a superior long-term stability performance in harsh environments but are also mass-producible on wafer-level. In addition to the soundings application, the technology has turned out to have broad commercial potential in applications from greenhouses, museums and warehouses to concrete moisture, moisture in oil and different ovens and dryers. Some of these applications are sustaining innovation in the sense that they replace other technologies through better performance for demanding customers, but some can be considered as new-market disruption because the more robust HUMICAP allows measurement where it was not earlier possible.

HUMICAP is not only technologically radical, and disruptive in the industrial measurements market, but also an example of external innovation. It was an industrial order from Vaisala for the Technical Research Centre of Finland (VTT) Semiconductor

Laboratory in 1971. The goal was to develop a miniaturized solid-state humidity sensor, and the solution was found in a capacitive sensor that was based on a polymer thin film. The development was completed by Jorma Antson and Tuomo Suntola by the end of 1973. (Puurunen, 2014)

Since the invention of the first HUMICAP polymer sensor, much of the incremental development in thin film sensors has happened internally in Vaisala. In 1997 Vaisala introduced the DRYCAP sensor that was optimized particularly for low humidity (dew point) measurements (Vaisala, 2020c). The technology is truly innovative as it has enabled significant new business growth in many applications in, for example, compressed air systems, drying processes and lithium battery manufacturing (Vaisala, 2020c).

HUMICAP is not the only core technology that were originally invented in close collaboration with external parties. Similarly, the development of MEMS based pressure sensor BAROCAP in late 1970s based on needs in the radiosonde application and utilized heavily know-how from external universities and research institutes (Vaisala, 2020a). Also, development of the key components in the optical CARBOCAP gas measurement technology in the 1990s relied heavily on complementing technical competence from VTT (Vaisala, 2020b).

The first key technological breakthrough in CARBOCAP technology was the miniaturized MEMS-based Fabry-Perot Interferometer (FPI) chip, which allowed superior long-term stability through measuring both gas absorption and reference wavelength bands with a single source-detector pair (Vaisala, 2020b). CARBOCAP can be considered radical, as it brings the benefits of spectrometric measurements into miniaturized size with a mass-producible MEMS chip. A traditional Fourier-Transform Infrared (FTIR) spectrometer construction requires expensive discrete photonic and optical components, whereas the CARBOCAP technology could be integrated into convenient probes and measurement modules at 1/10th or 1/100th of the cost. The first commercially significant application for CARBOCAP sensors was carbon dioxide measurements in incubators.

Not all technology was successfully utilized in products. For example, in 2001 Vaisala launched ammonia measurement products that were based on an increment from the thin film development stream, the AMMONICAP sensor (Ylikangas, 2001). However, Vaisala decided to discontinue the ammonia measurement business due to a less attractive market outlook along with the cost pressure at the time (Vaisala, 2004). Similarly from the MEMS stream, an accelerometer technology was developed as an increment from the silicon-based BAROCAP sensor in a joint venture called Vaisala Technologies Inc., which was divested and is nowadays known as Murata Electronics Oy (Murata, 2012). Another example is the launch of an oxygen measurement instrument, based on an in-house laser-based SPECTRACAP technology (Vaisala, 2006), which after a few years Vaisala decided to divest the business (Vaisala, 2010a).

Figure 6 summarizes how technologies in VIM evolved since their invention with respect to the firm boundary. From this illustration we can notice three important points. Firstly, the foundation of core technologies and most radical breakthroughs

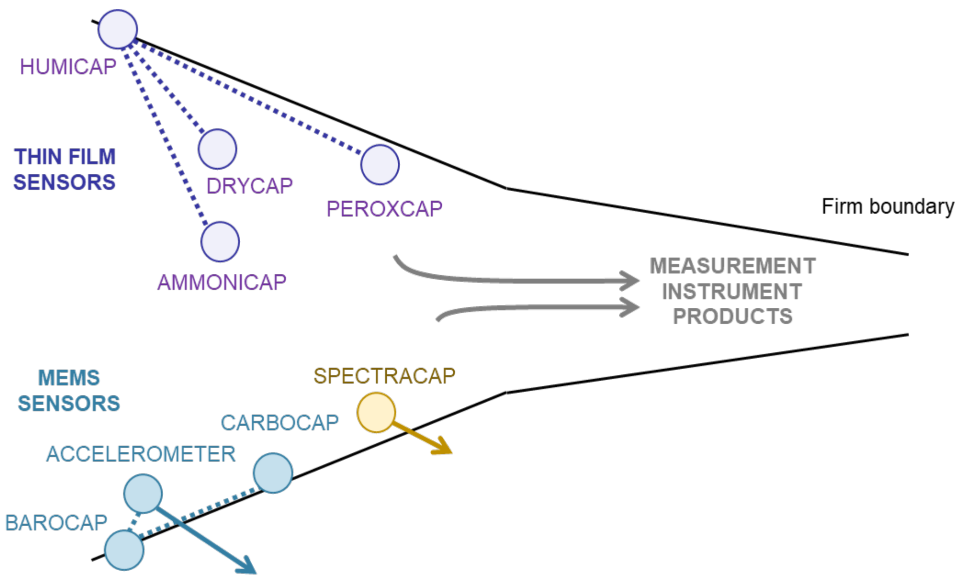

Figure 6: Summarized key technologies in VIM, and how they have formed and evolved in terms of firm boundary.

were made decades ago in collaboration with an external party. Secondly, the following technologies can be considered as increments in the thin film or MEMS development stream and this incremental innovation has happened internally, within the firm boundaries. Thirdly, the examples of divested technologies tell about the strong emphasis in technology development but lack of business understanding.

4.1.2 Segments bringing market understanding

After a long era of technology-driven approach, the need for a micro weather station can be considered as one of the first examples of a market pull force in the company. The idea of converting an entire weather station with discrete instruments into a beer-can sized multiparameter measurement instrument came as a strategic product vision from the CEO in the late 1990s. Through product development efforts, a compact Weather Transmitter WXT series products were developed. This is truly a disruptive product as it offers new non-professional weather customers an easy-to-use, affordable and more compact solution for measuring six different weather parameters. From an internal point-of-view, integrating internal HUMICAP and BAROCAP technologies for humidity and pressure measurements was rather trivial and incremental, but the development of piezoelectric rain sensor required a design from the scratch.

The strategy redefinition in 2008 brought more emphasis on market understanding. The business was divided into three business areas and ten market segments. VIM, at the time known as Controlled Environment, comprised of Clean Rooms and Chambers, Building Automation and Targeted Industrial Applications segments (Vaisala, 2008). Each segment was focused to run the entire business, including product management and sales, for that specific customer segment. The drivers for the organizational change were that the technology-driven innovation performance had begun to run dry, and the focus needed to shift into looking for new applications and scalability for existing core technologies as well as seeking acquisition targets.

The segments pursued a market-driven search for industrial applications, which led to considerably better understanding of customer needs in the organization. Kaisa Lehmus mentioned that in this setting, also technology development teams were involved in discovering customer needs and evaluating business cases. She thinks that even though there was ownership and support from the segment business leaders, this way of working forced the entire team to think of the entire case from different perspectives, and meeting customers was very motivating.

As a fruit of this work, CARBOCAP technology was effectively exploited in many new products that can be considered innovations. First, it was utilized in products for Heating, Ventilation and Air Conditioning (HVAC) applications where the competition was against similar measurement instrument designs, but Vaisala's key competitive advantage was in better measurement performance enabled by the CARBOCAP technology, making it a sustaining innovation. Inventions such as the microglow enabled CARBOCAP measurements in elevated temperatures, which Vaisala was able to exploit in a more disruptive way as products for incubator applications, where the challenging environment usage of earlier designs. Furthermore, FPI and other chip development into different wavelength regions expanded CARBOCAP measurement capabilities to other gases than CO2. This capability was disruptively used in a Dissolved Gas Analysis (DGA) from power transformer oil application in the OPT100 DGA Monitor product, where the spectrometric measurements with FPI measure a mixture of gases. For customers, this offers a more convenient maintenance-free solution compared to competitors that require regular calibration and maintenance.

Clean Rooms and Chambers segment was also able to identify a growing trend of the usage of hydrogen peroxide vapor for sterilizing different chambers. Simultaneously, it was known that the HUMICAP sensor was cross-sensitive to hydrogen peroxide. The project was initiated and a new PEROXCAP technology was developed, where the key invention was the introduction of two polymer sensors, the other of which is coated with a catalytic layer that breaks peroxide molecules. This together with a sophisticated algorithm allows very robust vaporized hydrogen peroxide measurement. As a technological step this was an increment to the existing technology, but as a business case a great success. From a customers' point-of-view there are competing products available but the Vaporized Hydrogen Peroxide, Humidity and Temperature Measurement HPP270 Series products offers a superior long-term stability, making it a sustaining innovation.

4.1.3 Product areas and the Runway

Figure 7 shows how in 2015 the customer segment based organization was separated into a sales organization with three geographical sales regions and a Products & Systems organization with four product areas: Industrial Instruments, Continuous Monitoring Systems, Liquid Measurements and Power and Energy. The Figure is scoped to segments and product areas of VIM business area, which at the time was called Controlled Environment. A key change from the innovation point-of-view is that the perspective is now more strongly on common denominators within the products, than pre-determined customer segments. Furthermore, the product area setting has been shaped by acquisitions. For example, the Continuous Monitoring Systems product area and Life Science market understanding were brought to Vaisala through the acquisition of data logger company Veriteq (Vaisala, 2010b). Moreover, the Liquid Measurements product area was formed not until VIM acquired a process refractometer company, K-Patents (Vaisala, 2018).

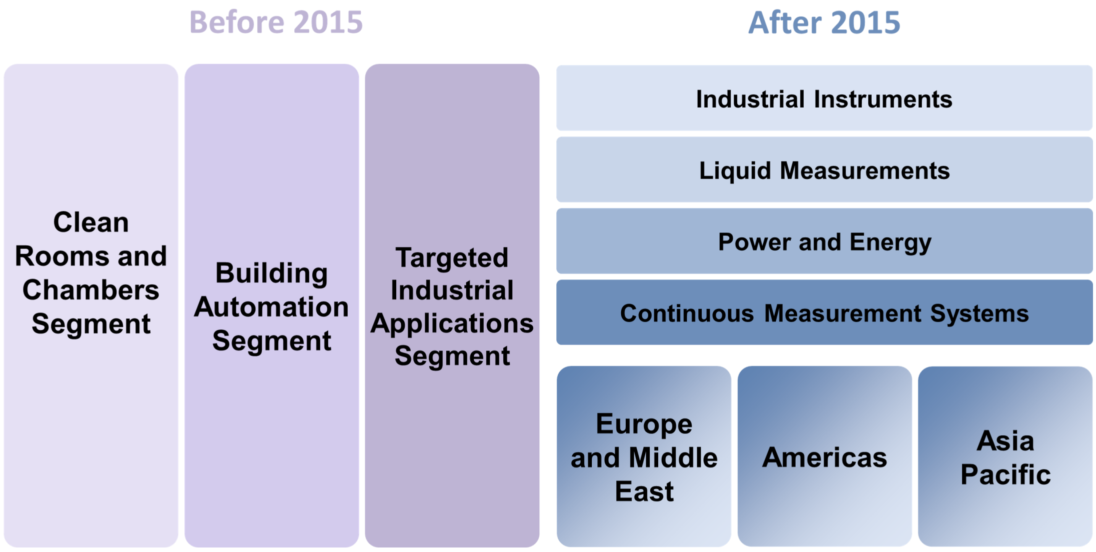

Figure 7: Overview of organizational structure change in 2015. Before the change organization was structured on segments that entailed both sales and product management, whereas after the change organization is divided into product areas and geographical sales regions that sell all products.

Each product area runs a slightly different kind of business. Industrial Instruments and Liquid Measurements serve numerous applications in various industries such as food and beverages, pharmaceutical, semiconductor and process industries. The Industrial Instruments area consists of dew point, humidity, carbon dioxide and hydrogen peroxide vapor measurement instruments and the sales is typically rather transactional based on instrument specification and performance, whereas the Liquid Measurements consists of an in-line refractometer portfolio that are slightly more expensive and require a more consultative and application-focused selling approach. Power and Energy business is focused mainly on very specific niche applications in power transformer oil and biomethane optimization. Continuous Monitoring Systems integrate various different measurement instruments into a cloud-based remote monitoring system for strictly regulated manufacturing and production environments such as laboratories, cleanrooms and warehouses.

The segment organization had become scattered into multiple parameters and applications, and growth in each segment had become more challenging. According to Jutta Hakkarainen, a key strategic paradigm shift happened from a more Customer Intimacy based segment approach into a more Product Leadership strategy (Treacy & Wiersema, 1993), where differentiation happens with technology. The approach was no longer in trying to serve a single customer segment with multiple niche and tailored products, but rather try to scale existing technologies into new niche applications in different segments.

The chosen Product Leadership strategy out of the three customer value strategies by Treacy and Wiersema (1993), makes sense in the given business environment. Customer Intimacy requires a comprehensive and customizable product offering, which becomes very difficult in a multi-industry setting. Moreover, even though the company puts considerable emphasis on its Operational Excellence and production quality, minimizing overhead cost would not be feasible with complex production system of the broad high-mix low-volume offering.

The financial performance shown in Figure 8 prove that VIM has been very successful in proving its innovation capability. The history shows many successful products and as Hannu Talvitie formulated, *"home turf has been secured"*. VIM is an established *"top of the pyramid"* player in niche markets. I believe a significant contributor to the performance has been successful productization and commercialization of ideas and technologies that root from the segment organization.

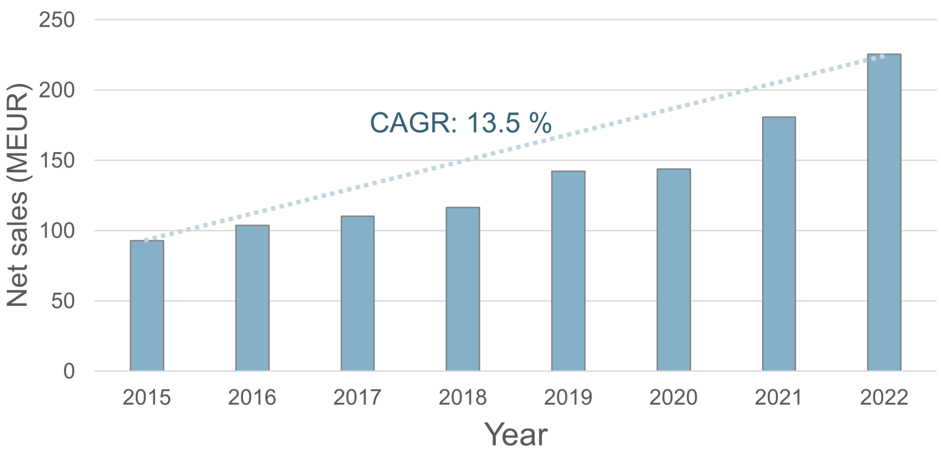

Figure 8: VIM Net Sales. (Vaisala, 2023).

The segments organization brought market understanding in the extent that had not existed before in the company, but the setting was not efficient in finding applications for existing technologies. Commercialization technology into products had taken a long time. To speed up the time-to-market, around the year 2015 Vaisala launched a practice called Runway. The Runway projects adopted a methodology similar to the Lean Startup (Ries, 2011), which allowed more agile ways to respond to changing market needs with an entrepreneurial team.

The Multigas Probe MGP261 for biogas measurements was the first example of Runway initiatives. It utilized disruptively similar characteristics of the CARBOCAP technology as the OPT100: In the biogas application the competitive products are at-line systems that measure a gas sample taken from the main gas pipe, whereas the optical CARBOCAP measurement and the MGP261 product design allows direct in-line measurement from the pipe in the hazardous environment. For the customer, this is a simpler and more convenient solution that requires less maintenance, space and has a lower cost of ownership. Thanks to the close collaboration with end users, a working team structure with both business and technology competence, but also the technological advancements developed for the OPT100, the MGP261 time-to-market was considerably shorter than with the OPT100.

Hakkarainen led the biogas project business validation, which was initiated from an assignment to find business potential for a certain expansion in technological capabilities that had happened in VIM. The goal was not only to develop new business (what) but also the way business is developed (how). Around 2015, she began the ideation phase with a global workshop, utilizing business development competence that had been spread across the organization in the restructure (Figure 7). The ideas were further shortlisted and prioritized with a global screening framework regarding certain aspects of the business model, and she continued to work on the most promising biogas initiative to business validation phase.

Hakkarainen emphasized the systematic thinking that comes with Lean Startup methodology. She thinks documenting things in a standard way using e.g. the Business Model Canvas (Osterwalder & Pigneur, 2010) and the Value Proposition Map (Osterwalder et al., 2015), and generating and prioritizing assumptions brings transparency to the business case. The Runway process also included certain checkpoints for assumption validation along the way, based on what had been learned from, for example, customer visits, trade shows or a new prototype design. Transparency and systematic way of thinking, she thinks, helps to a more objective view and fighting one's natural tendency to focus on finding proof for what has been done is correct. As also Ries (2011) argued, in business initiatives one should avoid falling in love with their own babies.

Hakkarainen thinks another key point was leadership and an aligned, entrepreneurial mindset across the team. There should not be much of conflict between different team members in how the mindsets are aligned towards a common business goal. Demands for a good startup team are many: the members be self-motivated, engaged, come from diverse backgrounds, as well as be able to cross job title boundaries, tolerate uncertainty and failures and flexibly adapt to changes. On one hand it takes leadership to align the team particularly in change situations such as pivots, but on the other hand everyone should adopt the necessary mindset in order for the initiative to progress fruitfully.

In the biogas project, systematic thinking, entrepreneurial mindset and leadership together enabled the core team to have an overall responsibility of the business case: Regardless of the specific competency areas of team members, everyone was aligned to solve issues whether it was related to customer need, market growth or a technical detail. After a few years when she was able to recruit a team which was able to run further business validation of these initiatives in parallel. I was involved in one of those Runway projects, which related to leveraging an existing product in a new industrial application. Although the business case turned out not to be attractive enough for VIM, I fully agree with Hakkarainen's thinking on leadership and overall responsibility. Even though my role as a technology prestudy project manager and chief scientist was technical, the best progress was achieved at the end when we had reached an excellent alignment and collaboration with business development. Regular official and unofficial encounters at the office, customer visits together and solving problems across role boundaries were key.

Not everything from the Lean Startup was directly applicable for VIM: For example, Hakkarainen mentioned designing an MVP to a hazardous environment in the Biogas project was a particular challenge. Her thinking aligns well with criticism by Felin et al. (2019) who think customer feedback is overstated, and Fitzpatrick (2013) who advices not to always take customers' words literally. While the methodology may help with new business initiatives, it does not always ensure success.

The methodology has evolved since the first projects. For example, when in the idea pipeline certain ideas did not feel right, Hakkarainen started working towards reasons why that is. The end result is a list of success criteria, including addressable market size and Vaisala's opportunity estimate of that, time-to-market, strategy, business model and technology fit aspects.

Hakkarainen has changed her role to head the Liquid Measurements product area. Today, projects in VIM are no longer called *Runway*, but Hakkarainen's successor Tommi Roman continues to utilize the methodology in the Strategy and Business Development team. Roman clarified that a key change recently has been that the approach for new opportunity identification has shifted from the original Runway idea, technological capability to measure certain parameter, into a more strategic level. The team starts by identifying attractive megatrends and themes, and from there identifies measurement needs and validates key assumptions related to those. Moreover, even though the methodology is not widely applied in all projects related to exiting product area businesses, I have adopted the Runway methodology and success criteria in the Liquid Measurements product area for validating new opportunities in the in-line liquid measurements domain.

4.1.4 Current state

Generally, Vaisala and VIM have been successful innovators for decades. One could say, in some sense the organization has already proven to run an Innovation Engine. It is running particularly well within its Horizon 1. For example, the Vaisala humidity measurement instruments have become a standard within the industrial customers. The financial performance in Figure 8 is an undeniable evidence of the past innovation performance.

Regarding the sight for future product offering, there are no alarming signs either: VIM is not forced to make major strategic changes or shift to entirely new markets. Talvitie expressed that the home turf has been well secured and it continues to offer feasible ground for further growth — *"there is no urgent need to embark on a Columbus-like journey in search of new continents."* Lehmus is also confident regarding new product innovation creation of customer value in ongoing product projects for existing product areas.

Exploitation and Protection (Phaal et al., 2001) of technology are on an adequate level. Lehmus commented that new technological features and increments are constantly invented in ongoing R&D projects that enable success of new products. She mentioned particular recent breakthroughs in algorithms. Lehmus did not see a clear need to, for example, a better identification of patentability of new inventions, as number of new patents or invention disclosures are not an end in itself. Moreover, Vaisala's product process is thorough in integrating product development with delivery capability and the Operations organization.

VIM organization has evolved into the current situation where it masters the Product Leadership in the chosen niche high-end instrumentation markets. Talvitie summarized that VIM now consists of functionalized blocks and is a relatively heavy-duty machine. The company is very process-oriented and product development is tuned for thorough verifying and validating of different aspects to ensure a perfect end result. Most successful have been the transactional sales of in-line or in-situ measurement instruments, where sales price is below a typical investment limit for industrial customers, as opposed to analyzers with a typical price tag of 100 000 €. Operations organization has grown to master the high-mix low-volume production.

However, while VIM has progressed a towards heavy-duty productization machine that runs a very profitable business, finding further growth opportunities and reclaiming the expectation of investors has become increasingly difficult.

4.2 Identified development areas

To help its Innovation Engine to run smoother and faster, I identified five areas for further improvement in VIM. The development areas are summarized in Figure 9. The partly overlapping areas address the process and project activity level in a single initiative, complemented by strategic, portfolio, organizational and cultural point-of-views.

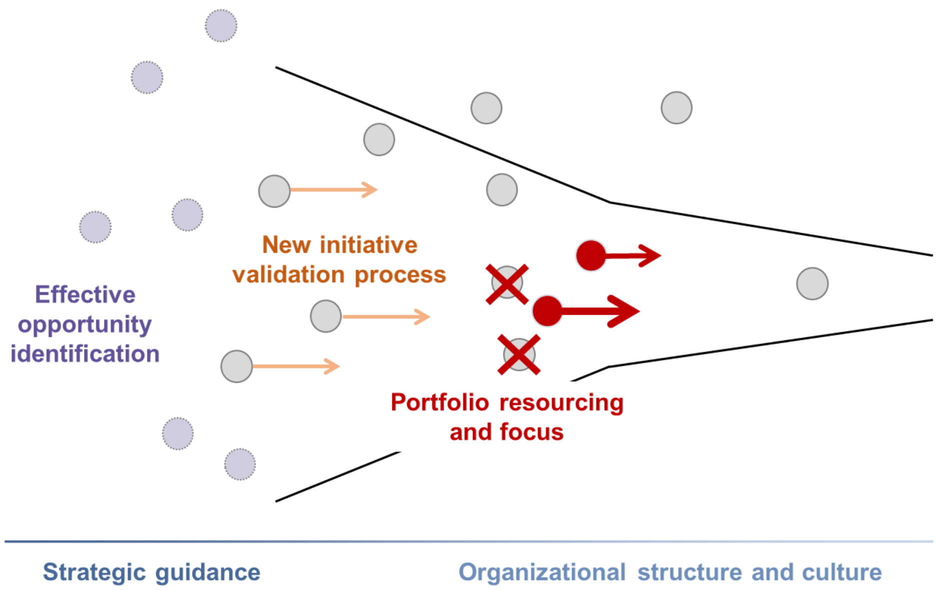

Figure 9: Five VIM development areas in an innovation funnel illustration.

4.2.1 Identification of new business opportunities

Firstly, I identify effective identification of customer needs and new opportunities, particularly from adjacent markets (Horizon 2) as a key development area. With the given context, the organization is forced to a multi-industry setting: serving a scattered portfolio of products for niche customer segments in different industries. Roman commented, that development within existing product areas is rather incremental. On the other hand, Horizons beyond existing markets are broad in the context where VIM is. The chosen Product Leadership approach makes discovering new customer needs from a wide range of different industries difficult and laborious compared to a setting where the company serves a limited number of customer segments. VIM needs to both get to know customer needs in the adjacent market but also solve them better than existing players, and doing this continuously requires considerable efforts in new business opportunity identification.

VIM is not widely exposed to diverse and complementary knowledge. None of the internal interviewees mentioned particular emphasis on implementing low-cost probes for effective new opportunity identification, in the sense that the Bird-in-Land (Sarasvathy, 2001) principle or the Absorptive Capacity (Zahra & George, 2002) model recommend. Roman's team is working with selected megatrends while product areas are focused on increments to existing business. Efforts are more focused on pursuing known initiatives, but the broad Horizons remain mostly unexplored. From the business opportunity perspective, Hakkarainen emphasized the significance of business development work in exploring effectively markets in the multi-industry setting. With the first Runway project, a key success factor was effective utilization of people who had had business development responsibilities in the Segment organization. However, such resource and mandate to seek for new opportunities from selected customer segments no longer exists in the organization in the same sense.

I think the problem is not the number of ideas as such — perhaps more ideas is better but on the other hand there is a constant stream of ideas from customer interactions and from within the company. The point is more about how many good and feasible ideas are produced. Roman thinks VIM should adopt a pre-screening of ideas that allow short-listing for the high potential ones already before a thorough validation process. Moreover, I think the current way of ideation in VIM might not ensure the best diamonds are necessarily among the ideas. If the radar looks too narrowly or to a wrong direction, it may only see noise and never identify the signals.

Similarly as customer needs, identifying of new opportunities from technology perspective is a gap in VIM. Lehmus and Roman both undermined a clear need for better exposure to external knowledge and scouting of technologies. Current core technologies are derivatives of the radical inventions made decades ago. Roman said: *"We lack visibility on what new technologies are created globally."* He thinks that the current mode of operation poses the risk that technological competence is and will be based too heavily only on the in-house technologies. This raises the concern regarding disruptive innovation, which is a key message of Christensen and Raynor (2004): new technologies may often be overlooked or underestimated by existing market players due to a lower performance or serving different customer segments. Even though VIM does not need to embark on Columbus-like journeys today, the technology base must be kept competitive, and I think exposure to external knowledge can help identify when it might be wise to start building a ship, or at least low-cost boats.

I think an important observation supporting this notion is that aligned with the Open Innovation paradigm, Vaisala's radical innovations happened at the boundary of the company, in collaboration with others instead of Vaisala R&D only. Since their invention, the commercial success of VIM has been from collecting the fruit with successful increments based on those few key technologies. Even though VIM has acquired entire businesses, such as K-Patents, it has not recently collaborated very actively with external partners regarding technology. The history shows how long technology development cycles into innovative products can be, and therefore planting the seeds early on would be advisable, regarding future core technologies.

For keeping technology base competitive, outside technology scouting is valuable as such. It can lead to valuable learning on how alternative technologies evolve and the focal firms' technology base competitiveness changes over time. Roman raised the need for networking in the technology field with key players also because it allows to identify potential opportunities for future partnerships or technology acquisitions.

On the other hand, Samuli Laukkanen for WEA technology context and Lehmus for VIM both raised the question of efficiency and scalability of external collaboration: technical problems that have been outsourced to 3rd parties have been so minor, that coordination is seen as a burden. As opposed to one-offs, more fruitful collaboration would need a longer-term relationship and collaboration, but recently single business opportunities have not yielded such a continuous stream of technical problems in a specific field to be outsourced.

4.2.2 Strategic guidance for innovation

The second identified development area is a lack of strategic guidance for new initiatives. Generally, strategic vision and success criteria are relatively clear: VIM aims for product leadership in niche markets, and new initiatives need to fit to sales channel and the Vaisala production model. However, this guidance stays on an abstract level and lack in giving guidance where to look for further opportunities. Talvitie thinks this is an important point, and argues that the strategy work indeed should give a framework that guides for where to look for further business opportunities and technologies. Laukkanen formulated the question for the context of WEA by drawing a red circle at the beginning of an innovation funnel on a whiteboard and asked: *"What are the unresolved problems with considerable business potential?"* When I raised this aspect in the conversation with Lehmus, she agreed that indeed a similar knowledge gap exists in VIM.

Lack of strategic guidance for innovation does not mean that VIM lacks strategy or market knowledge. Roman and Talvitie both emphasized that VIM does have identified industries and subindustries with attractive growth expectations, as well as interesting future megatrends. However, interviews revealed such knowledge is not effectively shared across the organization, nor are adequately connected to what technological capabilities would be needed. Therefore, the identification of unresolved *technological* problems with considerable business potential still remains undone.

Talvitie emphasized that a key question that needs to be integrated to the search for new opportunities is how synergies with existing strengths can be best utilized. The initiatives should leverage (increments of) existing core technologies, utilize the mass-configurable production capability and the sales channel. VIM should aim for where it is good at, and it would not be successful with new initiatives that stretch these boundaries. For example, in a Customer Intimacy type of tailored custom products business managing the complexity in Operations would become impossible. Moreover, managing the sales channel for a software product in parallel with the transactional hardware product based business would be very difficult. Much of these boundary conditions are captured in the success criteria list discussed by Hakkarainen.

Talvitie also thinks that focus must be an outcome from the strategic guidance. Generally, global measurement markets are not huge. This is well described by the fact that the Vaisala's half-billion business is spread over 300 product families. Some of those product families are very successful cash cows that enable the luxury of investigating new opportunities, but VIM can't afford to spend resources in entering too small niche markets. Therefore, the strategy must guide the usage of resources towards opportunities that show big enough growth potential for the company.

4.2.3 Process and Validated Learning for new initiatives

Thirdly, there is more to be done in terms of how Validated Learning is applied in VIM. Currently, all new product initiatives go through a traditional product process that is adopted the Stage-Gate model: it has different stages and gates for continuation. The interviewees and I see this rather rigid. For example, technology requirements or business case boundaries are fixed on an early phase. This kind of process favors and works better for increments to existing business where customer needs and the business case are well known. However, the current way of working is not as adaptive as theory (Eisenhardt & Tabrizi, 1995) suggests. Rigid processes are not efficient when entering adjacent and new markets that come with more uncertainty in these aspects. It is more probable, that along the way, the team learns crucial new aspects of the business case and iterations are needed.

Regarding business validation, there are somewhat varied practices between different product areas. To face uncertainty in new or adjacent markets, Hakkarainen emphasized that systematic thinking, entrepreneurial mindset and leadership were key enablers in earlier Runway projects. Validated learning approach prevents from blindly trusting the initial assumptions.

The Runway methodology had a good start, but its mindshare in VIM has decreased since a few projects were stopped. I think it is not the fault of the framework if a business idea doesn't fail — in fact, according to Ries (2011) avoiding the waste of more resources in bad ideas should be celebrated. Roman mentioned similar methodology is utilized in the strategy and business development team, and I have adopted it in a few Liquid Measurements initiatives, but still, such methodology is not systematically adopted across the organization, nor it is encouraged by the product process.

Technology development does have an own sub-process within the product process. Both Heads of Technology complimented how it brings clarity. However, the technology process is rather isolated from the business validation aspects, focusing purely on technology work. Moreover, the process does not emphasize or illustrate the iterative nature of new initiatives. If the process assumes fixed technology requirements at a planning phase, and does not adapt to market learnings, I think it may guide towards well-defined and perhaps within-schedule projects, but at a risk of compromising that the final technology or product meets customer needs.

Vaisala has traditionally been a process-oriented company, and the aforementioned development area arguments should not mean to add more complexity to processes, but quite the opposite. Talvitie commented, VIM would need a more compact process for better time-to-market for new initiatives. Roman's thinking went along the same lines: some projects should be allowed to work *"off the process"*. Describing something as a process can in some cases clarify, but on the other hand, sometimes limit how action is taken. Whether it is adding or modifying an existing process or not, the key point is a feasible way needs to be found for VIM to apply Validated Learning.

As an example of *off the process*, Lehmus mentioned Challenge projects, which was a model liked among scientists. The model allowed small teams of scientists to allocate little time to solve a technological challenge. The Challenge topics were selected through discussions with product areas, and scientists were able to affect what topic they would like to work on. The Challenge projects are currently not actively pursued.

One crucial point in successful business validation work is to be in sync with the technology development. I managed one Challenge project, which developed a prototype but never proceeded to testing in real applications due to poor strategic fit. I think of it as a result from the lack of business validation within the project team.

4.2.4 Portfolio resourcing and focus

Fourthly, internal interviewees had concerns regarding sufficient resourcing on innovative initiatives. In this sense, the VIM Runway trials, particularly to new markets, have been challenging. A stretch far from existing business can drain considerable business development resources and poses a higher risk for failure.

Restricted time and resources also shows in technology department. Lehmus raised the question of limited time in VIM scientist teams, and Laukkanen a similar point in WEA. Technology work has recently leaned heavily on engineering work and sustaining earlier projects. When attention dilutes into too many directions, new innovative initiatives are the first to suffer. With many low allocations, a scientist's way of working drifts more towards a task-oriented direction rather than taking a holistic ownership. Lehmus emphasized that to create innovation, one should not feel the burden of existing operational issues but should be able to keep an open mind.

Matter of resourcing is not about adding simply more of everything. VIM is in a good position in that it can afford to invest on new initiatives, but there still needs to be a sensible investment level. Lehmus commented that better innovation capability is probably not brought only by allocating more scientist work for new initiatives, and Laukkanen was troubled by similar themes. On the other hand, for competence it is important that a scientist also has experience from existing products and markets, but on the other hand what is an optimal amount of free time for passion projects.

Importance of focus was brought up by Felin et al. (2019) related to Lean Startup methodology. Low-cost experiments may encourage for too erratic changes in the course of action, and having too many ongoing initiatives dilutes the focus. It is important to only have a sensible number of ongoing initiatives, but wise selection of initiatives requires the good strategic insight to Laukkanen's question of unresolved problems with considerable business potential. Thus, the question of resourcing and focus is heavily overlapping with development area 3.

4.2.5 Organizational structure and culture to support innovation

Lastly, I identified that the organizational setting needs to be evaluated as it may not support innovation in the best possible way. Key driver is the point I mentioned earlier, and that most interviewees, including myself underwrite: the need to synchronize and bring business with technology development closer to each other.

I mentioned the example of my Challenge project that lacked the link to business insights, but also other interviewees mentioned similar examples. Such projects had been initiated based on initial and tenuous assumptions on the business case, and only after considerable technology development effort, a relatively light business validation revealed that the business case was not attractive and the initiative was shut down. Although non-attractive initiatives need to be shut down, doing so should be done preferably sooner than later. Timely identification of a non-attractive initiative requires that complementing competence areas are in close and regular collaboration.

Talvitie thinks that VIM organization is rather monolithic, because it is divided into functionalized teams. Technical competences come from different R&D teams, whereas business development work in product areas (existing business) and strategy and business development team (strategic top-level projects) is rather independent of technology development.

Cross-functional teams were emphasized by theory (Eisenhardt & Martin, 2000), but also by Talvitie: he thinks VIM would need smaller and more business focused teams with end-to-end responsibility on an initiative. The functionalized organization has led to too isolated silos and mode of operation that focuses on avoiding risks, rather than pursuing high-risk opportunities.

Composition of cross-functional teams is also a matter of competence. Lehmus thinks that it is difficult to be innovative if the competence level is not sufficient. Often the most innovative ideas come from a limited number of experienced scientists, which is a challenge for the team competence development perspective.

Culture and ways of working towards innovation need to be addressed as well. Lehmus raised the need to systematically develop towards a more innovative culture, and the questions of how to support that. She mentioned a few former colleagues who were particularly experimental Gyro Gearlooses and showed a particularly innovative spirit. I also think that her examples from the segment organization where also scientists took responsibility in validating business aspects show a desirable innovative culture which is lacking in VIM today.

Regarding culture, Hakkarainen emphasized that there needs to be tolerance to failure and *"courage to say no"* on initiatives when the validation feedback truly suggests so. Changing direction and taking risks is an entrepreneurial mindset aspect that is not yet fully adopted in VIM. The organization seems to be more oriented for risk aversion.

4.3 Benchmark interviews

In this subchapter I first cover general observations related to the benchmark interviewees and their represented companies, shown in Table 2. Then, I analyze what observations could be drawn from the interviews related to key themes, focus areas and practices for optimized innovation performance. In the analysis I emphasize some common denominator themes that showed in multiple interviews, but also cherry-pick most interesting examples from single interviewees when it is relevant for the research question and VIM context. This is appropriate because in some dimensions VIM is already ahead of the interviewed companies. An overall average of all interviewees would lead to a mediocre and ambiguous result, whereas learning from selected best examples can help towards better performance.

Table 2: Pseudonymized benchmark interviews done in this thesis

Name	**Role**	**Company**	**Industry**
Mark Allen	Head of Innovation	Corporation A	Industrial automation
Mark Williams	Head of R&D	Corporation B	Healthcare equipment
Neil Robertson	Director, Strategy & Innovation	Corporation C	Industrial equipment
Luca Brecel	Head of Technology	Growth Company D	Nanotechnology
John Higgins	Chief Executive Officer	Growth Company E	Nanotechnology
Hossein Vafaei	Head of Innovation	Corporation F	Information technology
Robert Milkins	Chief Executive Officer	Growth Company G	Cleantech
Jack Lisowski	Chief Executive Officer	Growth Company H	Sensor technology
Kyren Wilson	Innovation Manager	Corporation I	Building utilities
Stephen Henry	Head of Innovation & Ventures	Corporation J	Energy
Ali Carter	Product Area Director	Corporation K	Nanotechnology
Ryan Day	Head of Strategy	Corporation L	Consumer electronics

I chose to interview people in roles that have a relatively comprehensive view of innovation in the company, who all were able to discuss on a systemic level on what practices and processes link to innovation performance in the company or business unit. All interviewees expressed sharp thinking, but had differences in viewpoint from which they looked at innovation. Mark Allen, Mark Williams, Luca Brecel and Hossein Vafaei represented a more technical perspective where discussion about innovation leaned more into the technological invention and patents. Neil Robertson, Kyren Wilson, Stephen Henry, Ali Carter and Ryan Day looked at innovation more from a strategic and holistic, emphasizing the business potential and realized revenue more. All three CEOs of technology growth companies, John Higgins, Robert Milkins and Jack Lisowski showed both strategic thinking but also were enthusiastic to discuss technologies on a rather detailed level. Most interviewees had an extensive work history in leading roles on different sides of innovation. While we mostly discussed topics related to their current role and company, naturally interviewees drew some insights also from their previous experiences.

Vaisala is a multinational enterprise that employs over 2200 people, of which some hundreds work in R&D (Vaisala, 2022). Most benchmark interviewees were selected from large multinational corporations that are similar or larger in size. The R&D departments of the largest interviewee companies consist of thousands of employees across different countries. On the other hand, generally growth companies are known to be more flexible and agile in producing innovation than established corporations. To gain perspectives from both ends of the spectrum, also four interviewees from growth companies were chosen.

All interviewees represent mainly a high technology hardware product based business, opposed to software business where the key building blocks for an Innovation Engine would be entirely different. None of the interviewees are direct competitors for Vaisala, which allowed a more open dialogue in interviews, but the benchmark companies have similarities to Vaisala in some sense that brings relevance for this thesis. For example, regarding the products manufacturing processes some interviewed companies utilize similar microfabrication processes in their core technology that Vaisala uses to manufacture the sensor chips. High expenses of running a cleanroom, the batch-based process and long cycles of chip manufacturing bring certain boundary conditions to the technology development that is different from other types of product business. Moreover, some interviewed companies serve same or similar industrial customers than VIM, which affects greatly on how dynamic the business environment is. Industrial customers are much more inert and conservative than, for example, consumers.

Table 3: Summary of benchmark interviewee perspectives and main topics of discussion during the interview.

Name (Company)	**Perspective on innovation**	**Main topic of discussion**
Mark Allen (A)	Technology and invention emphasis	Effectively producing inventions within R&D and through external collaboration
Mark Williams (B)	Technology and invention emphasis	Regulative healthcare context and managing a rigid development process
Neil Robertson (C)	Strategic, corporate view	Adaptation of an entrepreneurial framework bringing transparency and boosting innovation performance
Luca Brecel (D)	Technology and invention emphasis	Their core technology and its commercialization; collaboration with external parties
John Higgins (E)	Both strategic and technical detail	Their core technology and its commercialization; collaboration with external parties
Hossein Vafaei (F)	Technology and invention emphasis	External technology scouting for competitive advantage; rapid cycles of consumer business
Robert Milkins (G)	Both strategic and technical detail	Bringing focus on selected customer segments and applications after an erratic start-up
Jack Lisowski (H)	Both strategic and technical detail	Running a hybrid of both structured and adaptive product development approaches
Kyren Wilson (I)	Strategic, corporate view	Innovation idea system and competitions on corporate level
Stephen Henry (J)	Strategic, corporate view	External business opportunity scouting on a strategic megatrend level
Ali Carter (K)	Strategic, corporate view	Innovation networks and how capex-heavy cleanroom operations affects innovation
Ryan Day (L)	Strategic, corporate view	Technological disruption and rapid cycles of consumer business

Level of R&D investments varies in the interviewed companies. Large multinational enterprises that I interview typically invest 1-3 % of their annual revenue to R&D, with two exceptions near 10%. Within growth companies, R&D investments share ranged from tens of percents to up to over a hundred. However, with the growth companies this metrics is somewhat irrelevant, as it is more of a matter of volatile or still ramping-up sales, how expenses are allocated in reporting is more subject to interpretation. Overall, VIM R&D investments, 11% of revenue (Vaisala, 2022) are in between the very high percentages of growth companies and low percentages of interviewed companies larger than Vaisala.

Table 3 summarizes perspectives and main topics of discussion that we had with each benchmark interviewee. Because of the differences in interviewee roles, background, thinking and company context, the conversations went different ways. I did not get, and the goal never was, to gain answers to all questions from each interviewee according to the interview structure in Appendix A. I began the interviews with the template, but used most of the available time on elaborating what resonated most and the interviewee felt had been most crucial in terms of successful innovation. Although not a statistically significant sample for quantitative analysis, this sample of interviews had an excellent representation of different perspectives for my qualitative case study.

4.3.1 Where innovative companies look for innovation?

The areas where benchmark companies look for innovation ideas vary greatly. Not surprisingly, as innovative companies have commercial success, all interviewed companies had an existing business where they continue to innovate. However, Corporations A, B, I and L had most clear emphasis on only the existing business, Horizon 1.

Allen represents one department from Corporation A which had one particular focus area related to process industry. The company is vertically integrated around that area, and thus the knowledge of customer needs comes as given. Williams from Corporation B was in a similar setting. He leads the R&D of one department related to a particular area in healthcare equipment, and the innovation efforts are relatively strictly focused on renewal of existing product platforms. Because of their existing business in that area, the needs are well-defined.

Both the process and healthcare industries are business environments where change happens slowly and innovation cycles are long. In process industry the stability is brought by the large investments: when a process component or system can cost half a million or more and it is expected to run for over 50 years, customers are not very open for upgrading. Allen commented, that because the Corporation A had gone to the particular process business, they do not lightly want to *"rock the boat with entirely new solutions"*, but rather try to optimize the existing solutions for better performance and efficiency. Similarly, Williams commented that healthcare providers are a heavily regulated customer segment and thus adopting new solutions is a slow process. For example, even though AI might have feasible applications in the area, productizing and commercializing such would be a long road because *"black boxes are not allowed"* in the industry. Williams thinks technological capability base Corporation B have increased incrementally over the years, but there have not been necessarily any radical technological leaps.

Corporations F and L make an interesting comparison as they both operate in consumer business. Vafaei described the environment as highly dynamic: in consumer products the competitive advantages can be very small, and such technical solutions can be caught up by competitors within months. Similarly, Day said that the technology cycles can be very cruel in the consumer business as the cost of switching is much lower than in a business-to-business environment. Corporation F spends considerable efforts in trying to achieve competitive advantage through deep technological core competences. Vafaei's team is looking for uniqueness from technology performance, cost or user experience of the product in a way that is hard to copy (Horizon 1), but also new growth from scaling the existing technologies into new application areas (Horizon 2). Corporation L, instead of pursuing to be the forerunner, had taken a follower strategy more strictly within their Horizon 1. Day described Corporation L as *"more of a development house than a research house"* and referred to the *not-invented-here syndrome*. He told examples about technological disruptions where they were not among the first ones, but were able to successfully catch up through taking rapid action.

Generally, the interviewed growth companies had been particularly disruptive and radical with their innovation. A typical story was that a startup was spun off around a technological invention from university research. Since then the growth company had become successful having found its key niche markets where their technology offered either considerably better performance or a more simple and convenient solution compared to established players.

Growth Company D was founded around the key nanotechnology invention from university research, and they began a rather opportunistic search for the proper application. Brecel described how the *"markets found them"*, with a key driver being their wide exposure in trade fairs, along with some element of luck. Today, they serve three key customer segments, but Brecel thinks they will have many more. Growth Company D seemed most widespread in their search for further growth areas, as well as a most ambitious target: they aim to disrupt an entire industry through becoming the de facto solution in the certain nanotechnology context.

Similarly, Growth Companies E and H were founded around a radical technical invention from university research, and both had found their key markets for the invention. Lisowki described that superior usability of their technology allows anyone to use a certain sensing solution that earlier required a trained expert, thus being a book example of new-market disruption. Growth Company E technology is radical compared to existing markets, but targets same customer segments as their competitors with considerably better performance, thus being sustaining innovation. Higgins mentioned that his personal background in the market gave him excellent understanding of customer needs, and thus had instantly recognized the commercial significance of the technical invention in the research team.

Growth Company G was founded on a more strategic level idea rather than a technology: the founders wanted to solve a certain world waste problem. The team chose to utilize a certain digital technology and only then began the search for a particular customer problem. However, they did not possess a radical technical invention from a university group in a similar sense than in Growth Companies D, E and H. Milkins described how the path of Growth Company G had in the beginning been too widespread to different customer segments and countries, leading to challenges. However, today, with a change in the strategy the company has successfully penetrated certain niche markets within its cleantech context.

Large corporations seemed to, in general, emphasize more on making increments in their existing product offering. Corporation interviewees did not mention particular examples of disruptive innovation as much, even though they may have examples of technologies that have disrupted some markets similarly to, for instance, HUMICAP in Vaisala. I believe one key reason for this is my research method. Within the one-hour interviews single products or technologies were not in primary focus, but the discussions were more about innovation as a phenomenon and the key processes and themes on a corporate or business area level.

Some of the larger Corporations look for opportunities from a strategic megatrend level. Many interviewees mentioned digitalization and sustainability as key drivers, but also more specific trends such as self-driving cars, COVID-19 or decarbonization of industries. Henry's team from Corporation J was an example of only looking at top level industrial megatrends and following what is happening in the world, rather than being confined with existing technologies or markets. Wilson introduced their innovation tool and competition practices in Corporation I, where the R&D organization is comprised of thousands of employees in different continents. He explained that their opportunity ideation at first had been entirely open, but they had later shifted to seeking innovation from selected strategic challenge topics such as safety or digital experience.

Established companies also seek inorganic growth. Robertson and Henry mentioned their Corporations (C and J) are looking for possible acquisition targets. The focus in Corporation C is within Horizon 2: in adjacent businesses that would complement or have synergies with their existing business and product portfolio. Out of all interviewees, Corporation J had most determined approach to Horizon 3 through collaborating with venture funds for extensive collection of market insights. Curiosity to learn widely about different markets is a key driver in Henry's team. Because disruption happens more often in startups, Henry's team is aware of all relevant startups within their interest scope, and keep up a constant conversation with most interesting ones. He thinks such insights could not similarly be gathered only through reading market reports.

4.3.2 Outside technology scouting and awareness

Nearly all interviewees mentioned a heavy emphasis with external technology scouting and collaboration with universities, research institutes and other companies, just as Open Innovation (Chesbrough, 2003) and Absorptive Capacity (Zahra & George, 2002) concepts propose. Also, the Crazy Quilt Effectuation principle (Sarasvathy, 2001) of forming and leveraging partnerships for mutual co-creation showed in various ways. The interviewed Growth Companies' technologies originate from university research, and therefore it is natural for them to be involved with different research consortium projects. Also, established Corporations put in considerable efforts for external collaboration. For instance, Allen said Corporation A often outsources R&D areas where they themselves lack the world-class know-how. Corporation A is very open in co-creation with other companies: Allen said that there *"isn't many relevant partners in our country we wouldn't have collaborated with"*.

Vafaei was most oriented towards exploring new technologies, as in the Corporation F context, the technological cycles are rapid and the competition is fierce. To avoid getting off track, he emphasized they need to define in the beginning clearly what they are looking for. From a clarified strategic target his team knows where to proceed. This framing is important because entering a new technological area requires reading a lot of scientific publications and visiting conferences. Their goal is in finding the key professors and research teams who are the primary source of novel cutting-edge technologies for Corporation F.

As a smaller company, Growth Company D had been able to amplify their resources through partnerships, ecosystems and consortiums where they had been able to integrate their own goals. In early development they prefer research consortium projects, and on later stages, partnerships with companies. Their key had been in finding a *"business champion"* partner, typically from world's largest corporations, who then provide the access to the value chain and complementing technology providers. Brecel prefers to have their beginning of the innovation funnel constantly filled with many early phase initiatives. Higgins' thinking went along the same ways: he thinks the surrounding ecosystem and access to a cleanroom have been vital prerequisites for the existence of Growth Company E. He also emphasized the access to relevant talent pool through the networks.

Henry too mentioned collaboration with research institutes and discussions with other corporations and startups, and his team was the clearest example of being the *"business champion"* in the sense that Brecel meant. They also seem to be an effective orchestrator of innovation networks (Dhanaraj & Parkhe, 2006): Corporation J holds a central position in pulling together necessary dispersed capabilities, and innovation is generated through the interaction. Henry thinks curiosity is their key enabler for having a constant stream of different strategic cases, and they are very open for a wide variety of opportunities. Many of them ultimately turn out to be not interesting for Corporation J, but every now and then something fits. He told about a few successful examples from energy storage or hydrogen economy related technologies. One idea came from collaborating and funding an university research team, another from conversations with other corporations. Sometimes emerging ideas become significant blocks in the corporate strategy, whereas others that do not fit to the company business model they have divested with good profit.

Carter talked about how crucial the ecosystems and communities are: *"our network has been very profitable for us in the long-term"*. I asked how they manage the efficiency in taking part in such ecosystems, and it turned out Corporation K has a special department to manage the relationships and, for instance, application processes in different partnership projects. Through their innovation networks they have been able to develop and facilitate a rather global value chain for their current products. Corporation K outsources certain manufacturing processes or sub-components of their products to different sub-suppliers in different countries, which they themselves have lacked. Utilization of the complementary assets externally had boosted their time-to-market in many nanotechnological end products, and Corporation K aims to develop in-house some of the lacking assets later. Carter added that university collaboration has been a win-win particularly in their nanotechnology field where heavy capital expenses of cleanroom production is an entry barrier for many. Corporation K can on the other hand share some of the costs with the university by allowing them to utilize their cleanroom production area, while on the other hand they gain innovative ideas from research teams for their future products.

Day thinks one of the values of technology scouting is the awareness of where the world is going in itself. He told that Corporation L had been monitoring its direct competitors, but it did not have a comprehensive understanding of the global development that had been happening around one of the crucial technology platforms. Unexpectedly, a few major companies entered Corporation L's market from the sidelines because they had developed competence in their original market that now could be exploited also in the Corporation L segment. Their market had been disrupted. Day's advice is that on one hand one needs to be widely aware of surrounding technological development steps and cycles, as well as monitor also what companies in adjacent markets do. However, on the other hand it is important to keep a wise *"signal-to-noise ratio"* and avoid too erratic reactions: not all small changes in the field end up disrupting the market.

Insourcing and exploiting outside technologies seems to be quite a case-specific theme, and the interviews did not provide many insights in these aspects. Vafaei commented that their way is an *"industrial standard"*, and the toolbox includes all the alternatives: acquiring, licensing, exclusivity or collaboration projects. Williams too remained on a rather general level: they may choose to recruit new people, purchase external know-how or involve university collaboration.

4.3.3 Leadership required for innovation

Executive managers' positive attitude towards innovation is crucial. Allen told how during his career in Corporation A, it had been crucial how such attitudes had improved. Henry was glad about how the past two CEOs had been very supportive towards innovation and venturing activity. Wilson told that their CEO was involved in the jury of innovation contests. Day concluded that for successful innovation, whoever owns the budget needs to be either a Gyro Gearloose type of person themselves, or actively listen to one within the organization. He thinks that *"A stubborn mindset can lead to missing a competitive advantage."*

A single initiative always needs a business champion to take ownership. Allen said *"No matter how good an idea, as long as there is no businessperson to lead and fund it, it doesn't fly."* Robertson said the same thing: projects without clear buy-in from the business move forward considerably slower. Wilson thinks it was crucial that judges in their innovation contest were same people who were responsible for product areas. They supported the innovation teams for pitching their ideas, but also had the dedicated budget and power to decide on implementing the best ideas. Vafaei emphasized that his team does not act before the top level strategic direction and the business buy-in are clear: as the team is heavily oriented towards looking for cutting-edge technologies from outside, one can easily waste considerably time and money if it is not clear what they are looking for.

One interviewee with an extensive earlier experience in multiple Healthcare corporations brought up an important point regarding top management involvement: strategic guidance is important but so is avoiding micromanagement. The project team needs to be empowered with decision-making. He told an example of how the opposite happened: decision-makers ended up too heavily to top management, and this led the organization to doing things that were guided by top managers' bonus incentives.

Innovation needs to be fully aligned with the corporate strategy. In Corporation C, Robertson said, *"everything starts from strategy"* and product areas' growth target setting. Both Williams and Vafaei are heavily top-down oriented: all new initiatives are systematically drawn from the business strategy. Wilson told about their innovation contest challenge themes being now drawn from corporate strategy. Henry too emphasized the clear alignment, but also told about a few bottom-up examples. Initially a side initiative in his team, remote from the Corporation J core business, had now become one crucial element in today's corporate strategy.

Of course, depending on where the company today stands, the innovation strategies in benchmark companies were different. Not all interviewees want to explore widely different initiatives. Williams told about the Corporation B strict focus on few major R&D projects related to existing businesses. In Growth Company E, Higgins is the business champion himself and told that their strategy is rather strictly in commercialization of their technology and that they are not *"a Gyro Gearloose firm."*. The company focuses on discussing with customers to find the common ground for a sales deal or collaboration. Milkins, too, now emphasizes the team efforts on a focused customer segment: *"In the beginning we ventured too aggressively into different countries and applications globally, which scattered our focus. A small organization can not have sufficient presence across so many segments."*

Robertson strongly believes that *"right ambition level in strategic targets leads* *to right things happening."* For Corporation C, nearly all innovation is drawn from growth and climate related strategic targets. In the strategy work they observe where the company is today, and how much growth needs to be achieved in certain period. This growth gap leads to better commitment of businesses on certain innovation initiatives as they know to what strategic targets the initiatives are linked to. Moreover, Robertson thinks the targets should always be business related rather than technical. For example, digitalization and being able to connect and transmit data between different products and systems would not be a good target, as the technical implementation is not an end in itself but rather the commercial benefit derived from it.

Milkins emphasized the need for openness in two directions between strategic leadership and R&D, marketing and sales. In Growth Company G he was happy that such a culture had been created. On other hand, top-down, the leaders must be open in what goals the company is pursuing, but Milkins also wants to constantly hear from bottom-up what is happening. Otherwise the strategy will be isolated from the market and technology.

Henry summarized that *"innovation requires a dedicated budget, patience and a mandate for action"*, and was happy to have those in Corporation J. Building new businesses from zero takes time and along the way there are many opportunities for failure, and therefore leadership must not be of the type *"you have two years, after which you have to have something big!"* Robertson too mentioned patience, and how they had had challenges earlier with management who were reluctant to invest beyond a horizon of few years. Corporation C then decided to create an innovation fund within the company that allows handling innovation initiative investments on the group level. The fund would pay for half the costs, making it more attractive for business owners to pursue. It also gave an encouraging message to managers across the organization that the fund would always be open to support great projects with money, which of course are evaluated case-by-case.

Few interviewees mentioned how the corporate business strategy was parent to and interlinked with technology strategy work. Robertson talked about their strategic foresight work, where the technology foresight work aims to bring input through exiting technological strengths in Corporation C. This is the way how Corporation C seeks new growth areas from Horizons 2 and 3 through a technology push mechanism. Williams similarly works with technology strategy that works as an input to business strategy planning. He introduced the technology ownership map, which was a framework he adopted in Corporation B. It consists of five swimlanes where different relevant technologies are mapped according to their strategic importance. The top swimlane will have the most strategically important technologies which would be crucial to have in-house (e.g. a core sensor technology), and towards the bottom the importance decreases. The bottom lane is filled with commodity technologies that are commonly available in the market (e.g. valves) and should preferably be outsourced. Regular reviews of the technology ownership map allow identification of, for example, new technologies that are of strategic importance but might lack clear owner or competence in the organization, or whether some technology that earlier was of great importance, has become less important today and should be less resourced or even divested.

4.3.4 Market and customer need understanding

Deep market understanding and knowledge of customer needs came up in all interviews as crucial for successful innovation. This rather obvious notion was emphasized because it seems to be easily forgotten in day-to-day operations. The importance of customer needs is well described by a story from one interviewee on what happened with touch screens and Nokia: the first touch screen phones performed rather poorly and the non-touch-screen Nokia mobile phones dominated in many aspects of technical performance. Still, despite the poor battery capacity or worse antenna expertise, Apple's iPhone was able to enter the market through relatively good browsing experience with the capacitive touch screen. As we know, since then the capacitive touch screen has become the dominant design in all smartphones. The key takeaway from the story is that Apple had understood what customers appreciate better than Nokia.

For some interviewed companies gaining the deep market understanding is rather trivial. For example, Corporation A is vertically integrated and in a way that the end user know-how is within the same company, or in Growth Company E Higgins brings such expertise personally to the company through his extensive work history in the customer's position. Other companies had to work harder for the customer insights. Williams, for example, mentioned it is particularly challenging as customers easily become remote in a business model where sales are done through distributors.

Entrepreneurial *go-out-and-see* attitude showed particularly strongly in Growth Company interviews. Lisowski said they had found their current two customer segments through exploratively trying dozens of different things and evaluating what could yield a scalable business. As a book example of the Lean Startup, Lisowski explained how they travelled to meet different customers and introducing MVP prototypes in different trade fairs to probe for market feedback, showing off the prototypes as better performing as they in reality were at that time. Higgins emphasized learning through customer interaction and thinks trade fairs are important. Brecel explained how Growth Company D existing business had been found through trying different applications with an opportunistic trial-and-error approach and that they still aim to serve multiple different industries and customer segments with their nanotechnology solution. The Growth Company D technology is on the other hand universal, but on the other hand it requires development and tweaking for particular applications, which is why they constantly keep interviewing people in different positions across the value chain. Milkins mentioned their start might have been even too widespread to different applications, but now when they have chosen their segments they were able to better identify needs. They did exactly what Fitzpatrick (2013) recommends: observing customers' behaviors and actions rather than solely relying on their words. Milkins mentioned they had taken 4 or 5 people to customer and see the actions of customer around a certain process and through neutral observation they collect up to 100 aspects that could be done better, and later shortlist them to actionable items.

Established companies, even within their Horizon 1 emphasized customer interaction. Carter said that they always want to start talking with the customer from the beginning of new product development: *"We know our tech but often customer's problems are very application-specific."* He thinks this considerably speeds up the development process but also helps to create entry barriers for competitors as the early involvement allows them to tweak the technology and influence the customer so that Corporation K becomes the specified supplier for the particular component. Williams said last year six times their R&D people have visited a customer for an entire day without a specific agenda, just to learn. He thinks *"There's never enough of this, always could do more!"* One interviewee with long history in another healthcare company too emphasized that development needs to be very close to the customer. He mentioned that they recruited end-user doctors into product manager positions and believes that it was critical for success to retain these individuals, who have a history in customer organizations, in decision-making positions.

Lisowski thinks the explorative approach came naturally in the beginning for their team of less than 10, whereas the current organization of dozens of people already requires a different kind of leadership and a more structured process. Henry, representing a much larger corporation, thinks the similar explorative curiosity needs to be maintained, but in a structured way. His team has a template and certain criteria for an opportunity market size and growth, but they still explore the world broadly for new opportunities. Henry thinks an important thing in his innovation team activity is that the learnings are shared, because learning is the primary goal. He thinks of his team as an internal consultant office, and sharing the learnings is the counterpart for Corporation J paying the consulting invoice.

Many interviewees emphasized that for effective market understanding a dedicated business development resource is needed. One interviewee mentioned that he was able to wangle in the rigid healthcare corporation in a way that he was able to recruit few business development managers in his R&D organization. They were then able to target key customers with selected salespeople and validate whether the sales would be able to sell a future product. The business development manager was able to be closely involved with customers and then bring the customer feedback directly to R&D. This had revealed many valuable things on how certain products are sold and why some products are not performing well in sales.

Working in such business development role within the VIM R&D organization myself, we ended up discussing different meanings of *business development* in a few interviews. In theory, it could mean *developing* virtually anything related to business. A friend of mine once framed it as a *"fancy title for a salesperson"*, whereas in some organizations it is a more strategic role. Even though there are links to strategy work, sales and marketing, I think of my role primarily as a link between customer needs and new product development. Lisowski described it as an *"upstream product manager"*. With him we concluded that in such role it is important to have both technical and business understanding. Regardless of the title, such resource for hearing and understanding the customer feedback and linking it to technological capabilities seems to be at the core of innovation.

The emphasis on customer needs and market understanding aims for managing business risk in new initiatives. Robertson and a few others mentioned the challenge of the engineer mindset tendency on solving the known and most challenging or interesting technical problems, but not necessarily thinking what problems have the biggest potential. This can easily lead to waste (Ries, 2011): developing something customers do not need. Milkins mentioned that in one area they currently have a solution but are struggling to find the customer need. We discussed and agreed with the point brought up by Fitzpatrick (2013): the company can affect its technology development (tech risk) but cannot generate customer needs (business risk). No R&D investments make a difference on whether the customer pain points or market needs exist or not.

4.3.5 Entrepreneurial frameworks and business validation

Entrepreneurial frameworks like Lean Startup aim for learning about customer needs through a systematic approach. Recognizing the vital importance of understanding customer needs, I asked whether and how the interviewees had embraced such methodology. It became apparent some had little involvement in utilizing the frameworks. Allen did not mention any examples of Validated Learning. Williams said they have development ongoing and are moving towards the Lean Startup direction in Corporation B, but are not currently adopting such framework. Brecel mentioned they have no methodology whatsoever, but proceed more in a trial-and-error way. Carter mentioned that they tried but were not very successful with adopting the Lean Startup. Corporation K is undergoing some organizational changes at the current moment, but he hoped they could come back to entrepreneurial frameworks in the future.

Other companies did show different adaptations of Validated Learning or other entrepreneurial frameworks, although none of them said they *adopted* Lean Startup per se. Higgins said they do not apply such framework, but still the Growth Company E activity resembles much of what Ries (2011) proposes: they actively learn from trade fairs and customer meetings, and Higgins mentioned an example of a pivot. Growth Company H was even more in line with the Lean Startup methodology. Before I even got to ask about entrepreneurial frameworks in the interview, Lisowski had mentioned MVPs, proof-of-concepts, iterative way of working and getting out of the building. He thinks this entrepreneurial mindset came naturally for the team: to survive as a startup, they had to accept not everything is perfect the first time and optimized the resources of the small team for validating most important assumptions. Henry, too, mentioned how his team starts with certain assumptions of, for example, achievable market and business growth, and then validate for customer traction with different concept studies, mock-ups and experiments.

However, within the large corporate context, Henry faces the challenge of measuring success in innovation initiatives that have an extended timeline. While bonuses are typically awarded annually, certain initiatives, such as those related to the hydrogen economy, may not generate revenue until as late as 2040.

The most interesting adaptation of entrepreneurial frameworks, and also an answer to Henry's question for measuring innovation came from Robertson. It was rooted from Lean Startup, but Robertson shared that it was not sufficient for Corporation C as such. Their challenge initially was that teams were making their own metrics and the learnings not being comparable between different initiatives. That's why they developed a common model for all innovation initiatives that start from assumptions and then continue for Validated Learning to collect evidence for different categories. The teams have a template that guides them to evaluate different product, business model, market and operations related aspects that are related to new business development. Instead of milestones, the maturity of the evidence is converted into a numerically measurable value using a simple heuristic. These measured evidence values form a shared situational picture for both the project team and the steering group. The progress of the maturity of each category could then be monitored on an initiative level as well as portfolio level.

The model in Corporation C allows effective identification on how and why initiatives are or are not progressing. Robertson told examples that they have been able to show business unit leaders data evidence on how much faster and more efficient an initiative is when they include a salesperson to the team. When a team sends an application to the Corporation C innovation fund, the template forces to propose an entire business case having evaluated the different dimensions, rather than only a technical invention. The model makes the entire team better aligned towards holistic success of the business case rather than suboptimization. Robertson explained that with the help of the framework, often the team themselves or together with the steering group have been able to identify, for example, if they are lacking a certain kind of competence or support.

Robertson also told about the importance of progressing at the same pace in evidence collection in all categories. If, for instance, the product evidence is much ahead of evidence maturity commercialization or business model categories, they probably have invested too much on R&D. This reminded me of the examples from Vaisala where after thorough technology development, a relatively light business validation efforts were able to reveal that the business case was not attractive. With help of Robertson's model, the steering group can identify on a timely manner if a project team needs to focus less on the product or technology and more on the market evaluation.

We discussed about Ries (2011) with Lisowski, and his thinking aligned much with Bocken and Snihur (2020): the methodology is not a panacea for all challenges. He emphasized the importance of not overlooking the product while focusing on customer needs during business validation. There needs to be a strong connection between product feedback and R&D. In order to collect valuable feedback, an individual must have a comprehensive understanding of both customer problems and technological capabilities; otherwise, the feedback collected may be too scattered or broad to be effectively utilized. As a deep tech company, they must conduct product development based on their own technical capabilities. Therefore, the business validation process should aim to find matches specifically with their technological competencies, rather than just any technology. Lisowski thinks in the beginning this was easier for Growth Company H but the current setup of dozens of employees already requires a different kind of leadership approach — a more structured and process-oriented one.

No framework is an end in itself, and one should not try to outsource general thinking, market or technology understanding to a framework. Robertson commented how it is *"easy to say build-measure-learn"* but the significance is in how it is applied and what is the outcome. Lisowski too criticized how such things are too easily taken as mantra. One interviewee mentioned that his previous employer had thorough efforts to adopt Design Thinking, but he disliked the way it was done. The methodology ended up circulating as a buzzword among only some corporate and key initiatives, where top managers, distant from the technology and market needs, mainly supervised whether a Design Thinking process is followed rather than whether sensible things are being done in the initiative.

Fail fast is another cliché repeated in entrepreneurial frameworks that is often misunderstood. Robertson thinks failing should not be the target, as it would only lead to bad projects. The goal should be to succeed, but if the idea is to fail, it should be done fast. For this, their own framework has been able to help: the common template makes the entire team to faster understand and accept the situation when the initiative should be closed down. This links to what Hakkarainen meant by *"courage to say no."* Brecel and Milkins both thought very similarly of failures: it should be done rather in the beginning than when the product is launched to market. Milkins considers being stuck with a hundred installations across the globe being the worst failure — the company is suffocated by the maintenance burden and market pull doesn't allow scaling up the business to hundreds or over a thousand installations.

Brecel commented that Growth Company D has been quite successful with adopting a positive attitude towards failures. For them, failed experiments have become important trade secrets and learning opportunities. Learning was also key in how Henry saw failures: attitude needs to be aligned to Validated Learning, and one needs to try discovering why something would not work if such reasons exist. He thinks that a team that aims for the business case *"not to fail"* can be a detrimental target. This leads to *"wearing the eye patches"* and collecting selectively only the feedback that supports the assumptions.

An important notion from the Robertson interview is that developing the currently very successful framework took iteration. In a way, one needs to do build-measure-learn iteration on how they adopt the build-measure-learn on product innovation. This reminds me of how philosopher Esa Saarinen often talks about thinking of one's thinking to enable better thinking. In our my thesis context this means making assumptions on how a suitable framework should be, building a prototype of such framework and then trying, measuring and learning how it works in the organization. The framework can be fine-tuned and iterated according to learnings. Alternatively, it might as well turn out that the framework itself is not the root cause, and perhaps the organization needs to pivot into developing cultural, competence or structural aspects.

Robertson thinks of new business and innovation as a highly complex problem, and one needs to develop the solution together with the customer to gain the best understanding of what to productize for that market. Another interviewee proposed a similar co-creation idea, as they had integrated the customer need understanding in the product development process. The company chose 3 to 5 friendly and progressive customers to utilize together in product development workshops, and later the same customers became first reference sites, which the company exploited to market the idea forward to further customers.

Finally, it seems real business validation is very difficult and there are no bullet-proof ways for it. Even with the right entrepreneurial framework and mindset, there is always business risk. Milkins formulated that *"only after you have been realizing the revenue you have truly validated the business."* Higgins also emphasized that the paying customer is fundamentally the signal one needs to look for, but the fundamental problem is that it is often impossible before the product is developed.

4.3.6 Product development and innovation processes

Product processes adopted from the Stage-gate model were very common among the interviewed corporations. Allen characterized their product process as a *"stiff model where an year is the basic unit."* Williams described that the healthcare industry dictates how product development is done, and thus they always go through the typical phases of conceptualization, feasibility study, product development, testing, notified body acceptance and production ramp-up. Another interviewee with experience from healthcare repeated similar lines: the industry is very regulated and thus they obey a rather rigid R&D process. Williams, however, told that this process is only what shows to top side and the practical work is more agile. What they call gates is in reality more like project milestones, and often for example the development phase can start before conceptualization is entirely finished. Williams wants to keep this kind of flexibility in Corporation B product development.

The Stage-Gate product process seems to be an obvious choice for developing increments in existing business. However, more refreshing findings for VIM can be made regarding the early stages of the innovation funnel: how interviewees manage early-stage innovation initiatives that are on the fringes of current business. Most intriguing was the entrepreneurial framework developed by Robertson where the team is empowered to collect evidence for the entire business case. The project team works with short cadences and a metered funding principle: with more evidence they can proceed forward with the project. Instead of gates, they focus on maturity of the business case, which allows the team to better *"keep the eye on the ball"* — the ball here referring to the innovation and its successful commercialization. Robertson's framework helps Corporation C to better orient for a holistic approach and closer collaboration with customers when solving the complex problem of new business development. Measurable metrics steer the team to work on areas that need the most validation, as well as allows them to identify possible dead ends and needs to pivot.

Vafaei told about their concept development process, which also is located at the beginning of their innovation funnel. In Corporation F the concept development process is used for initiatives that are not yet official R&D projects but *"more like pre-projects"*. The technology team spends typically 3 or 6 months to evaluate and produce a proof of concept of a new technology. Small amount of money, not more than 100 000 EUR, is reserved and the team has ownership of the idea and is empowered on decision-making up to the budgetary limit. Typically, before such a pre-project they already have a clear business case, and concept development is rarely chartered in unclear business cases in Corporation F.

Growth Companies had varying practices. Growth Company D has a product development process that is related strongly to technology and was rather distant from business aspects. Brecel told about gates that ensure that the technological maturity of the product excludes failures at later stages. He also mentioned a ticket system that allows doing quick experiments, less than 500 EUR, without asking anybody. They do not have a formal time allocation for such side experiments as Brecel didn't believe such allocations would ever be realistic anyway. These experiments are where Brecel believes they often get failures, but also provide valuable learnings. In such innovation work, Brecel mentioned they had found Theory of Inventive Problem Solving, TRIZ to be a useful tool.

The innovation funnel of Growth Company G is focused on existing business, but Milkins mentioned he is trying to adopt the Scaled Agile Framework way of working on both their hardware and software development. However, he was not yet sure on how well it works. Similarly, Growth Company E focuses much on production ramp-up of their current product and therefore they avoid too erratic new innovation initiatives at the current moment. Higgins mentioned an innovation process, which is used in the company to maintain pool of potential future patents.

Growth Company H had most flexible approach and they are running two types of processes in parallel. Lisowski considers processes, much like roles, to be guiding templates rather than obligatory or fixed entities, allowing for alternative approaches when they make more sense. Their product development process is a hybrid from different models. On one hand they have Gantt charts and milestones to guide projects forward, certain aspects are agreed on the roadmap and, for example, product approval processes are handled in a structured and linear manner. Growth Company H has regular product releases which require strict coordination between different competence areas, which Lisowski called the *"continuing breath of the company."*. On the other hand the aforementioned way of working, Lisowski thinks, guided too narrowly towards iterative development of the existing product. Therefore, the company began to run a maximum of three parallel projects alongside this main product pipeline. In those projects they aim for new MVPs for new business cases, and being fully isolated from the releases and approvals, they are able to work in a much more agile and Lean Startup way.

4.3.7 Focused portfolio and rapid cadences

VIM is not alone with the challenge to manage resourcing and broadness of the project portfolio. Carter was similarly troubled with the efficiency R&D department: they have dozens of parallel projects that only progress little. The research methodology of my thesis is not suitable for providing specific guidelines regarding the VIM portfolio, such as the number of projects or resource allocation. However, I bring a focused innovation funnel and short cadence to the forefront as portfolio and project management themes, as they emerged from several benchmark interviews.

Many interviewees emphasized that a focused portfolio with high allocations of employees to a limited number of initiatives had been key for innovation performance. Focusing the resources to a few key initiatives had enabled a rapid cadence and progress for validating a business case. For example, Robertson told that their early initiatives have a monthly cadence of follow-up between the project team and steering group to review schedule and business case evidence, and only few months is approved at a time for evidence collection for the business case. Vafaei too told about their typical concept development phase taking 3-to-6 months to evaluate a new technology and provide a proof of concept. Milkins too, when explaining his Scrum Agile Framework approach in Growth Company G, thought that short enough interval is important. An interval of month or two combined with clear and tangible targets brings good results.

The cadence of innovation initiatives seems to heavily depend on the context, which is considerably slower in cleanroom manufacturing or the healthcare industry. Higgins told that they have been struggling a few years to find an industrial partner to finalize the productization and production ramp-up as their manufacturing requires a cleanroom environment. Williams told about hindrances that regulation poses in the healthcare products. I discussed the issue of long technology development cycles with Henry and he understood the problem: for example customer tests can take three months. He commented that business model or digital innovation are faster by nature.

Moreover, effective focus of the portfolio meant different things for different companies. Corporation B and Growth Company E were examples of most narrow focus in only few initiatives, whereas most benchmark companies run in parallel multiple projects that are at different stages. Growth Company H is a good example of this, as they run up to three projects alongside with the main development pipeline. Growth Company D seemed to have an exceptionally broad innovation funnel. As Brecel commented that in their multi-industry approach there *"needs to be plenty of early-phase initiatives in the funnel."* This probably stems from the nature of their core solution, which is rather universal and applicable to different industries with minor changes.

Robertson's framework had helped to bring data evidence on the decision-making for effective portfolio management. The template and way to validate evidence is shared for all initiatives, making the situational picture also transparent to portfolio managers. Robertson thinks the model gives good visibility on the business case risk rather than typical project plan reviews that mainly address schedule risk. Corporation C also has plenty of data evidence from past cases on how risk evolved and initiative progressed with respect to resourcing. Robertson thinks that the focused resourcing and clarity of strategic targets had been key to success. He had been able to prove with data and also motivate the business units to dedicate for example 3 days per week of key developers' time for a certain initiative for two months, or include a salesperson to the project team as it increases the pace of progress.

Transparent situational picture allows more equal handling of the initiatives in project portfolio. There has to be progress in all evidence categories before more R&D money can be granted. Robertson told that when the innovation fund gets an application, they often notice that technical evaluation is well covered, but they pinpoint gaps in other categories that need to be filled before further funding.

Robertson and Henry both emphasized the importance to avoid spending too much resources too early, and liked the idea of metered funding. Robertson explained how in Corporation C a typical early validation cost ranges between 10s and 100s of thousands of euros, whereas productization and market entry requires an investment of millions. Vafaei told about similar a ballpark in Corporation F. Because proceeding comes at a growing expense, it is important to know when to proceed. Williams shared a cautionary example in which the business leaders pushed to rush the start of the development phase. He emphasizes that nowadays it is important for them to mitigate technical risk during the feasibility and concept stages. Robertson thinks with their framework they have currently been able to avoid projects that drain too much money in a too early phase.

Linking with the fail fast theme, killing bad projects came up also with portfolio management. Particularly one interviewee with history in healthcare corporations said he had seen very little of ending projects and would focus heavily on that if he went back. The need for *"courage to say no"*, as Hakkarainen formulated for VIM context, showed also in Corporation J. They often have realized at a late stage of the project that the assumptions had been optimistic, which has led to terminating certain business areas. Also for this issue, Robertson thought their framework brought help. Transparent evaluation of the evidence has allowed both the steering group and project team to faster identify and commonly decide on project closure.

4.3.8 Ways of working, competence and organizational structure

According to Lisowski, central to innovation is a holistic understanding and a strong linkage between market feedback and R&D. As their team has grown, Lisowski said, maintaining this link has become more difficult but they do put efforts in maintaining product understanding in the sales team, and utilize product managers in this respect. As discussed earlier, business development can act as such linkage, and some interviewees had successful experiences with such roles within R&D organization. While Lisowski emphasized the need to know thoroughly the product and technical capabilities, Brecel and Robertson emphasized the need for business thinking in such role. Milkins has solved this through a very open and bidirectional communication between management, R&D and sales & marketing. While management decides and clarifies strategic direction, the understanding of technology and markets is constantly being updated.

An innovative company must foster curiosity and experimental culture. Henry thinks that curiosity has been the key reason for finding such interesting cases in his team. Brecel seemed a good example of a curious person himself. Their invention offers very a favorable ground where, he believes, are numerous built-in opportunities that he is eager to explore and discover. Such culture comes organically in startups, but both Lisowski and Brecel brought up that it requires increasing efforts to maintain when the firm grows.

The team must be competent to explore. Vafaei's team is strongly oriented for external world and often entering new technological areas, and Henry's team similarly for strategic megatrends. To be able to discuss and collaborate with external parties that represent adjacent or new areas for the focal firm, I think, require a high Absorptive Capacity (Zahra & George, 2002) and competence from the team.

Also, when it comes to technical solutions and inventions, it is not only about allocating enough people. An innovative organization must be inclusive for and utilize the curious and innovative minds. As mentioned earlier, Day emphasized how the decisions regarding the budget must be made or affected by an innovative Gyro Gearloose. He is a strong advocate for utilizing such individuals, who often think differently than the rest of the organization. Day told that in Corporation L they had had much success by bringing such individuals to workshops and including them in innovative initiatives. Innovation leave, a concept in use in Corporation J, is one means to utilize such flexibility in the organization. Henry explained that the company permits an employee for a maximum of one year leave from their current role into pursuing an innovative idea within the company.

The team needs to be cross-functional and empowered for the decision-making because it has the best knowledge of the technical capabilities and market needs. Day was the strongest advocate for such self-directed teams that have a clear mandate and power. He thinks a strategy team can't lead initiatives alone as they often lack the technical competence. While, Robertson and Vafaei explained that there is steering and guidance from the management, the initiative teams in Corporations C and F are rather autonomous within their budgetary and time limits. Vafaei commented that in his technology team they still have a holistic responsibility on clarifying the business case: *"If it's your baby then you need to clarify it"*. Higgins emphasized the importance of diversity in the team, not only regarding competence backgrounds, but also with regards to e.g. gender, age and nationality.

Finally, interorganizational linkages are of utmost importance for innovative performance. Allen raised a key point regarding innovation programs that is probably true for any major corporation: *"in the end, quite a small group of experienced inventors generate most successful ideas"*. He has been planning on a mentoring program to allow knowledge transfer to the less experienced technologists and helping them to see technology in a more inventive way. However, fundamentally no program can replace the internal contacts and network within the organization. With Allen, we spent some time around this topic, as this had been my personal experience as a young scientist at Vaisala too. Knowing who are the best experts in different competence areas, and basic understanding to be able to discuss and facilitate is a very powerful combination in problem-solving.

4.3.9 Innovation programs and incentives

Corporate level innovation programs are a way to keep innovation a topical theme in the company. Allen mentioned annual invention campaigns in Corporation A and Williams told about an idea bank practice in Corporation B. Henry and Wilson brought up most extensive innovation programs in Corporations I and J that resembled each other much. First, a few strategic themes are selected where business units then brainstorm for innovative solutions. Ideas are collected both from individuals and teams within a few months, and then best ideas are incubated in small teams with support of the jury for some weeks. The program culminates in a physical finals event or camp where cases are pitched to a jury and best ideas are awarded.

Many of the innovation programs involved top management, and Allen, Henry and Wilson greatly appreciate the enthusiasm of top executives regarding such innovation initiatives. For instance, both Henry and Wilson highlighted the CEO's participation in the judging process and their presence in the grand finale. Henry believes that this contributes to fostering a stronger innovative culture within the company.

It is crucial that the best ideas in the program get a dedicated budget and a business owner. Allen said that it is clear that an idea without business ownership gets nowhere. Wilson thinks the best thing in the Corporation I program was that the judges who did short-listing and awarding decisions on the ideas were the same people who were responsible of the product areas and therefore would be able to support the team and use a dedicated budget for developing forward the best ideas.

Innovation programs should be well incentivized and marketed. One interviewee said that in their program the best idea wins 100 000 € project funding to pursue the idea further. Another said that the winning team gets personally awarded for

10 000 € and the second prize is 6 000 €. A third interviewee, also emphasizing the incentivizing theme, commented that they had *"considerably increased the invention awards"* in the company. The innovation leave practice in Corporation J also works as an incentive for pursuing a passion project. Regarding marketing, Allen mentioned he had put effort on corporate wide innovation training material and he and Wilson both mentioned visible advertising in the corporate intranet.

Such programs come with the need to measure and compare different ideas. For Allen, this essentially means inventions that are patentable since for the long product lifetime cycles in the Corporation A context the 20-year protection of patents is very suitable for a competitive advantage. Wilson, too, talked about number of total ideas and patents. Most of the ideas never get forward and therefore innovation programs can also be a source of disappointments: someone thinks they have submitted a brilliant idea but the jury decides not to continue it. Allen thinks the campaigns need to address this and appreciate and also reward for a well-written idea submissions.

Fundamentally, innovation programs seemed to be more to gather together the different business units across the organization and inspire for innovativeness, and the actual innovation performance seems to be thought of more of a side product. Wilson told a few examples of successful product features that had been sourced from the program, but he spent more time in elaborating the inclusiveness of the program. With their R&D organization of thousands of employees, he thought choosing on purpose challenges from different countries played a role to include different nationalities.

5 Discussion and managerial implications

In this chapter, I obtain the analysis results from both the VIM context and current state (4.1) and the external benchmark interviews (4.3), and contrast these findings with the relevant theoretical frameworks (2) to derive managerial implications for the case company. Each subheading here addresses the development areas that were identified in VIM context and current state (4.1). If successfully implemented, over the course of a few years, VIM should be able to identify how the recommended actions outlined here have contributed to enhancing VIM's Innovation Engine.

This chapter does not mean that VIM would be performing poorly regarding innovation performance — in fact, quite the opposite. However, I would like to remind the reader here that the purpose is to provide managerial implications on *changes* that help VIM to become a *better* innovator. Therefore, I do not elaborate on the aspects VIM has done well, and instead, my focus is strictly on the proposed actions related to development areas.

5.1 Increasing external exposure and collaboration

VIM needs to adopt a wider exposure to external complementary knowledge. This needs to be done on strategic megatrend, customer need, competitor and technology dimensions, and on a more synchronized and interconnected manner. Such exposure is strongly recommended by theory. Among others, Zahra and George (2002), Chesbrough (2003) and Felin and Zenger (2014) are strong advocates for low-cost probes, networking and wide exposure to diverse and complementary external knowledge sources, which fosters collaboration and partnerships and leads to better innovation performance. While nearly all benchmark interviewees mentioned a heavy emphasis in external activities, according to the internal interviewees VIM does not have particular emphasis on such themes in the present.

Most need for more emphasis is in outside technological scouting. That need was explicitly brought up by both Roman and Lehmus. The review of Vaisala's past innovations revealed that the radical inventions happened at the boundary, in collaboration with a research institute, whereas recent development has been more of incremental innovation developed in-house. In benchmark interviews of Growth Companies D, E and H similarly the most radical inventions done in university research teams from where the startups were spun off. Furthermore, Vafaei's team considers the key professors and research teams to be the best source for state-of-the-art technologies: *"They have the technologies!"* Finding such technologies requires effort in reading scientific journals and visiting relevant conferences, and it may take several years before realizing the commercial success is possible. I think in this kind of Boundary Spanning, Vafaei's team is an exemplary example. If VIM aims for further radical or disruptive innovation in the long-term, it must commit to such actions and more heavily orient itself towards exploring and discussing with such research groups.

Collaborating with venture capitalists and research institutes is something VIM should consider. Roman already had thoughts towards deep tech funds, but Corporation J was clearly ahead and more established in this sense. Henry's comment that his team is aware of all relevant startups within their scope of interest was a powerful statement. Unless the purpose is to acquire an entire company and technology, investing in single startups may be a too costly move in the multi-industry setting where VIM is. However, along the lines of what Corporation J does, investing in and closely collaborating with venture capitalists can provide a broader view across an entire scene for a similar expense. Henry thinks market reports could not provide as deep insights on the new frontiers of technology.

VIM needs to find a balance and an efficient way to collaborate externally. Dhanaraj and Parkhe (2006) introduced the concept of orchestrating innovation networks, where a hub firm holds a central position and pulls together capabilities from the network. While Corporation J seemed to be an example of such activity, I think it is not feasible for VIM to a similar extent. This comes from the differences in business environment. As a measurement instrument manufacturer, VIM more often plays a supplier role in the value chain of an industrial process and thus may not play such a holistic role in an innovation network, as for example Corporation A in industrial automation or Corporation J in the energy industry. Still, it is important to have an access to external forums and complementary assets that VIM lacks, such as new measurement technologies or core optoelectronical components that may bring novelty and competitive advantage to the measurement instrument products. I propose to follow along the lines of what Carter and Brecel do: firstly, networking widely to know the relevant partners, and then joining the ecosystems and consortium projects where VIM can integrate their own goals. This, as Brecel formulated it, can amplify the resource use then in technology development, and can provide long-term profits as it did for Corporation K.

Of course, according to Zahra and George (2002), only knowledge that has been transformed into functional assets can be exploited for profit generation. Still, even acknowledge existence of relevant new technologies can be valuable per se, as it tells of the competitive position and possible upcoming disruptions more clearly. Even though technological cycles in the industrial context are considerably slower than in the consumer business and therefore risk of disruptive technologies is lower, I propose to follow Day's advice on observing the surrounding technological development and adjacent markets with an appropriate signal-to-noise ratio.

Detailed understanding of customer needs is obvious but crucial need for VIM, when it comes to identifying business opportunities. Product areas know needs in existing businesses rather well through feedback of existing products, and direct competitors are monitored. However, according to the Parallel Play concept I propose that VIM should keep an eye also on players and potential opportunities in adjacent markets. This allows timely identification and reacting to a phenomenon that happened for Corporation L: major companies from the sidelines entering and disrupting their core market. For such awareness, VIM needs to have an assigned responsibility. Although some benchmark interviewees referred to it by including salespeople or product managers, I would use the word business development to describe the link between customer needs and R&D. Such business development responsibility needs to be an integral part of any cross-functional for a new product initiative unless the customer needs are thoroughly known through, for example, existing product business.

It is clear that in the multi-industry setting of VIM, the deep understanding of customer needs is laborious, and therefore it needs to be emphasized with appropriate resourcing. On one hand, the person in such role needs to be able to go deep into the customer's world. One interviewee mentioned recruits of end-user doctors into such roles. Whereas VIM may not be able to recruit dozens of customer personas from different industrial segments, the organization should have diversity and representativeness from most attractive growth industries regarding the backgrounds of the business developers. On the other hand, as we discussed with Lisowski, the business development role must not be isolated from the product and technical capabilities. Innovation can not be created just on any customer need, but only when it can be connected to a capability that the focal firm has or can acquire.

Roman's team is working with strategic megatrends, but has been doing so for only a relatively short time and with a small team. Henry's team in Corporation J was on a more mature level in curious exploration of what is happening in the world without being confined with existing technologies or businesses. This way, they had found new crucial areas that earlier were not within their radar but today are crucial blocks in the Corporation J strategy.

The work for business opportunity identification between strategic megatrends, customer need, competitor and technology dimensions needs to be better interconnected. I see a contrast between theory that emphasizes ambidexterity and interorganizational linkages (Felin & Zenger, 2014; Taylor & Helfat, 2009) and the internal interviews that show how remote and functionalized competence areas are in VIM. For example, technology departments were unaware of unresolved problems with considerable business potential. Although Roman and Talvitie thought VIM has identified attractive industrial segments and megatrends, the interview of Lehmus showed they are not effectively communicated nor are connected to technological capability needs. Another example of isolated work in the functionalized teams was that Roman mentioned visiting a technical conference but being surprised not to see anyone from technology department present.

The different competence areas need to be in closer interaction with each other. To truly find business opportunities, one needs to be able to connect technical capabilities to customer needs. Talvitie talked about the importance of physically locating people close for the day-to-day communication. I also propose to adopt Henry's thinking of these different competence areas considering themselves as internal consultants, and only by sharing the learnings the work truly pays off. A concrete example could be to integrate this to personal targets of certain technical, product area and strategy team roles. The target could be to visit a certain number of scientific conferences, perhaps together with representatives from other competence areas, or as a takeaway, provide a number of potential technical or business opportunity ideas or relevant collaboration partners. Building collaborative ways of working and the network needs to be more systematic, and driven with curiosity across competence boundaries.

5.2 Defining an innovation strategy

Where and how VIM aims to look for opportunities and realize those into innovations and revenue should be stated on a strategic level. Current VIM business strategy is based on the thought of product leadership and is clearly communicated across the organization, but statements such as *"discovering customer needs"* or *"winning in selected niche markets"* are inadequate and too abstract in giving guidance for where and how VIM should look for further business opportunities or technologies. I think Vafaei's comment *"you need to know what you are looking for"* applies well here. The resourcing and emphasis I earlier proposed regarding strategic megatrend, customer need, competitor and technology dimensions could easily turn into endless drain of time and money without clear strategic guidance. As discussed earlier regarding Talvitie's thoughts, focus must be an outcome of such strategy as single measurement markets generally are not huge and the Vaisala business already now is scattered into hundreds of product families. On the contrary, proper strategic guidance and ambitious targets *"leads things to happen"* as Robertson stated.

I propose that VIM should define an innovation strategy. Drawn from my definition of innovation, this innovation strategy would describe how VIM captures substantial commercial from new technological inventions. This means addressing opportunities from both customer need and technology perspectives, and how those are combined for successful business. I prefer the wording of *innovation* strategy over a *technology* strategy, because technology should not be an end in itself, but rather the commercial success it brings. Moreover, while practices drawn from the innovation strategy may be also applied for incremental development steps of existing products, the focus of the innovation strategy needs to be in novelty — new (to Vaisala) technologies to expand business in existing, adjacent or new markets.

The VIM business strategy should be parent to this new innovation strategy. Whereas the VIM business strategy must entail the entire business, innovation strategy could dig to a more concrete level giving the necessary guidance. Both, however, need to be in perfect alignment.

As Henry stated, *"innovation requires a dedicated budget, patience and a mandate for action"*. I believe that Lehmus's comments on current technology work in VIM being burdened by engineering work and sustaining earlier projects, or diluted to many directions so that most innovative initiatives suffer, is a signal of lack of such mandate and dedicated budget. To address this, I propose that the new VIM innovation strategy needs to address the following four key areas.

Firstly, I propose to define what kind of innovation VIM pursues. Based on the analysis, to use the analogy of Chesbrough (2003), I would characterize VIM to be more of a calculative chess player than a risk-taker in poker. Over the years it has drifted to focus on incremental innovation, as technology development efforts have been solely on improvements on the existing technologies. From the customers' point-of-view, the current product leadership strategy drives mainly to sustaining innovation, and designing high-end products. However, in subchapters 4.1.2 and 4.1.3 I told about few disruptive examples from VIM history where measurements that earlier were measurable only through sample-based laboratory analysis could now be measured with an in-situ or in-line probe.

Where VIM *wants* to be remains to be decided in the strategy work. In this thesis I don't make those strategic decisions, but the analysis shows the need to make and clarify such decisions in VIM. For example, Roman argued that current innovation work is *"too incremental"*, and I interpreted similar undertones from other internal interviewees as well. On the other hand, technologically radical inventions, or constantly disrupting markets is a tough nut. Regardless of whether VIM aims to remain in the incremental and sustaining innovation categories, or shift more towards radical technological leaps or to disrupt more effectively markets, I advise stating that clearly in the innovation strategy. This strategic decision would then give mandate to create the appropriate organizational structures, cross-functional teams, as well as implications on what technology development should be continued in-house or through external partnerships, or whether customer needs are discovered from demanding high-end segments or among customers that would appreciate a simpler, more convenient solution.

Secondly, the innovation strategy needs to state what megatrends and industrial segments are believed to have most attractive opportunities. Defining this on a strategic level allows then orienting the organization towards finding customer needs from right directions. This orientation applies to collaborating with right industrial partners, venturing capitalists, research institutes, as well as even recruits of experts from such segments.

Thirdly, it needs to define on a general level the attractive technological capabilities that are believed to be necessary in such opportunities. In other words, it needs to answer Laukkanen's question: "What are the unresolved (technical) problems with considerable business potential?" This would then have implications, for example through a technology ownership map work, on how significance of existing capabilities change, what capabilities or competences should maybe be acquired in house or what should be outsourced. It makes a difference whether, for instance, technology work is oriented to explore analysis methods such as Raman or mass spectroscopy, compared to in-situ measurements of a single-parameter such as humidity or pressure.

Fourthly, the innovation strategy must set boundaries and success criteria for new initiatives. As mentioned, such already exist through the Runway projects, but if an innovation strategy is to be created, the should be integrated and applied broadly. To bring focus and avoid excessive use of resources in new opportunity work, the strategy must ensure how the search of opportunities and each project initiative should be aligned to utilize the synergies and existing strengths of VIM, for example regarding the relationship to the existing core technologies, mass-configurable production capability and sales channel. As Roman said, new initiatives should not squirrel around with the VIM business model. Particularly with the beginning of the innovation funnel where there is virtually endless number of opportunities, the strategy must be effective in filtering and short-listing.

There needs to be constant communication and knowledge exchange bottom-up and top-down, similarly as Milkins applies in Growth Company G. Firstly, towards the top, the relationship between the business and innovation strategies could be nurtured by a similar way as, for example, Williams does through regular reviews of the technology innovation map, or how Robertson's technology foresight work act as an input for the business strategy. Then, innovation strategy relationship towards the bottom needs to be close and recurring. The innovation strategy, on one hand, needs to be updated regularly based on input from technology, customer needs and megatrend work, but on the other hand it must clearly state the direction where and how innovation is generated in VIM.

As Heim (2017), McGrath (2000) and Bocken and Snihur (2020) propose, the innovation strategy should be stable, and the long-term strategic direction and key building blocks or values should not change erratically. On the other hand, it needs to constantly reflect the market input and respond to the changing environment accordingly. One example of this could be the choice of innovation category. Today, VIM may still want to remain in the incremental and sustaining innovation regimes, but markets or technology awareness input may become extremely valuable if a technological discontinuity and a disruption will emerge.

5.3 Adopting a Validated Learning process

I propose VIM to iterate and develop for an appropriate way to adopt Validated Learning and other key entrepreneurial practices systematically across all new innovation initiatives. Through Runway projects, VIM has adopted such practices in the past, but they were never fully adopted to all initiatives, and the mindshare of the methodology has decreased recently in the organization. I would describe that the current Stage-Gate based product process in the company may be effective for productizing increments to VIM's Horizon 1, but it is suboptimal for finding innovation, in the meaning of novel technological inventions with substantial commercial potential.

Reflecting the Vaisala product process to theory, the Stage-Gate model is old-fashioned and rigid. It works as a template for metered funding and productization, but does not steer activities on the practical level nor encourage for an adaptive, agile and iterative way of working that theory suggests (Cooper & Sommer, 2016; Eisenhardt & Tabrizi, 1995). I think the most important drawback is that the product process too strongly assumes a fixed and beforehand-known business case and customer needs for all initiatives. Obviously, there needs to be understanding of customer needs and the business case, but the most important aspect of the more adaptable frameworks is that it is not carved in stone early on, but rather constantly validated throughout the process. This is crucial especially when entering markets that are at the borderlines of the well-known core business.

An optimal model needs to address different needs. According to the internal interviews, Talvitie thinks the process should be more concise, referring to the goal to shorter time-to-market rather than being thorough in avoiding risks, and Roman thinks this could be achieved through allowing some projects to work *"off the process"*. Hakkarainen commented that most important would be to adopt the concept of Validated Learning, which I think is also the core message of Ries (2011). I believe that when implemented accordingly, relying on customer feedback through MVPs and an iterative build-measure-learn loop can be very powerful.

In the wording *appropriate adoption* lies the thought from Bocken and Snihur (2020) and Lisowski that no framework is a panacea. In fact, none of the benchmark companies said they *use* Lean Startup as such, but rather many of them have adopted such thinking. The purpose should not take the model as granted nor focus solely that all initiatives follow a process at the cost of doing sensible things. Based on my experience and according to Camuffo et al. (2020), careful framing of the problem and formulating relevant hypotheses is very important. A common pitfall is to formulate hypotheses that are not truly falsifiable, or validate them in a biased way so that only supporting feedback is heard. Practical guidance from Fitzpatrick (2013) may help: avoiding fake compliments, asking open-ended questions, focusing on the customer problem instead of the solution, and observing customer actions rather than only relying on their words. No expert competence, technological or customer need insights can be outsourced to a framework. Ultimately, what matters is how it is applied and what outcomes it produces. In Henry's words one must *"not wear eyepatches"*, and instead, in Robertson's words, *"keep the eye on the ball"*.

One alternative that VIM could adapt systematically on all its new innovation initiatives is the framework that Robertson had developed for Corporation C. It not only takes all the good from Validated Learning by Ries (2011), but also makes innovation measurable. A common template needs to have universal assumptions that require collection of evidence. Finding applicable universal assumptions for VIM business and learning to adopt those in project work definitely takes time and a few iterations, but successfully adopting that would bring numerous advantages.

Firstly, continuation of projects would be oriented for learning about the holistic business case. Comparing to the current product process based on Stage-Gate, this new framework should still be based on metered funding, but instead of gates it should have learning milestones. With the given budgetary and time constraints, the team needs to find optimal ways to collect evidence equally to the different assumption categories. At each milestone, the team and steering group would together evaluate, whether continuation, and towards what direction and with how much money, is feasible. Along the way, understanding of the business case can grow and even the business environment can change. According to Robertson, the transparency of the evidence allows a more objective view and helps both the steering group and the project team to understand when a pivot or discontinuation of the project is the right thing to do. In other words, the model could bring the needed *"courage to say no"* which was emphasized by Hakkarainen.

Secondly, the model should fully empower cross-functional teams on *how* to collect evidence. The team should consist of the best experts regarding the required technological capabilities and customer needs, and leadership from outside the team should be minimal in that regard. On the other hand it would not be an open check for the project team: certain evidence categories that are crucial for successful business would be fixed through the model, and steering allows for certain budgetary and time limits until the next learning milestone. I would describe this one way to implement Semistructures: just enough structure to ensure progress towards sensible direction, but also flexibility to adapt to the specific needs and context of the business case at hand. A similar message was given by one benchmark interviewee who talked about avoiding micromanagement: focus needs to be on doing sensible things rather than strictly following a process, and therefore day-to-day decision-making must not be in the top management who is remote from the business case.

Thirdly, the process needs to allow early-phase experimentation but must not let forward initiatives where evidence for different assumptions is out of sync. The new model should indeed allow early-phase experimentation, similar way as Challenge projects that Lehmus mentioned. Experiments is a fundamental part in entrepreneurial frameworks and was also brought up by benchmark interviewees. For example, Brecel allows experiments below 500 € without asking, and Lisowski told about them showing off MVPs at a trade fair as better-performing as they in reality were, just to collect feedback. In Vaisala, experimentation is perhaps too often considered as technical laboratory or field testing, but I think of it more broadly. If experimentation is being done for technical product-related evidence, the team needs to similarly collect evidence for the business model, market and operations related assumptions. For example, while a scientist is testing in the laboratory if a certain sensor has sensitivity for a certain quantity, at the same time another team member should be at a trade fair showing fake datasheets or 3D-printed mockups to potential customers.

Fourthly, the same process for all initiatives provides data that allows continuous improvement and keeping the Innovation Engine running. Earlier trials have shown that frameworks not integrated to the product process are easily forgotten. Internal interviews showed how mindshare on Runway methodology and Challenge projects have decreased. Currently in VIM there are somewhat differing practices in product and technology projects in different product areas and the Roman's strategy team, and learnings are not shared. Data from an uniform model would bring transparency on a different level on which projects progress, which don't and most importantly, why. Robertson's key learning had been that they need to include a salesperson in each team. Another useful takeaway could be related to resourcing: both Lehmus and Laukkanen were troubled on what kind of allocations per scientist is most efficient, as currently the focus is diluted in too many directions. Moreover, an initiative that progresses particularly fast in terms of evidence collection may have interesting learnings to share to others on how they implemented the build-measure-learn.

Transparently seeing how evidence in each initiative and each category across the portfolio progresses, allows identifying the bottlenecks and best practices, whether it is including certain business competence, an optimal scientist allocation, a way of doing experimentation or something else.

I would like to bring up that even though Validated Learning brings most value for initiatives at the borderlines of the current business, it doesn't hinder an incremental project for an existing business. Within Horizon 1, the evidence for business model, market and operations related assumptions comes as given from the earlier product business. These projects are the easiest, because developing the product is at VIM's hands whereas business risk is *out there*. As Milkins and Higgins both emphasized, only paying customer and realized revenue are the fundamental evidence for the business case.

Fifthly, the framework for initiatives must be in close relationship with the innovation strategy. In VIM, Runway has not been fully deployed in all projects, but it was implemented in some individual projects in parallel with the ones that progressed in a traditional way. For Robertson, in addition to data proof of what works and what doesn't, key way to motivate and get business units to commit to the new framework was ambitious enough strategic targets. Corporation C was in a strict financial situation where they had to invest to the future in a smart way, the new model seemed a more feasible way to reach the targets rather than traditional Stage-Gate.

Finally, VIM should not expect to hit a perfect framework the first time. Similarly as, according to Henry, innovation requires patience, I think finding the suitable framework requires too. It took iterations from Robertson in Corporation C and it will also for VIM. Hakkarainen emphasized that there is already a fruitful collection of learnings from earlier Runway projects on how the model should be applied, and with the comparison to benchmark interviews, I too am confident that the key building blocks are there. Now it is time to build a next iteration with the framework, and then measure and learn for continuous improvement.

5.4 Rapid cadence in a focused portfolio

As time-to-market is essential (Eisenhardt & Tabrizi, 1995; Vesey, 1991), rapid cadence on how initiatives progress is of essence. For Robertson, this meant monthly cycles with steering group meetings, and for Vafaei, early concept development should take not more than 6 months. Another example of rapid cadences was the regular product releases from Growth Company H, where each release forces different competence areas to constantly collaborate and synchronize the advancements into a working end product. To use Allen's words, for the innovation initiatives VIM should instead of the *"stiff model where a year is the basic unit."* adopt a cadence that is measured within months. While the team is empowered for finding the evidence, this kind of pulse forces the team to show results, or together with the steering group, rapidly find out where is the bottleneck.

The fundamentally long cycles in technology development are a challenge. Henry identified this and thinks business model innovation can be much faster. However, here business model innovation is out of focus for VIM. I think here key is to carefully evaluate when it truly is feasible to initiate a long-term technology path where everything is tested, and when a more light progress is sufficient. Moreover, to find speed on technology development, I think one needs to find creative ways to do experimentation. For example, instead of spending 6 or 12 months in a field test, maybe VIM could accept a higher technical risk in measurement performance or long-term stability and only use results after one or two months.

I propose that VIM should consider lowering the threshold for utilizing external know-how and technology. The wider exposure to external technological knowledge may help to avoid the *not-invented-here* syndrome. For Corporation K broad networking in communities and research projects had allowed finding opportunities where a complementary asset had sped up their time-to-market considerably. VIM could adopt similar principle: acquiring external technology with the *"industrial standard"* methods such as licensing or collaboration projects when it allows faster access to the market, and possibly iterating or developing the asset in-house later.

As no company has endless resources, rapid progress is possibly only in a focused portfolio. In other words, benchmark interviewees think fewer projects provides more progress. Corporation K was suffering from broadness of the portfolio the most, Carter commented that they have *"more like 50 projects that progress annually 2% rather than 2 projects that'd progress 50%.* I think Lisowski was well in control of the project portfolio, having one main product stream and a maximum of three parallel experimentation projects. Perhaps this 1:3 ratio could work also for VIM product projects and early-phase initiatives.

One key point for keeping a focused portfolio is to avoid spending too many resources too early. Both Henry and Robertson emphasized that the metered funding principle needs to take care of this. While Growth Company H explorative approach or Growth Company D style less-than-500 € experimentation are favorable, VIM needs to become effective in killing bad projects as early as possible. The framework and strategic guidance must provide the backbone for *"courage to say no"*. As Robertson said, the transparency in evidence helps: it allows both the project team and steering group to understand and commonly decide faster on project closure.

5.5 Cross-functionality, interconnectedness and curiosity

Current VIM organization has evolved over the years and is today rather monolithic and has functionalized teams common for multiple businesses. Talvitie thinks that in a small company it is easy to have all knowledge present and available because roles of different people overlap, whereas the roles become more isolated as the firm grows. This exactly had been the case in Growth Company H: What came naturally for a team of less than ten employees, an organization of dozens already requires more structure and different leadership. While current VIM organizational structure may have many benefits, the identified issue for innovation performance is that business and technology development are rather distant from each other. Regarding the organizational structure, Hakkarainen thought that there is no one right answer, but rather each structure has a certain lifecycle and advantages. Depending on the maturity of the organization and the markets, one needs to choose the game to play. One of my thesis key findings was the importance of deep understanding of market and customer needs.

My thesis analysis is inadequate to provide detailed implications on the whole Vaisala organizational structure. Therefore, I do not address how profit and loss units or sales organization should be divided. However, based on the identified gap between VIM current state and the emphasis from theory and benchmark interviews on customer need understanding, it is clear that an organizational structure oriented more for key customer segments would promote innovation performance. Key is in integrating market insights closer to R&D and decision-making of new initiatives, which was brought up by Robertson and Williams, for example.

Regarding VIM's innovation performance it is clear that cross-functional teams are needed to run each innovation initiative. The theory in this regard is clear: including diverse functional backgrounds in the team is known to bring broader viewpoints in generation of ideas (Bassett-Jones, 2005; Henard & Szymanski, 2001; van Gelderen, 2017). While current R&D work in VIM is already done in project teams, I would like to emphasize the meaning of *cross-functional*, particularly through colliding business thinking more with technical competence. Talvitie emphasized bringing the market understanding to technology development, and benchmark interviews support this. For example, Robertson's one key takeaway from their framework had been to integrate a salesperson in each team.

Benefits of diversity in cross-functional teams extend beyond bringing competence areas together. Higgins emphasized importance of team diversity in a broader sense, such as gender, age and nationality. I would argue that the point of nationality is particularly important for VIM where the majority of employees are based in Finland: a team of multiple nationalities, for example, has a higher probability for broader networks and external exposure for outside researchers, companies and technologies.

Cross-functional teams need to be empowered to act within the time and budgetary limits, and on the other hand, the team must take a holistic ownership of a business case. In Robertson's framework this is the case, but also for example Vafaei emphasized how in Corporation F the technology team clarifies the business cases of new inventions. As Lehmus said, holistic ownership is important, and by contrast to the segment organization she sees how currently scientist way of working has drifted to a more passive task-oriented mindset. In addition to organizationally assigning business ownership to key members in each project team, the implications regarding portfolio and Validated Learning process will also support teams towards a more holistic approach. A narrower portfolio and shorter projects allows increasing allocations of individuals and preventing the dilution of focus in too many directions. Moreover, a Validated Learning process will bring transparency to what aspects need to be addressed in a holistic ownership of a business case.

Holistic understanding is crucial for successful innovation, as Lisowski said. This requires competence. Deep technical knowledge and business understanding should preferably be within the same person, or at least a couple of employees who closely communicate and work together. Broad expertise combined with an entrepreneurial mindset is not necessarily easy to find, but still should be addressed from the human resources perspective in new innovation initiatives. More importantly, I propose to drive VIM to become more of a Learning Organization (Senge, 2006) that fosters competence development towards more holistic ownership. I think taking enthusiastic employees inclusively to the initiatives, utilizing their strengths across role boundaries and fostering continuous learning will in the long-term lead to better systemic innovation performance.

To achieve a holistic viewpoint, I also propose finding leadership approaches that encourage crossing traditional role boundaries. Depending on an individual's preferences, their personal targets could include evaluating product, business model, market or operations related assumptions regardless of whether the person works in a technical or a commercial role. Moreover, leadership on individuals with technical or commercial roles should promote Boundary Spanning. In finding evidence, it is important to cross boundaries between VIM and its external environment such as suppliers and customers.

Sharing understanding in the cross-functional team is important. Milkins emphasized communication in all directions: top-down, bottom-up and between competence areas: from customer frontier to R&D and vice versa. Talvitie thinks the small, day-to-day communication is key. Locating team members physically close to each other eventually leads to mutual learning in a way that is not possible only through remote meetings. While roles may be functionalized, the culture should foster more interaction across competence boundaries. In this thesis it became apparent that no initiative should be pursued without business buy-in and ownership. Here, too, it would help if functions interacted more.

Individuals in the team must be driven by curiosity. I remember the slogan of the Vaisala Giant Leap internship program back in 2015 when I joined it: *"Come as you are, as long as you are curious".* Of course, curiosity is hard to quantify, but I would still say it should show more in VIM. Henry said explicitly that curious mindset had been a key factor for success, but sensed entrepreneurial and curious thinking in between the lines from also other interviewees such as Brecel who were excited to tell about their technology and its applications. I think innovation requires curiosity on multiple levels. Team members need to have curiosity over their roles and competence areas on what others in the company do. Top managers need to be curious for further innovative initiatives. Everyone needs to be curious to explore the external world, whether it is potential business opportunities, new technologies or interesting megatrends.

Perhaps most important for a single initiative is to maintain curiosity for customer needs. Robertson's key learning was to involve a salesperson for each project, for

Lisowski and other interviewees this was product manager, and I think of it as business development. Regardless of the name of the role, customer need validation always requires a dedicated resource. A dedicated role, however, is not enough. Such activity needs to be integrated to R&D. Perhaps VIM should adopt similar practices as as Milkins when they send 4 or 5 people to observe customers, or Williams who last year sent multiple times R&D personnel to visit to observe and communicate with a customer for an entire day without a specific agenda.

VIM needs to adopt tolerance to failure, as Hakkarainen said. This is a cultural thing, and again, easier said than done when a business initiative has to be shut down with sunk costs, but still important. I would like to elaborate the word *failure* a bit more. In case of an initiative, it can indeed mean lack of success, as in, a technological idea not becoming a commercially successful product. However, discovering what not to do is one of the key values from entrepreneurial thinking. In fact, if it was learned quickly, I would not use the word *failure*, but instead the *"no-go"* was successfully learned. What I would consider more of a failure, is when, despite efforts, the team fails to learn about the business case. Only validating technical feasibility but never meeting a potential customer, or not taking in account the Fitzpatrick (2013) notion that most customers provide biased answers would, in my opinion, be real failures. Milkins also formulated failure well: that is launching a product and having a hundred installations, but not being able to scale to hundreds or above a thousand installations while having the maintenance burden. *"failed"* experiments or business cases should be considered valuable learnings, which can even bring competitive advantage as Brecel said, but even when a team has failed to *"fail fast"* or validate a business case, the organization needs to align to learn from those failures.

VIM needs to utilize inter- and intraorganizational connections better. Based on Talvitie and other interviewee thinking VIM as a functionalized organization, I think it is apparent that there is more to be done regarding the organizational Ambidexterity and Boundary Spanning. According to Taylor and Helfat (2009), middle managers are in crucial role when it comes to effectively managing knowledge flows and collaboration between teams. As Henry formulated it, people working around innovation need to share the learnings within the organization in a way an internal consultant would. Day brought up that the Gyro Gearlooses who perhaps think differently than the mainstream, must be inclusively utilized in workshops and innovation initiatives. I like this idea very much. In my discussion with Allen we concluded a powerful notion: learning to know who knows, basically grants all the capabilities and know-how of the organization, which in the case of VIM, is a massive pool. In my experience, when asking anyone about a topic they have deep expertise in, the individual always gives at least 15 minutes, no matter how busy they are. Such open and helpful culture exists in VIM, but it is not optimally exploited.

Finally, VIM should consider an innovation program to promote an innovative culture. Maybe for VIM it is not feasible to establish as extensive programs as the largest benchmark corporations had, but according to theory, innovation contests can be good approach especially for solving innovation problems with high level of hidden knowledge (Felin & Zenger, 2014). Such contests should be aligned with the innovation strategy and selected attractive megatrends, and product area owners need to be closely involved and empowered to take the best ideas forward.

Even though contests may not provide quick breakthrough technologies, and perhaps similarly as in Corporation A, the most innovative ideas come from a limited number of experienced scientists, a program or a contest helps VIM to bring visibility and keep innovation a topical theme. Few benchmark interviewees saw valuable also the fact that executive managers were enthusiastic and visible characters in the innovation contexts. A contest setting that encourages individuals and teams to more innovative action through incentives may have cultural and long-term learning impacts in the organization.

6 Conclusions

In this thesis I studied key enablers for an Innovation Engine for a high-technology hardware product based business, using VIM as a case study. I further outlined that the focus was in technological hardware product innovation as opposed to other types, such as business model or digital innovation. This study was based on qualitative research method that utilized five internal interviews and twelve benchmark interviews as primary research data. The analysis was based on the Gioia methodology (Gioia et al., 2013).

Some of the reviewed literature brought anchor points for a common understanding between myself and the reader in the further discussion. For example, I classified innovation into different types, such as incremental and radical innovation (technology perspective) and sustaining and disruptive innovation (customer's perspective) (Christensen & Raynor, 2004; Hopp et al., 2018; Tushman & Anderson, 1987). I used a technology management framework by Phaal et al. (2001) to introduce the processes of technology identification, selection, acquisition, exploitation and protection, and the Three Horizons Model by Baghai et al. (2000) to classify initiatives within a portfolio, based on their alignment to existing (Horizon 1), adjacent (Horizon 2) or new businesses (Horizon 3).

The literature review also introduced practices or principles that are believed to promote innovation performance. The review included the Open Innovation paradigm (Chesbrough, 2003) and other arguments for external technology scouting. I discussed how modern product development process has evolved since the Stage-Gate model (Cooper, 1990) to a more adaptive, agile and iterative direction (Cooper & Sommer, 2016; Eisenhardt & Tabrizi, 1995). Moreover, I introduced different entrepreneurial frameworks such as the Lean Startup (Ries, 2011), Design Thinking (Blank, 2013) and Effectuation principles (Sarasvathy, 2001), as well as discussion on how those models are or should be applied. I covered different organizational capability related themes such as the Absorptive Capacity (Zahra & George, 2002) and the power of diverse cross-functional teams (Bassett-Jones, 2005; Henard & Szymanski, 2001; van Gelderen, 2017). Finally, I introduced conclusively top level themes that different scholars argue to be connected with Innovation Engines.

The research question, based on literature review and the internal analysis, was further broken down into five development areas for VIM. I provided managerial implications for each.

Firstly, I identified that VIM needs to be more effective in identifying attractive business opportunities. The organization needs to adopt wider exposure to external complementary knowledge on the levels of strategic megatrends, customer needs, competitors, adjacent players and key technological areas. VIM needs to become more effective in deploying low-cost probes particularly for outside technology scouting. Radical innovation happens only in collaboration with external parties, and VIM is not very effective in this kind of Boundary Spanning. Awareness of key researchers, professors, but also venture capitalists, startups and established companies in the adjacent field is important. Innovation is found from the crossroads of these different fields and parties.

Secondly, VIM lacks strategic guidance on where and how it aims to look for opportunities and innovation. Thus, it needs to create an innovation strategy that is well in line with the existing business strategy but provides more concrete guidance for initiatives. The innovation strategy needs to define what kind of innovation VIM pursues: sustaining or disruptive, incremental or radical. It also needs to state the top level directions where most attractive innovation is believed to be found, as well as linking these megatrends more concretely to the technological capabilities that VIM needs to adopt. Finally, it is crucial that such an innovation strategy is strongly interlinked and regularly updated based on learnings from the external world. Using Robertson's words and logic, I believe such an innovation strategy and ambitious targets will *"lead things to happen"*.

Thirdly, VIM needs to adopt a systematical process for Validated Learning in innovation initiatives, as the current Stage-Gate based model is suboptimal for innovative initiatives, particularly outside Horizon 1. I propose to adopt a similar framework as Robertson in Corporation C, where a common template, practice and self-assessment guidance are applied for all projects, and universal assumptions that are relevant for any new business development need to be addressed through Validated Learning. The model needs to empower cross-functional teams to collect that evidence and encourage for creative experimentation, but also adopt a metered funding principle. It needs to encourage a holistic view and ensure evidence collection different categories in synchronized manner. VIM already had good learnings from the Runway methodology, and now it needs patience and perhaps some more iteration to find the perfectly suitable model to adopt Validated Learning in all innovation initiatives.

Fourthly, restricted time of individuals and sufficient resourcing across the portfolio was identified to be a limiting factor for innovation in VIM. The new innovation strategy needs to prioritize the most attractive initiatives in a way that allows reaching a more focused portfolio of fewer initiatives. Moreover, initiatives must adopt a rapid cadence where early development phases are measured within months rather than years. A common template for Validated Learning and utilizing measured data from innovation initiatives on how to tackle bottlenecks will help. Whereas explorative and experimental approaches are favorable in early-phase, the strategic leadership must also be effective in killing bad projects.

Fifthly, regarding the organizational structure it was discovered that the current organization with functionalized and rather isolated teams does not support optimally creation of innovation. Market understanding was found to be distant from the technological know-how in the organization, and they need to be brought closer. On work level this can be achieved through diverse cross-functional teams. Also leadership must strive individuals to take more holistic responsibilities and reach targets beyond traditional role boundaries. Repetitive and constant communication to shared learnings, as if individuals worked as internal consultants, need to be adopted. Finally, an innovation program should be considered to create a more inclusive and innovative culture in VIM.

This thesis was able to distinguish five development areas and provide managerial implications for them. The research question is therefore successfully answered. The research method utilized a *go-out-and-see* principle that is also encouraged in entrepreneurial thinking. Because the benchmark interviewees were not direct competitors for Vaisala, I was able to discuss rather openly and get to the point already within the 60-minute interview.

Not all insights from each interview were directly applicable for VIM, but the interview data was broad enough to provide fruitful analysis and managerial implications. From the twelve benchmark interviews, I was able to bring fresh perspectives that did not come up from the internal interviews.

Needed actions are now known, but reading this thesis does not alone suffice in making VIM or any other company a better innovator, but rather works similarly as the output of a consultant project. VIM now needs to take action to implement these initiatives, which requires change management and determination. While finding theories and frameworks is rather trivial, the right implementation is, I believe, the most challenging part. I hope my thesis was able to lower that threshold.

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A Appendix: interview structure

Introductions

- Attendees: names, roles and background
- Thesis title and scope

Part 1: Understanding on company business environment and operation

- What kind of product areas and customer segments the business consists of?
- Does the company actively seek to enter new markets?
- What is the nature of the business environment? (stable or dynamic)
- What are main drivers for developing the business?
- What are the earlier and current technological turning points?
- How much is invested in R&D? (e.g. of revenue)
- How innovation and R&D targets and investments are divided between sustaining innovation to existing customers (development) and entirely new technologies (research)

Part 2: Understanding the key focus areas and practices for optimized innovation performance

- What are the key enablers for innovation in your company/team?
- Theme 1: Organizational responsibilities
  - Who is responsible of innovation? Does someone have a dedicated role or is it a shared responsibility?
  - Are research and development working together or separately?
  - Who has and brings in the market and business understanding?
  - In new innovation initiatives, how are technical and business aspects linked? How business and technology departments collaborate?
- Theme 2: Innovation process
  - Where ideas for innovation mostly come from? How technology push and market pull are emphasized in the process?
  - What is the process for new initiatives? Linear stage gate, internal ventures or something else?

- Theme 3: Entrepreneurial practices
  - How entrepreneurial practices or frameworks such as the Lean Startup or Design Thinking show in the organization?
  - How has the company been able to shift the focus from traditional incremental innovation into fast Validated Learning? Is learning measured in projects? What kind of challenges there are in the practical implementation?
  - How would the interviewee describe the culture and attitude is towards failure in new technology development?
- Theme 4: External innovation
  - Do the core technologies come internally from your organization or externally?
  - How is the company networked with other innovators outside your firm?
  - What practices there are for scanning new technologies?
  - If a suitable external invention or technology is found, how is it acquired?