Innovation Accounting

An Empirical Study of Performance Measurement in Industrial Research and Development in the Norwegian Oil and Gas Sector

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Abstract

The technology risk aversion among decision makers in the oil and gas industry leads to over-cautious technology decisions. To enable an acceleration of technology development and adoption on the Norwegian Continental Shelf, the need for new ways to measure innovation performance are escalating. This thesis assessed various approaches to R&D performance measurement, and identified some key characteristics of a project level measurement system which is both theoretically sound and practically useful. Further, the thesis examined performance measurement in industrial R&D, by use of a survey of the DEMO2000 program portfolio.

The R&D projects had set a broad range of project specific goals, which were generally suitable for fostering both project excellence and creative freedom. Even though goals who supported customer interactions and collaborations were to some degree lacking. The performance measurements used by the projects seems to fail compared to what the literatures conceders as 'highly effective'. The actual usage of the measurement output is decisive for the effectiveness of performance measurement. However, only 30% of the projects assess their KPIs within the frequency which in the literature is considered to be sufficient (monthly).

To better understand the entire technology value proposition of a new product development, the R&D project needs to build strong relations between researcher, developers, and customers, with a multi-disciplinary approach. This interplay both can and should be measured by KPIs, to ensures the project is delivering according to plan (business process perspective) and asking the right questions to the right people (customer perspective). However, currently, only a handful of the survey respondents seem to capture these important aspects in their performance measurement procedures. A holistic performance measurement system, which captures both the potential value proposition and the project progress, while the right competence is involved, is considered to make innovation teams thrive. However, the lack of effective measurement systems in the DEMO2000 projects, may increase the risk of the 'wrong' products being built. In that case, optimizing the product will not yield significant results.

Preface

This thesis was inspired by the massive evidence of technological change in the Norwegian petroleum sector, like 4D seismic, enhanced oil recovery methods, amazing horizontal wells, and even subsea production facilities. However, I think that it is actually quite a while since we were doing 'ground breaking' progress in our "North Sea laboratory".

Maybe our revolutionizing technology development and adoption from the nineteen eighties and ninths, which created our county's enormous wealth, has distracted us from the fact that our surroundings on the offshore platforms, today are strangely old. Only computers and communications have improved dramatically since the end of the last millennium. However, my daily work at an offshore oil installation, combined with my engagement for innovation, may make me biased towards undermining the where we are today and exaggerating the possibilities of the future. I will try my best to be aware of this potential bias throughout the thesis.

Despite the fundamental importance of innovation activities, they can be tricky to measure. I think that "what you measure is what you get", and, thus, better performance measurements can help industrial R&D projects to excel. Therefore will I in this thesis seek to better understand the 'status quo' of R&D performance measurement in industrial petroleum research. In addition, i have found interest in 'lean innovation' and its associated management accounting system of 'innovation accounting'. This is a emerging tool for performance measurement which I will seek to understand.

Maybe, this thesis can be a small contribution to making the process of setting meaningful goals, and thereafter effectively measure performance in industrial R&D, into something every R&D team can appreciate.

Acknowledgements

My two years at the Master of Technology Management program has been intense, both challenging and rewarding, and absolutely fantastic! Thanks to all the proficient lecturers at both NHH and NTNU, including the exciting guest lecturers, and, most of all, the great classmates, for making this journey such an adventure.

A big thanks to my supervisor Malin Torsæter, Research Manager at SINTEF petroleum, for your invaluable advices along the way. And, especially, thank you for helping me understand early on that my thesis had to 'pivot' into the field of performance measurement. That was a 'key success factor' for the self-realization this thesis has become for me.

Thanks to Øyvind Veddeng Salvesen, Senior Advisor at The Research Council of Norway, for providing me with guidance on how to obtain the right to access to the active projects in the DEMO2000 program. Also, thank you for taking time to meet with me, and for our interesting discussions on industrial R&D.

I would also like to thank all the DEMO2000 project managers who responded to my survey, for both your time and showing interest in my work.

Thanks to my brothers, Bendik & Peter, and Mamma & Pappa, for the valuable exchange of views on innovation, and all other fun and laughter, that we have had around the dining table at Gjøvik.

Finally, a monumental thanks to my beloved wife, Rikke. You made me set clear objectives and milestone at the outset of this thesis, and constantly helped me measure my performance underway. You have read the thesis tirelessly, time and time again, and your feedback is always constructive. I could never have done this (in time of the deadline) without you, and all your support and encouragement, and all the tender love and care.

Andreas Nybakk Torsæter
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List of Abbreviations

ABC	Activity based costing
KPI	Key performance indicator
KRI	Key result indicator
LII	Legal Information Institute
NSF	National Science Foundation
OECD	Organization for Economic Co-operation and Development
OG21	Oil and Gas for the 21st Century
PI	Performance indicator
PM	Performance measurement
PMS	Performance measurement system
R&D	Research and Development
RI	Result indicator
RQ	Research question
SRQ	Sub-research question
SSB	Statistics Norway

1 Introduction

1.1 Background

> *"The belief that profits are assured by an expanding and more affluent population is dear to the heart of every industry. It takes the edge off the apprehensions everybody understandably feels about the future. [...] If thinking is an intellectual response to a problem, then the absence of a problem leads to the absence of thinking. If your product has an automatically expanding market, then you will not give much thought to how to expand it. One of the most interesting examples of this is provided by the petroleum industry. [...]*
>
> *The petroleum business is a distressing example of how complacency and wrongheadedness can stubbornly convert opportunity into near disaster."*

These words belong to the late Theodore Levitt (1975). Even though the article was originally written in 1975, his research is of great relevance for the petroleum industry, maybe now more than ever.

The Norwegian oil adventure begun in 1969, just six years before Levitt wrote about the possible end of oil. However, before the end of the millennium, Norway had developed a domestic oil industry which in several areas were at the worlds forefront, and was still looking ahead. As late as in 2005, Norwegian petroleum research was hailed for its contributions (Keilen, Thirud and Tjelta 2005).

The monetary input to oil and gas R&D in Norway is still substantial. In total the Norwegian petroleum industry spends approximately 4 billion NOK on R&D every year (SSB 2018). The Ministry of Petroleum and Energy, in 2018, contributed with more than 340 million NOK as direct allocations to the Research Council of Norway's two oil and gas R&D programs, the PETROMAKS 2[1] and DEMO2000[2] (Norwegian Petroleum 2018).

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[1] PETROMAKS 2 provides funding to a broad range of projects, from basic research at universities and research institutes to innovation projects headed by the private sector. In 2018 the program had approx. 120 active projects and a budget of approx. 270 million NOK (Norsk Petroleum 2018).

[2] DEMO2000 provides funding for pilot and demonstration projects headed by the industry itself. The program had a budget of approx. 70 million NOK in 2018, with 64 active projects in December 2018.

However, while petroleum research is still vigorous, a study by OG21[1] found that the technology adoption on the Norwegian Continental Shelf is lagging, mainly due to the combination of risk management tools that fail to consider value creation opportunities (OG21 2018). A study performed by Menon Economics found that out of 88 projects who received support from the DEMO2000 program between 2011 and 2016, only 14% had yet been commercialized (Høyseth-Gilje et al 2017). Technology risk aversion among decision makers leads to over-cautious technology decisions (OG21 2018).

Innovation projects in the industry has often been regarded as more difficult to measure than the business units, who are executing on a known business plan. However, the need for performance measurements in innovation has aroused from the growing importance of effective and efficient R&D, and the increased pressure on R&D to become accountable for its actual contribution to company success (Samsonowa 2012). Several studies has found that 'measuring performance' is one of the discriminating factors between 'the best' and the rest (Kerssens van Drongelen, Nixon and Pearson 2000). Gupta and Wilemon (1996) found that, on average, the capabilities of R&D groups in the area of performance measurement were low.

Standard financial reporting is not helpful for evaluating R&D performance (Christensen, Kaufman and Shih 2008). Research projects are too unpredictable for forecasts and milestones, to be accurate. This thesis will seek to understand how industrial R&D projects in the Norwegian oil and gas sector currently measure innovation performance. Further, the thesis will reflect on the emergence of new performance measurement techniques designed for the innovation process, and evaluates the applicability of 'innovation accounting', a management accounting system descending from 'lean innovation', in industrial R&D.

[1] OG21 (Oil and Gas for the 21st century) is Norway's technology strategy for the petroleum sector, established in 2001, to identify technology priorities for efficient and environmentally responsible petroleum activities on the Norwegian continental shelf.

1.3 Problem Statement

The Norwegian petroleum industry has over the last few years demonstrated remarkable efficiency improvements, and break-even costs are currently highly competitive with other oil producing regions, including US shale oil (OG21 2018). However, there are still uncertainties about the long-term competitiveness of offshore petroleum projects, since renewable energy becomes cheaper and gain market shares, and shale oil projects offer shorter development times and earlier cashflow (OG21 2018). These economic and environmental challenges will require novel ideas and co-operation.

Innovation is getting an increased attention (OECD 2018), and both oil and service companies are placing the "innovation imperative" at the center of their agenda. Based on the oil oil and gas industry's need to overcome the challenge to develop, qualify and implement technologies faster than before (OG21 2018), the main research question which will be tested in this research is:

> ***RQ:*** *Are industrial product development projects in the oil and gas industry currently using adequate performance measurement systems to facilitate an accelerated technology adoption on the Norwegian Continental Shelf?*

This thesis will in particular explore the interplay between measurement objectives and performance dimensions of a performance measurement system. More specifically it aims to understand the 'status quo' of performance measurement in industrial R&D projects. The research design will be a survey of the project managers in the DEMO2000 program. Both the DEMO2000 program and the thesis survey will be presented in depth in chapter 3. Further, the thesis will explore the possibility of adapting the principals of the emerging management accounting system of 'innovation accounting', which is used for performance measurement in 'lean innovation' projects, for use in industrial R&D.

To explore the main research question, as given above, four specific sub-research questions were developed, which defined separate axis for analysis. These sub-research questions were:

SRQ1: *Which measurement objectives are currently pursued by the DEMO2000 projects?*

***S*RQ2**: *Which approaches to R&D performance measurement are currently used by the DEMO2000 projects?*

***S*RQ3**: *How effective is the current performance measurement systems in the DEMO2000 projects on the basis of relevant performance measurement literature?*

***S*RQ4**: *How relevant are the emerging performance measurement system from 'lean innovation', 'innovation accounting', for deployment in industrial R&D in the Norwegian oil and gas industry?*

1.4 Theoretical Background

The thesis is heavily influenced by the innovation theorists who has proven the importance of customer focus when developing new product. This includes the theories 'Jobs to be done' by Clayton Christensen, 'Discovery driven planning' by Rita McGrath and 'Lean innovation' by Steve Blank and Eric Ries.

Tatjana Samsonowa, and her thorough book "Industrial Research Performance Management", runs as a 'red line' through the thesis. Also, Edwin Locke, the father of goal setting theory, and the research performed by respectively Vittorio Chiesa and Federico Frattini, and Inge Kerssens van Drongelen and Jan Bilderbeek on performance measurement in the R&D context was important to be able to answer the thesis' research questions.

The 'balanced scorecard' theory of Robert Kaplan and David Norton steered the direction of the thesis, and their work became important for the preparation of the questionnaire used in the thesis survey.

And last, but not least, Eric Ries' principals of 'innovation accounting', which became a focal point for the thesis, and also inspired the thesis title.

1.6 Overview of Chapters

The thesis is divided into six chapters.

Chapter 1 is an introduction to the thesis. It outlines the research objectives and present the research questions to frame the scope of work.

Chapter 2 is a review of literature. The chapter sets a context for industrial R&D, and discusses the difference between invention and innovation. The four phases of innovation: input, activity, output and outcome, are all examined. Furthermore, the chapter discusses what in the literature is regarded as innovation success factors, also examining emerging trends such as 'lean innovation'. Current performance measurement systems are than discussed with regards to goal setting and performance measurement theory. Finally, the chapter is tied together by a discussion on performance measurement in R&D applications specifically, and the introduction of the recent concept of 'innovation accounting' performance measurement.

Chapter 3 provides an overview on the methodology, and presents the survey performed on performance measurement in Norwegian oil and gas R&D.

Chapter 4 presents the data obtained and the empirical findings from the survey. Also the quality of the data is evaluated.

Chapter 5 discusses the data as an examination of the qualitative results from the quantitative perspective. Furthermore, an evaluation of the applicability of 'innovation accounting' in industrial R&D is performed.

Chapter 6 summarizes the key results of the work and provides answers to the research question. Furthermore, it discusses limitations of the thesis and suggest areas for future research.

2 Theory

2.1 Innovation and industrial R&D

> *"Innovation has nothing to do with how many R&D dollars you have... It's about the people you have, how you're led and how much you get it."*
>
> Steve Jobs
> (Isaacson 2011)

2.1.1 Invention vs. innovation

Innovation is key to improve competitiveness for companies in the Norwegian oil and gas sector. Understanding the dynamics of the phenomena is necessary to identify its emergence and to monitor progress. Innovation is not the same as invention. While the output from research will be an invention, the subsequent development and commercialization of the invention will transform it into an innovation (Samsonowa 2012).

The term 'innovation' was initially coined by Schumpeter in 1911 (Goss 2005). Schumpeter provided a typology based on his five types of innovation (Croitoru 2012):

1. A new good or a new quality of a good.
2. A new method of production.
3. A new market
4. A new source of supply or raw materials or half-manufactured goods.
5. A new organization of any industry, like the creation of a monopoly position or the breaking up of a monopoly position.

According to Schumpeter (1934), innovation was measured by commercial or economic gain achieved through new or improved products, changes in economic production systems or expanding distribution networks.

A single correct definition or classification of an innovation does not exist. However, this thesis will use the classification given in figure 1, and the following definition:

An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). (OECD 2018)

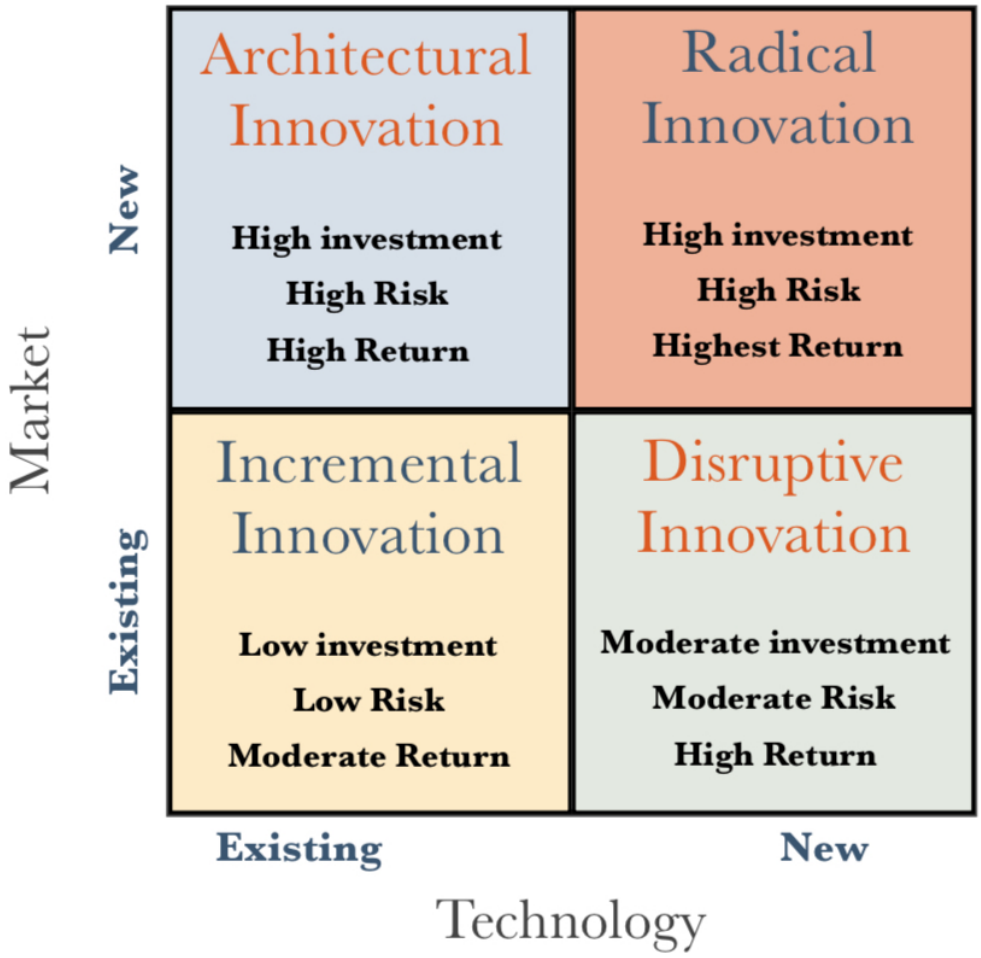


Figure 1: Classification of an innovation based on Schumpeter (1942) and Christensen (1997).

The innovation literature commonly distinguishes between different stages of an innovation process (OECD 2018):

- Inputs: Resources for an activity
- Activities: Work performed
- Outputs: Generated by activities
- Outcomes: The effects of outputs

Outputs include specific types of innovations, while outcomes are the effect of innovation on firm performance (sales, profits, market share etc.), or the effect of innovation on conditions external to the firm, such as environment and market structure (OECD 2018). Figure 2 presents a generic logic model for the innovation process.

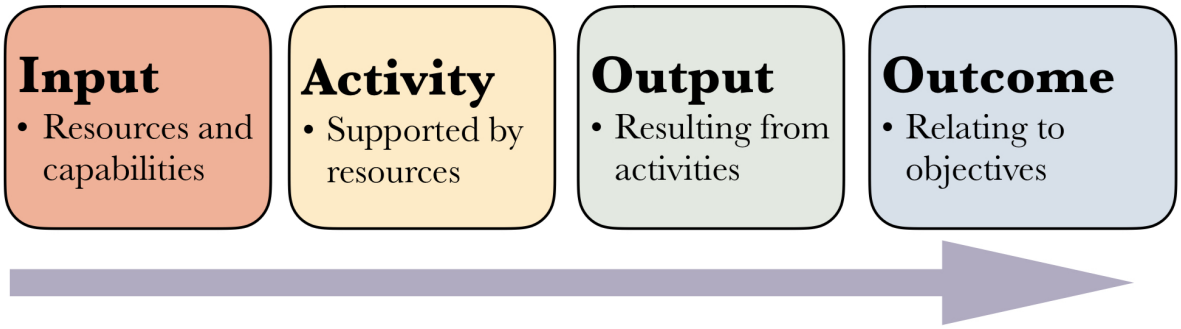


Figure 2: A logic model for the innovation process (Brown and Svenson 1998)

The logic model shows a linear relationship between input, output and outcome, however in practice they will be related through non-linear processes of transformation and development. Any analysis therefore has to identify appropriate dependent and independent variables and potential confounding variables that provide alternative routes to the same outcome (OECD 2018).

The term 'innovation' can describe either the activity or the outcome of the activity. The definition above is for an innovation outcome. However, the Oslo Manual (OECD 2018) provides separate definitions for both, and the other concept of innovation is defined as:

> *Innovation activities include all developmental, financial and commercial activities undertaken by a firm that are intended to result in an innovation for the firm.*

The concepts of 'invention' and 'innovation' must be distinguished, and the main differences between them are summarized in table 1.

Table 1: Main differences between 'invention' and 'innovation' (**Samsonowa 2012**).

Element	Invention	Innovation
Order	Occurs first, in the form of an idea	First attempt to implement the idea
Nature	Often a single product or process	Often a combination of products and processes
Time-lag	5-20+ years	
Location	Anywhere (universities, research organizations, R&D depatments)	Typically commercial firms
Skills	Inventor: Narrow, deep, domain specific	Innovator: Broad, entrepreneurial

The Troll Oil project can be used as an example to illustrate the difference between invention and innovation. The field has a narrow oil zone of only 10-20 m thickness. This was not drillable with the technology available in the early 1990's. However, it was made possible in 1992 by combining three inventions: horizontal drilling techniques, tools for downhole measurement and a rotary steerable assembly, into one innovation (Keilen, Thirud and Tjelta 2005).

1. Horizontal drilling, had been used on both Statfjord and Gullfaks prior to Troll.
2. Tools for downhole measurements (inclination and azimuth) was in use worldwide, however, Navigator, a near drillbit instrumentation, was developed for Troll to be able to keep the wellpath within a 1m target in a 2 km long horizontal section.
3. The AutoTrak, an intelligent drilling system were commands can be be given from surface to change direction while drilling, was originally developed for a project in Italy before the first use on Troll.

This example shows how inventions happens before the innovation and that several inventions can contribute to a single innovation. Two out of the three inventions were already commercialized, and thus innovations (horizontal drilling and Navigator). The AutoTrak was not yet a proven technology, thus only an invention at the time. However, through the Troll project the AutoTrak became an innovation in it self, while simultaneously being part of a larger innovation.

From the examination above it seems obvious that the commercial success of an innovation does not solely depend on the quality of the invention(s). Samsonowa (2012) suggest that the success of a new product, process or service depends on three phases, invention, innovation and diffusion, were diffusion is the market adoption after a technology has been proven and is commercially available.

Rogers (1983) defines 'diffusion of an innovation' as:

> *The process by which the innovation is communicated through certain channels over time among the members of a social system.*

Figure 3 shows Rogers (1983) model of the stages in an Innovation-Decision Process, with five stages:

1. Knowledge: The customer is exposed to the innovation's existence and gains an understanding of how it functions.
2. Persuasion: The customer forms a favorable or unfavorable attitude towards the innovation.
3. Decision: The customer engages in activities that leads to a choice to adopt or reject the innovation.
4. Implementation: When the customer puts the innovation into use.
5. Confirmation: The customer seek reinforcement for the innovation decision already made, but may reverse the decision if exposed to conflicting messages about it.

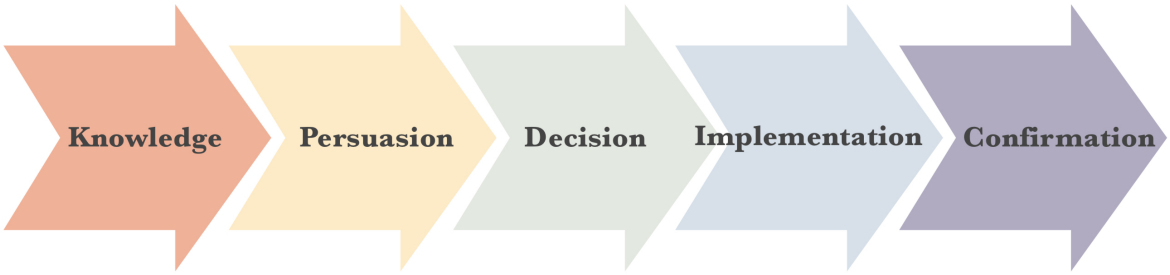


Figure 3: A model of Five Stages in the Innovation-Decision Process (Rogers 1995)

Rogers (1985) also showed how the diffusion of an innovation typically follows an innovation adoption S-curve, as shown in figure 4.

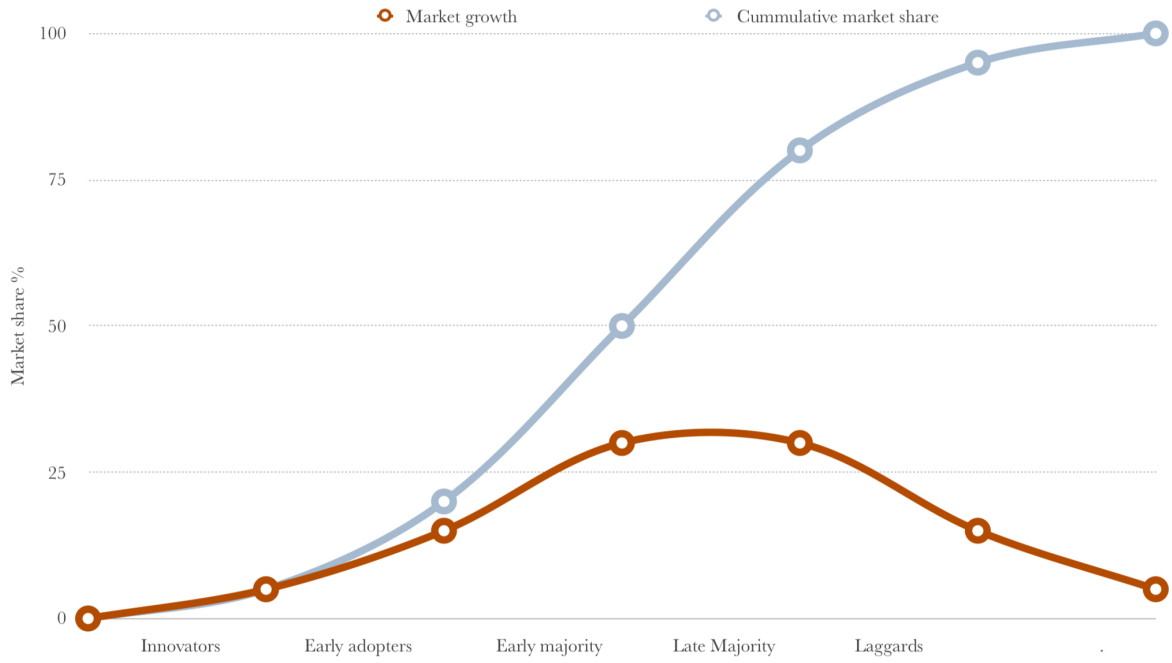


Figure 4: A technology adoption S-curve (from Moore 2014)

The success of an innovation is closely related to management throughout these three phases. As such, innovation management covers all of the tasks that are required to create technology know-how and to transform it into marketable innovations. (Samsonowa 2012). The next sub chapter will focus on the distinction between research and development, and discuss the term "industrial R&D" which will be examined in this thesis.

2.1.2 R&D

Research and development (R&D) can describe either 'an organizational unit' or 'a set of activities' (Samsonowa 2012). The OECD Frascati manual (2015) provides a definition:

> *Research and experimental development (R&ED) comprise creative and systematic work undertaken in order to increase the stock of knowledge and to devise new applications of available knowledge.*

The Frascati Manual (OECD 2015) divides R&D into three activities, as shown in table 2, with the respective definitions and focuses.

Table 2: R&D activities acc. to Frascati Manual (OECD 2015).

Activity	Definition	Focus
Basic research	Experimental or theoretical work to acquire new knowledge. *No particular application in view.*	Creation of knowledge *in general*
Applied research	Experimental or theoretical work to acquire new knowledge *directed primarily towards a specific practical aim or objective.*	Creation of *marketable* knowledge.
Experimental development	Systematic work, *drawing on knowledge gained from research*, directed to produce new materials, products or devices or install new processes, systems or services.	*Development* of new products, processes or services.

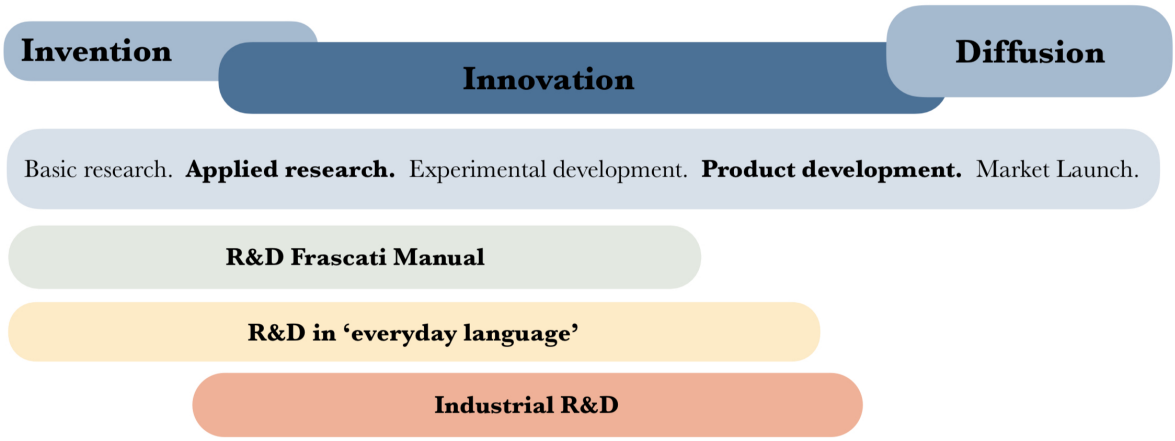
The Frascati Manual (OECD 2015) also discusses a set of activities which typically take place after experimental development, such as prototypes, pilot lines, design, engineering, pilot production, routine test and data collection. Samsonowa (2012) gives this group of development activities the term 'Beyond experimental development'. This thesis will use the term 'Product development' for these activities. The use of 'product development' must not be confused with the Frascati Manuals use of the term, which is "the overall process (...) aimed at bringing a new product (good or service) to the market" (OECD 2015). Table 3 is used by this thesis as an addition to table 2 from the Frascati Manual.

Table 3: Product development as the last stage of R&D activities

Activity	Definition	Focus
Product development	Systematic work, *drawing on knowledge gained from experimental development*, directed to build prototypes or pilot lines, or perform design, engineering, or pilot production.	*Enhancement* of new products, processes or services, prior to market launch.

Since this thesis focuses on development in an industrial environment, it is necessary to put the term 'industrial research and development' into context. Industrial research and development, in contrary to the Frascati Manual's definition of R&D, may include the construction of prototypes or pilot lines, when necessary for the industrial research and notably for generic technology

validation. Figure 5 shows the scope of activities of R&D related to respectively:



Invention, innovation and the various phases of R&D.

Figure 5: The scope of activities of R&D related to invention, innovation and the phases of R&D (The figure is derived from Samsonowa (2012) combined with the OECD manuals Frascati (2015) and Oslo (2018)).

2.2 Moving from R&D output to innovation outcomes

> *"More often than not, failure in innovation is rooted in not having asked an important question, rather than in having arrived at an incorrect answer."*
>
> Clayton Christensen
>
> (Christensen, Kaufman and Shih 2008)

The previous chapter placed experimental and product development in the context of industrial innovation and R&D. Before moving into performance measurement in industrial innovation, we must seek to understand how successful industrial innovation can be done.

The OECD Oslo Manual (2018) defines a firm's innovativeness as a result of four groups of inputs: innovation activities, capabilities for innovation, knowledge flows, and external factors influencing innovation. Table 4 shows the four groups with examples of relevant inputs.

Table 4: Inputs to a firm's innovativeness (based on OECD Oslo Manual 2018).

Activities	**Capabilities**	**Knowledge flows** (Open Innovation)	**External factors**
R&D	Resources	Collaborations	Customers
Engineering & design	Management team	Sources of ideas and information	Competitors
Marketing	Workforce skills	Linkage to other firms	Suppliers
Intellectual property	Ability to design, develop and adopt technology	Linkage to public research organizations	Labour market
Employee training		Linkage to universities	Legal conditions
Software development		Barriers for engaging in knowledge exchange	Regulatory conditions
Acquisition of tangible assets			Competitive conditions
Innovation management			Economic conditions

2.2.1 Innovation process

Historically, management theory has tended to focus on finding long term competitive advantages (Porter 1985), and once found, it should be protected through good financial management and operational excellence. However, in contemporary management thinking, companies should quickly exploit current competitive advantage and move on to the next advantage (Viki, Toma and Gons 2017).

Corporate innovation processes has in the past often been run in the same manner as other business units. A plan is prepared based on analyzing market data, make revenue predictions, allocate resources, and set milestones. And from there, it is solely a question of proper execution to reach the project's targets (Gallo 2017).

However, business planning seldom works for innovation (Viki, Toma and Gons 2017). New ventures, which are less predictable, require a different set of planning and control tools (Gallo 2017). Christensen et al (2016) writes that a staggering 94% of global executives are dissatisfied with their organizations' innovation performance, and that "the vast majority of innovations fall far short of ambitions".

Blank (2013) distinguished searching versus executing as key differences for every company. An established company mostly executes on a known business model that addresses the know needs of known market segments. However, for the company to innovate successfully it will have to search for new business models while it is executing (Christensen 1997).

After decades of watching great companies fail, Christensen et al (2016) found that what should be emphasized in a firms innovation process is the progress that the customer is trying to make in a given circumstance, "what the customer hopes to accomplish". This view on innovation has come to be called the 'job to be done' theory.

The 'customer' will be of profound importance throughout this thesis, and therefore the needs to be defined. While the customer in 'everyday language'

describes "a person who buys goods or services from a shop or business" (Oxford 2019), this thesis will use the broader 'business management' definition of the term:

> *A customer is the recipient of a good, service, product or an idea, obtained from a seller, vendor, or supplier via a financial transaction or exchange of money or some other valuable consideration.* (Kendall 2007)

This definition includes both the terms 'internal customers' and 'end-users', however if these terms are used explicitly in this thesis, the following definitions will apply:

> *An internal customer is a customer who is directly connected to an organization, and is usually (but not necessarily) internal to the organization. Internal customers are usually stakeholders or employees.* (Tennant 2001)
>
> *An end-user is the person that receives and ultimately uses the good, service, or technology.* (LII 2019)

Conventional business processes does not provide the necessary freedom for innovation activities. However, innovation should not be seen as set of unconstrained activities with no discipline (Blank and Newell 2017). According to Christensen et al (2016), innovation processes are often hard to see, but matter profoundly. By focusing the firm's innovation process on the job to be done, a clear guidance to everyone on the team is provided.

Viki, Toma and Gons (2017) writes that R&D departments in companies often succeed at making great new products, but fail at innovation, and that investments spent on industrial R&D labs often generate poor return. In a study of the 1000 most innovative companies in the world, it was found no statistical significant relationship between R&D spendings and sustained financial performance (Viki, Toma and Gons 2017).

While the higher R&D spendings seems to generate an increase in number of patents held by a company, this increase does not correlate with the number of successful innovations (Viki, Toma and Gons 2017).

Innovation needs to be designed as a process from start to deployment. Every innovation project should be part of a self-regulating, evidence based innovation pipeline. This pipeline should operate with speed and urgency, and prioritize problems, ideas, and technologies. Before a innovation reaches engineering, substantial evidence must be in place, such as validated customer needs, processes, legal security, and integration issues (Blank and Newell 2017). McGraths and MacMillan (1995) offers a framework for such a process called Discovery-Driven Planning.

2.2.2 Discovery-Driven Planning

While conventional business planning operates on the premise that managers can extrapolate future results from a well-understood and predictable platform of past experience, a firm's innovation activities will be uncertain. The assumptions made at the outset are not likely to hold up as new information emerges, requiring substantial adjustments to the plan along the way (Gallo 2017).

Discovery-driven planning offers a lower-risk way to move a product forward in the face of "what is unknown, uncertain, and not yet obvious to the competition" so that firms can "learn as much as possible as cheaply as possible" while pursuing new ventures (McGrath and MacMillan 1995).

Discovery-driven planning includes the following five steps (Gallo 2017):

1. Define success: Decide what success will look like in concrete terms. Then link this outcomes to what might drive them. Find what needs to be true to achieve the outcomes the project is seeking.
2. Do benchmarking: Figure out how realistic it is for the project to reach its success outcomes by benchmarking metrics.
3. Define operational requirements: Perform a critical analysis of what must be true to realize goals. Lay out all the activities needed to qualify, produce, sell, and deliver the new product to customers.
4. Document assumptions: This step is an essential difference between conventional and discovery-driven planning. In innovation, leaders often don't see that they are basing decisions on big assumptions. To avoid this

trap, list all of the assumptions behind a successful outcomes and test them. As the cost and risk of the project increase, also increase the thoroughness of assumption testing. Identifying an assumption at an early stage, that turns out to be false, can save the company a lot of money.

5. Plan to key milestones: Identify a series of milestones at which it can be determined whether assumptions are holding true or need to be redefined. Use the milestones to decide either to continue the project according to plan, redirect it based on what has been learned, or stop it before investing more time and money.

The idea of discovery-driven planning was picked up by Steve Blank and Erik Ries, and became the foundation of the more recent 'lean innovation' movement, which is core to how industrial innovation should be thought of today (Gallo 2017).

2.2.3 Lean innovation

The 'lean innovation' methodology favors experimentation over elaborate planning, feedback over intuition, and iterative design over traditional 'big design up front' development (Blank 2013). Concepts such as 'minimum viable product', 'rapid prototyping' and 'pivoting', is important to the iterative process of both discovery-driven planning and lean innovation (McGrath and McMillan 1995 and Blank 2013).

While lean innovation was originally developed as a management system for use in high tech start-up companies (Ries 2011), the methods has later been adapted to also be applicable for large scale, low tech industries (Ries 2017).

Lean innovation is a 'customer-centered' innovation methodology, which use concrete steps to learn about the customer (Blank 2006). Ries (2017) provides a definition of 'lean innovation':

> *A methodology for developing businesses and products, which aims to shorten product development cycles and rapidly discover if a proposed business model is viable, achieved by adopting a combination of business-hypothesis-driven experimentation, iterative product releases, and validated learning.*

The lean development process can be divided into three phases which are relevant for the development stage (Blank and Newell 2017):

- Solution exploration and hypothesis testing: This process delivers evidence for defensible, data-based decisions. A business model canvas is made to present and test each hypothesis, such as product-market fit or solution-mission fit. The framework also requires answers to compatibility, scalability and deployment long before engineering.
- Incubation: When hypothesis testing is complete, projects will need to gather additional data and further build the prototype. This incubation requires dedicated leadership oversight to ensure the projected is allocated sufficient resources.
- Integration and refactoring: The integration of R&D projects into the existing organization often result in chaos and frustration, when new, unbudgeted, and unscheduled innovation projects meets engineering organizations with line item budgets and resource results. In addition, innovation projects often carry both technical and organizational dept.

Two main objectives of the lean innovation process is to effectively and efficiently reach first 'problem-solution fit' and subsequently 'product-market fit', or alternatively understand as soon as possible if one or both of the objectives are out of reach (Ries 2011).

A problem-solution fit is were an industrial research project should demonstrate a real market need, and a solution to the market need that customers are willing to pay for. While a product-market fit is the demonstration that the right product can actually be built. Also, it needs to validate a plan for growth, and show that the revenues will be sustainable related to costs (Ries 2011).

Neither lean innovation nor discovery-driven planning, nor any other dedicated innovation pipeline, will in itself represent successful innovation. The ultimate measure of success is the development of new products with sustainably profitable business models (Viki, Toma and Gons 2017). Innovation requires a rigorous process, where the difficult part is prioritizing, categorization, gathering data, testing and refactoring (Blank and Newell 2017).

A main point is that companies should separate their innovation activity as much as possible from the running of the core business (Ries 2017), and use the right investment practices and metrics to measure success (Viki, Toma and Gons 2017). The next two chapters will look into performance measurement, first in general, and thereafter for specific R&D applications.

2.3 Goal setting and performance measurement

> *"Measurement is complex, frustrating, difficult, challenging, important, abused and misused" yet as Lord Kelvin once said, "if you cannot measure it, it does not exist"*
>
> Michel Lebas
>
> (Lebas 1995)

Performance has for long been important to businesses. The Venetian sailing expeditions measured its performance already in the 12th century, by the difference between the amount of money invested by the ship owner and the amount of money obtained from selling all the goods brought back by the ship's captain (Lebas 1995).

Few people agree on what performance really means (Lebas 1995). Performance is not an absolute, but a relative measure of success. However, it is related to two terms: effectiveness and efficiency. Drucker (1974) writes: "Effectiveness is the foundation of success and efficiency is the minimum condition for survival after success has been achieved". Thus:

- Effectiveness: Doing the right things
- Efficiency: Doing things right

Management is meant to create and shape the future of an organization, thus performance is about the future, and the capabilities, of the evaluated unit. Lebas (1995) suggests the following definition of performance:

> *Performance is about deploying and managing well the components of the causal model(s) that lead to the timely attainment of stated objectives within constraints specific to the firm and to the situation.*

Although performance itself is difficult to define accurately, it is possible to derive some components of performance (Lebas 1995):

- *Targets* to be reached.
- Elements of *time* at which the target or milestone to that aim are reached.
- Rules about a preference ordering about the *ways to get there.*

These three elements indicates that performance implicitly presumes the existence of a pre-defined goal, and rests on a causal relationship between inputs

and outputs (Lebas 2015). The same is true for effectiveness and efficiency, which can only be evaluated against a goal (Drucker 1974). Effectiveness is an indicator of the degree of goal attainment, and efficiency is an indicator of the resources used to reach the achievement (Samsonowa 2012). This thesis use the term 'performance' as the degree of goal attainment, as shown in figure 6.

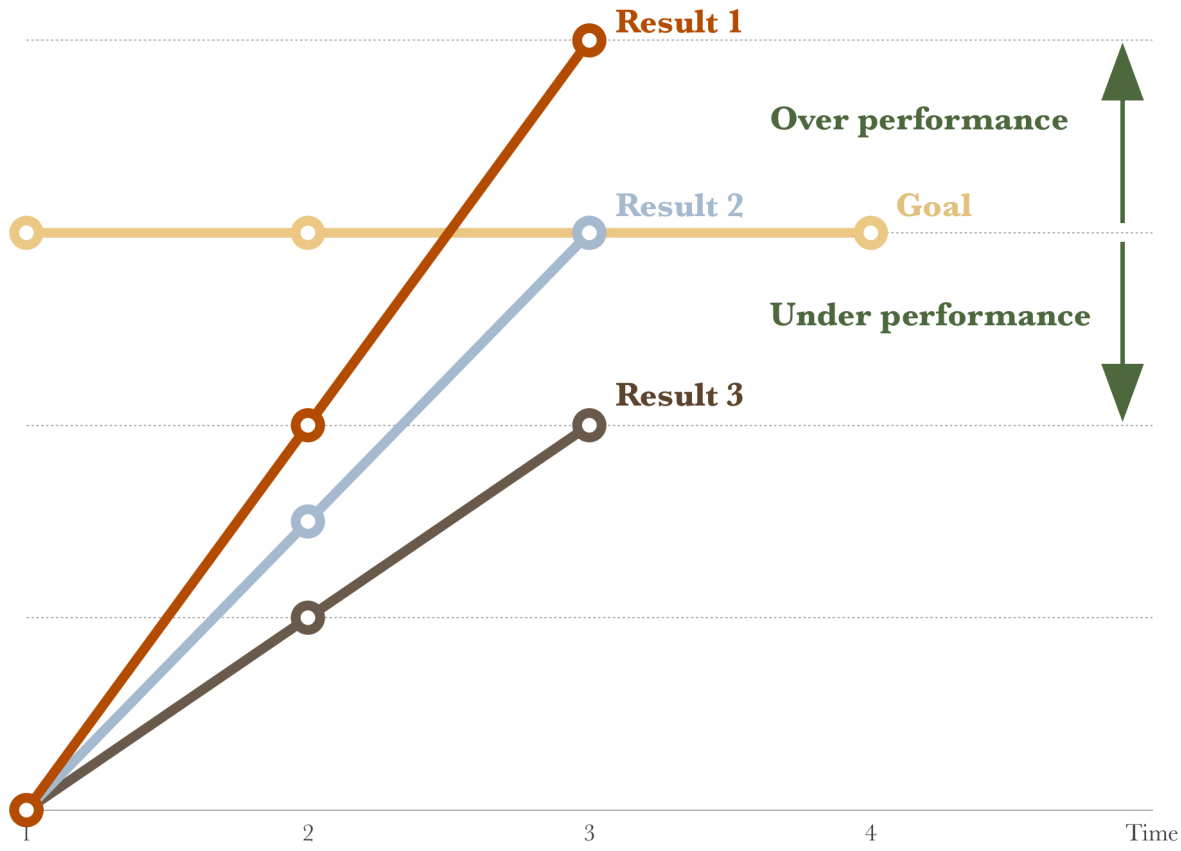


Figure 6: Performance as the degree of goal attainment (Samsonowa 2012).

2.3.1 Goals

In organizational psychology goals are often defined as either (Samsonowa 2012):

- The objective of an action.
- What the individual is consciously trying to do.
- What the organization wants to achieve.
- A common element to motivate performance.

This thesis will use the definition:

> *A goal is an idea of the future or desired result that a person or a group of people envisions, plans and commits to achieve.* (Locke et al 1981)

In addition to forecasting, a goal also shows activity: "within the goal, intent of attainment or completion is logically included" (Samsonowa 2012). Locke and Latham (2002) found that specific, difficult goals lead to higher performance than either easy goals or instructions to "do your best", given that feedback about progress was provided, the person was committed to the goal, and had the ability and knowledge to perform the task.

Goals affect performance in the following ways (Locke and Latham 2002):
- Goals direct attention and effort toward goal-relevant activities.
- Difficult goals lead to greater effort.
- Goals increase persistence.
- Goals indirectly lead to the use of task-relevant knowledge and strategy.

The goal setting process is a systematic reduction of complexity which can be realized either by decomposing and structuring in a goal system, or through iterative goal creation in the problem solving process (Samsonowa 2012).

A positive relationship between goals and performance depends on the goal being considered important by the individual, and that the individual must be committed to the goal. For goals to be effective, people need feedback that details their progress in relation to their goals (Locke and Latham 2002). Therefore, to assess goal attainment, measurements are necessary.

2.3.2 Performance measurement

The term 'measure' can be defined in several ways (Samsonowa 2012):
- A fixed limit
- A dimension, capacity, amount, degree or unit
- An estimate of what to be expected
- A measured quantity

In this thesis, a measure is defined as "a quantifying value".

Geisler (2000) writes: "Measuring the objects and the events in the world around us is not only a scientific necessity, but also the means to make sense of the complexity of natural phenomena. We continuously live by measures of our surroundings. We measure the passage of time, the temperatures in our climate, our economic situation, and everything else with which we make contact".

The purpose of measuring performance is to support and enhance improvement. In order to improve, information about the current status is required. This will be the reference for an improvement analysis (Sink and Tuttle 1989).

Although the term performance measurement is frequently used, its definition is incomplete. This thesis will use the definition from Kerssens van Drongelen and Bilderbeek (1999):

> *The acquisition and analysis of information about the actual attainment of company objectives and plans, and about factors that may influence this attainment.*

Table 5 shows the terms used for performance measurements. A metric puts a measure into a certain context, and the context is given by an item or an object which defines a unit of measurement and a reference unit (Samsonowa, Buxman and Gerteis 2009).

Table 5: The relationship between the four types of metrics (from Parmenter 2007)

Performance measurements	
Metrics	
Result indicators (RI)	**Performance indicators (PI)**
Key result indicators (KRI)	Key performance indicators (KPI)

Result indicators summarize the work an organization does, typically in financial terms. Because they are broad, result indicators work best for monitoring organizational performance, not team performance. Key result indicators (KRIs) provide broad-based data typically used on CEO and board level (Parmenter 2007).

Since the scope of this thesis is an assessment of performance measurement on team level, result indicators will not be further discussed.

Performance indicators measure the work of a team or group of teams working together, and do not concern financials. They provide indicators for judging specific work units according to their accomplishments (Parmenter 2007).

Performance can not be seen as something absolute, and it is difficult to capture and quantify performance precisely. Thus, the indicators are needed. A performance indicator is defined as (Samsonowa 2012):

> A*n auxiliary metric that partially reflects the performance of an organizational unit*.

Based on this definition it can be concluded that, in general, performance can not be sufficiently quantified by a single indicator. Sound statements need a set of indicators. Information reduction through consolidation and selection provide a need for key performance indicators (Samsonowa 2012). Parmenter (2007) defines key performance indicators as:

> *A set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization.*

According to Parmenter (2007) a KPI has six characteristics, that are of relevance to the project level:

- Non-financial: Financial measures belong to results.
- Timely: Monitoring should take place frequently, i.e. daily or weekly.
- Simple: Point directly to the actions employees should take to help the firm succeed.
- Team based: Reflect the goals of specific teams.
- Significant impact: Concerns a goal of the project.
- Limited "dark side": Once you target a KPI, test it to ensure that it works and do not prompt negative outcomes or spur dysfunctional employee behavior.

Performance measures are by nature data that are accumulated about the past. By inserting the measures in models, or transforming them to predictive parameters, the data can be of value for decision making. The great difficulty with using past data is that it requires some form of extrapolation. Therefore,

data should be captured as "soon as possible", so that the extrapolation can be more responsive to changes in the causal relationships (Lebas 1995).

The Brown and Svenson (1998) model (figure 7) shows how the processing system transforms inputs into outputs, which are taken up by the receiving system that in turn produces outcomes. The distinction between output and outcome is important.

A key feature of the processing system is that the result will not be known ahead of the output. Thus, the 'expected output' from research activities will be a reflection of the definition at the company. If this is not clearly defined, measurement will be very difficult.

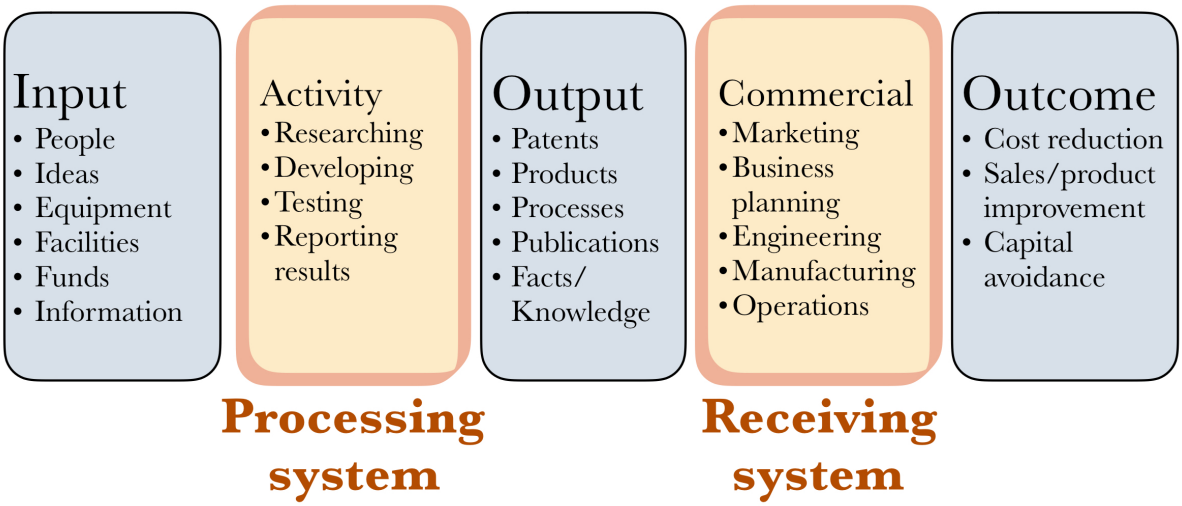


Figure 7: The macro system of an entire innovation organization (Brown and Svenson 1998).

Understanding the process underlying performance is the only way to define the measures that lead to actions. If only the final, most aggregated version of performance is looked at, no corrective action can be identified. For example, knowing whether customers are satisfied or not is already better than simply observing sales numbers. However, measures should be placed upstream of the desired outcome, thus represent the conditions that will generate performance. Managers can then use the measures to anticipate the causes of the performance (Lebas 1995).

2.3.3 Performance management

The linkage between goals, measurement and improvement is termed 'performance management' (Samsonowa 2012).

Simply knowing the performance does not improve the performance itself. The performance has to be actively managed, and management could hardly exist without measurement (Kerssens van Drongelen and Bilderbeek 1999). Thus, performance measurement is part of performance management. The distinction between the two terms is essential for this thesis. The following definition of performance management is used:

> *The acquisition and analysis of information and the interpretation of this information to determine what to do and how to do it and the application of the chosen measures to influence people so that their efforts are aligned to company objectives and plans.* (Kerssens van Drongelen and Bilderbeek 1999)

Performance measurement and management are not separable, there is a loop where the two follow one another in an iterative process. Performance management create the context for performance measurement. One that exclusively focuses on measurement, without understanding that measures only tell what the consequence of a decisions was, will never master the process of creating performance and success for the organizational unit under scrutiny (Lebas 1995).

Lebas (1995) found that a powerful performance measurement system is one that is build on, and supports, measures that:

- Give autonomy to individuals within their span of control.
- Reflect cause and effect relationships.
- Empower and involve individuals.
- Create a basis for discussion, and thus support continuous improvement.
- Support decision making.

Samsonowa (2012) found three categories, with six subcategories, of performance management, which is shown in table 6.

Table 6: The performance management categories and subcategories (Samsonowa 2012)

Goal setting		Evaluating goal achievement		Motivation	
Communication	Alignment	Status quo	Prediction	Organizational	Personal

Setting goals is a prerequisite for the assessment of the actual performance, and reflects the planning phase. The subcategories are communication, the decomposed and cascaded goals, and alignment, which provides assurance that the sum of all cascaded goals reflects the overall goal.

Since goals has been defined as "an envisaged and intended future state" (Locke et al 1981), category two must be an evaluation of goal achievement. This reflects the measurement and analysis phases. The subcategories are status quo, the current performance level, and prediction, the performance level aimed for. The last category is motivation, which mainly refer to the review phase.

A great number of studies from applied psychology has shown that motivation impacts the individual performance, and consequently the organizational performance. The subcategories are personal motivation (rewards, career planning, etc) and organizational motivation (Samsonowa 2012). Figure 8 shows the various phases of the performance management process.

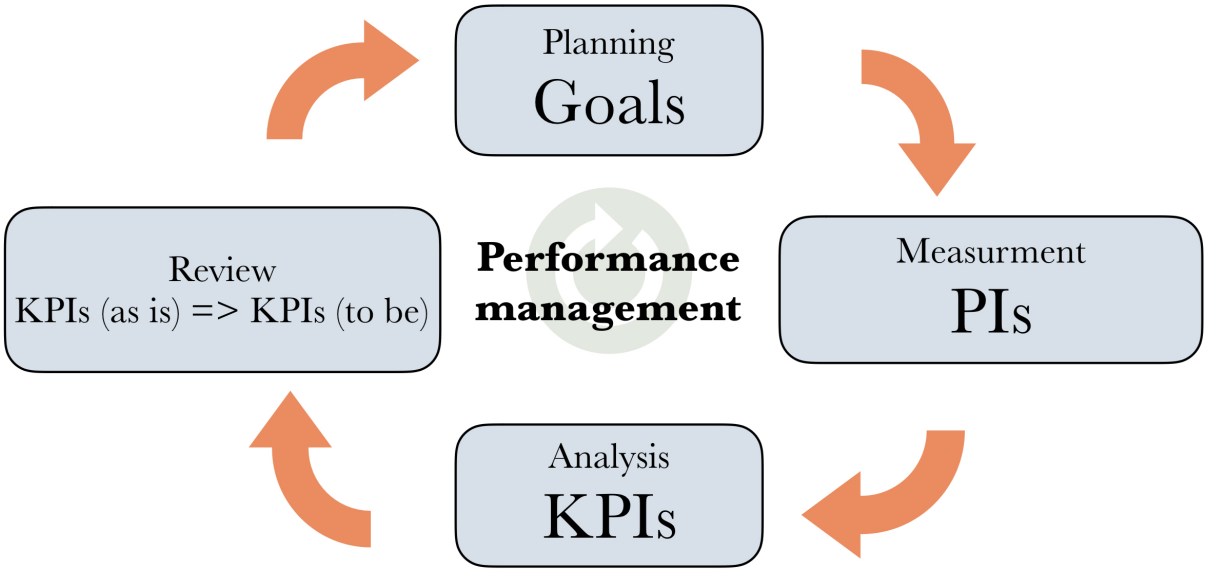


Figure 8: The performance management process (based on Samsonowa 2012)

McLaughlin and Jordan (1999) found that the performance measurement practices in general, needs to be adapted to an R&D environment, which will be explored in depth by the next chapter.

2.4 Performance management in industrial R&D

> *"Creativity is an indispensable feature in the search for new ideas, new products, and innovations."*
>
> Tatjana Samsonowa
> (Samsonowa 2012)

2.4.1 Performance measurement i R&D

R&D in industrial organizations is broadly accepted as one of the most important factors affecting future profitability (Samsonowa, Buxman and Gerteis 2009). However, the question of whether to measure performance of research projects remains controversial (Samsonowa 2012). Brown and Svenson (1998) showed that scientists did not accept performance measurement, and the following arguments were used:

- It is impossible to measure R&D productivity.
- Management should have faith that R&D is a good investment without trying to measure it.
- Fear that such systems may expose inadequacies and lack of productivity.
- Previous attempts have resulted in dismal failure.

The argument that rigorous measurement kills creativity is probably the most prominent. Creativity is an indispensable feature in the search for innovation, and covers a significant part of the activities in industrial R&D (Samsonowa 2012).

However, several studies have concluded that the best performing companies apply explicit performance measurement techniques to their industrial R&D (Kerssens van Drongelen and Bilderbeek 1999), and phenomena like shortened product life cycles, globalization, increased R&D costs and risks, have encouraged the development and adoption of specific approaches for assessing the performance of R&D.

According to McLaughlin and Jordan (1999) there are essentially two main purposes to measure R&D performance:

1. Accountability (communicating value)
2. Improvement

Kerssens van Drongelen and Bilderbeek (1999) found evidence to support that performance measurement systems are perceived by R&D managers to be of value and to have a positive impact on performance. Performance measures in R&D should be built around a limited number of indicators that measure results rather than behavior. Objective and external metrics should be used instead of subjective and internal ones (Brown and Svenson 1998). Hauser (1998) showed that metrics should be chosen based on the type of R&D, whether it is basic research, applied research, or technological development.

A study by Chiesa et al (2009) supported Hauser (1998), that performance measurement should be R&D setting specific, with a given amount and quality of available resources, and within the scope of a firms specific business strategy, mission, values and management style.

Kerssen van Drongelen, Nixon and Pearson (2000) found that performance measurement, especially in complex new product development projects, can serve the purpose of favoring communication and coordination among managers and researchers.

Chiesa et al (2009) supported that the need for control when measuring performance is stronger in new product development than in basic or applied research. The main reason is that the output of product development activities is sold directly on the market. Therefore, the respect of deadlines, quality requirements and target cost has a more direct impact on the firm's market competitiveness than in the case of basic and applied research, whose clients are basically internal. Moreover, the amount of financial and human resources involved in new product development is larger compared to research, which means that higher stakes are at risk.

Exerting tight control over R&D activities requires that outputs are, at least to some extent, predictable. In addition, for this tight control to be applicable, the

standards to measure performance against must be easily identified, and the progression of project activities can be identified beforehand. It is clear that product development is more foreseeable than research, but predictability also depends on the characteristics of the industry in which a firm operates (Chiesa et al 2009).

Profitability is the most commonly used measure for performance in general, and sets inputs in relation with outputs. Thus, a pre-condition for calculating profitability is quantifiability of the outputs. Samsonowa (2012) highlights several obstacles to quantifying the monetary value of R&D outputs:

- Although R&D expenditure is linked to future earnings, it is impossible to illustrate the exact cause and effect between R&D spendings and company income.
- An appropriate methodology for measuring and evaluating R&D output does not yet exist.
- The periodical accounting system in firms does not fit the typically long delay between expense and income dates in R&D.

Measures that relate to specific functions (i.e. the number of patents or publications obtained) may make responsibility clearer, and thus increase the value of the measure. However, this type of narrow output goals are of little worth to project teams, since they do not reflect the emphasis placed in current new product development literature on both internal collaboration among functions and external collaboration with customers, suppliers, research agencies and even competitors (Kerssens van Drongelen, Nixon and Pearson 2000).

Samsonowa (2012) states three major problems of industrial R&D measurements:

1. Accurately isolate R&D contribution to company performance.
2. Match specific R&D inputs and intermediate outputs with final outcomes.
3. The time lag between R&D efforts and their pay-off in the marketplace.

To answer these questions it is especially important to understand all of the influencing factors (Samsonowa 2012). The basic dimensions of performance analysis is given in table 7.

Table 7: The basic dimensions of performance analysis in R&D (Samsonowa 2012).

Perspective	Purpose	Level	R&D type	Process phase
FOR WHOM?	WHY?	WHERE?	WHAT?	WHEN?
Customer	Strategic control	Industry	Basic research	Input
Internal	Justification of existence	Network	Exploratory research	Activity
Financial stakeholders	Benchmarking	Company	Applied research	Output
Other stakeholders	Resource allocation	Department	Product development	Outcome
Learning	Development of activities	Process	Product improvements (incremental)	
Others	Motivation, rewarding	Project, team		
		Individual		

It becomes clear that more than simple measures are necessary to control the performance of R&D projects and organizations, thus a performance management system is needed.

2.4.2 Performance management in R&D

Performance management systems can be classified in four groups based on the major focus of the respective approach (Samsonowa 2012):

1. Finance focused: The guiding principle is that "we are running out of money". Beyond Budgeting (Hope and Fraser 2003) is an approach example in this category.
2. Strategy focused: The guiding principle is that "we know where we want to go and we all pull together". The Balanced Scorecard (Kaplan and Norton 1992) is an approach example.
3. Process focused: The guiding principle is "management and control of the business process". Approach examples are Total Quality Management, and its successors Six-Sigma (Tennant 2001) and Lean Manufacturing (Holweg 2007).

4. Employee focused: The guiding principle is that "our employees must use their knowledge within the teams. The goal of these approaches is continuous improvement through self-adaptation.

R&D has an inherent nature of experimentation. Researchers do not know what the result will be. This uncertainty makes it difficult to plan, manage and measure the activities. The finance focused approach is hard to apply because R&D lack tangibility. The process focused approach is difficult to use due to the non-repetitive nature of the experiment (Samsonowa 2012). Thus, the strategy focused and the employee focused are the performance management systems that should be evaluated for R&D applications.

Kerssens van Drongelen, Nixon and Pearson (2000) found that failures in the R&D management process can easily result in a measurement system that contributes to 'segmentalism' rather than the integration of cross-functional teams that is required for rapid, successful product development.

For teams to function effectively, a close collaboration is required. Such collaboration can easily be eroded by an emphasis on individual contributions. Yet, an individual focus is not uncommon in R&D performance measurements (Kerssens van Drongelen, Nixon and Pearson 2000).

Kerssens van Drongelen and Bilderbeek (1999) performed a study to distinguish highly and hardly effective R&D measurement procedures. They found that "the most important characteristic, that seems to distinguish the most effective systems from the less effective ones, is customer focus". For team performance measurement they found som interesting patterns:

- The most effective systems are characterized by measurement on a 1, 2, or 3 monthly basis, with the involvement of customers in the measurement procedure.
- The least effective team measurement systems are based on measurements on a yearly or half yearly basis, carried out solely by R&D managers.
- Less effective systems are focused on control and correction of the evaluated project (team) only.
- The most effective systems are broader, aiming also at supporting process improvements and strategic adaption.

When managers are faced with accountability requirements, they focus on collecting evidence of their accomplishments, such as the value added for customers or the problems that have been solved. However, another way to be accountable is to collect information that enables managers to understand how well their R&D effort is working. For a such an understanding, information that provides a balanced picture of the health of the R&D project or program is necessary. (McLaughlin and Jordan 1999).

Table 8 shows the various characteristics and the associated measurement requirements that should be evaluated in a balanced picture of the health of an R&D organization (Samsonowa 2012). It also addresses differences in approach to respectively research and development phases. While research projects needs to emphasis the inventive process, that is, expansion of a technology base, development, on the other hand, should emphasize on bringing a new product into existence. Thus, the following aims can be deducted:

- Research task: Generate knowledge.
- Development task: Create physical output.

The literature on performance management indicates that a system must take into account all the complexity and uncertainties shown in table 8. A solution to such a balanced picture of the health of a R&D project may be found in the balanced scorecard.

Table 8: The relevant complexities and uncertainties of a performance management system in industrial R&D (from Samsonowa 2012).

Characteristic	Description	Measurement requirement
Task types (routine vs exceptions)	Researchers: Theoretical knowledge Developers: Engineering the product	Consider the nature of research tasks
Time-lag	Significant time lag from output to outcome. Turning output into outcome is not under the control of research. Research can generate disruptive 'jumps'. Development is an evolution of existing ideas.	Reflect time lag between output and outcome. Cope with the irregular generation of outputs.
Validity of both positive and negative outputs	Research output can be both positive and negative. Both cases can be valid research results.	Consider both results without penalizing the negative findings.
Output uncertainty	Research outcome is uncertain to result in a economically successful product. The risk is commercial rather than technical.	Reflect the uncertain conversion of research output into successful products.
Investment	Research is an investment without tangible results.	Assessment must be based on activities or outputs, not outcomes.
Different stakeholders	Research often has a variety of stakeholders: e.g. academia, industrial partners, political bodies, media, and internal units.	Consider interactions with different stakeholders.
Knowledge depth	Research often requires specific competence. Development requires knowledge from a wide range of areas.	Consider the different skill sets.
Quantifiability of output	Results of industrial research have no immediate commercial value. Difficult to directly quantify monetary value.	Identify reasonable indicators for the monetary value of research output.
Definition of output	Difficult to define output definition in advance. The lack of repeatability makes 'expected' research output difficult to measure.	Identify benchmarking values for the output.

2.4.3 Balanced scoring

Peter Drucker was in 1954 the first to introduce the "balanced" set of measures, based on the desire to quantify performance, without the negative consequences of measurement, such as managers "feeding machines all the easy orders at the end of the month to meet [their] quota" (Neely 2005).

Kaplan and Norton (1992) proposed the concept of the balanced scorecard, which revolutionized conventional thinking about performance metrics. By going beyond traditional measures of financial performance, the concept gave a better understanding of how companies are really doing. These non-financial metrics are valuable mainly because they predict future financial performance rather than simply report what has already happened (Kaplan and Norton 2007). After Kaplan and Norton followed a rich stream of work on the design and deployment of performance measurement systems (Neely 2005).

Many scholars have attempted to apply the balanced scorecard approach to R&D. Kerssens van Drongelen and Cook (1996) showed how to develop a measurement approach to integrate a firm's R&D with its competitive strategy. Bresmer and Barsky illustrated how the balanced scorecard approach should be integrated with the stage gate system.

Kerssens van Drongelen and Bilderbeek (1999) showed that the balanced scorecard offers an appropriate framework to cluster metrics used to measure R&D department performance. Such a scorecard is shown in figure 9.

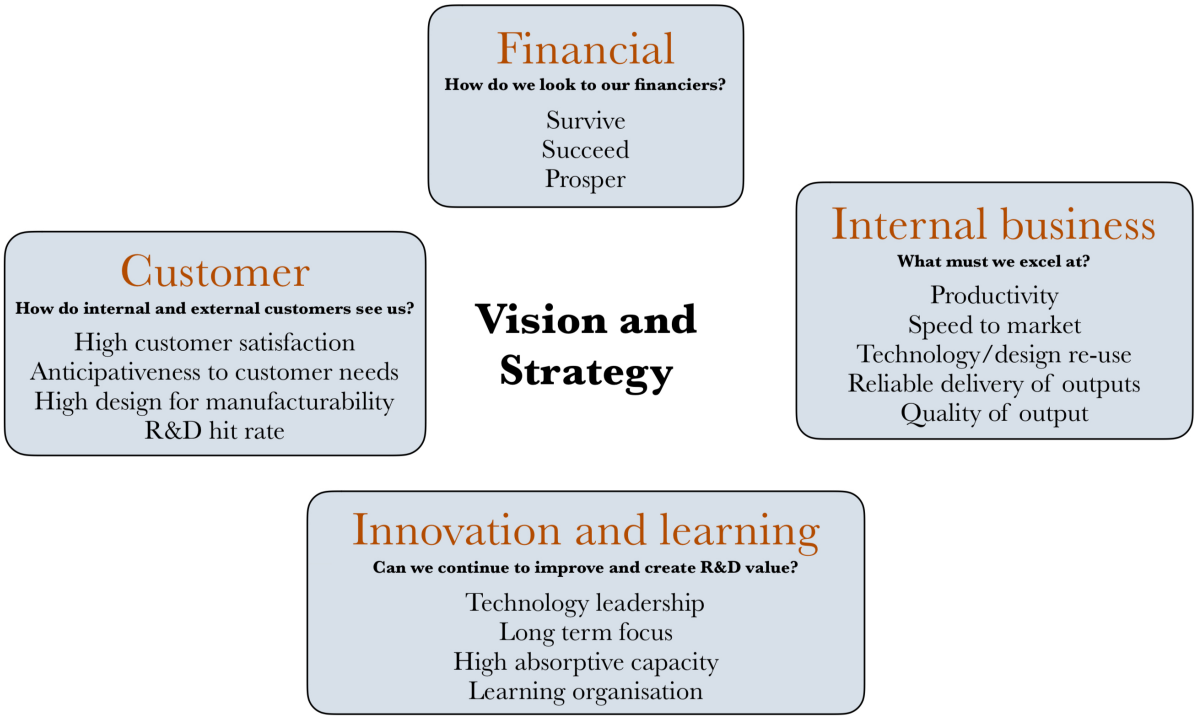


Figure 9: Example of a balanced scorecard for an R&D department (Kerssens van Drongelen and Bilderbeek 1999)

Chiesa et al (2009) supported that the dimensions along which R&D performance is evaluated can be brought back to the balanced scorecard perspectives. The companies in their study measured R&D performance on the following aspects:

- The economic and financial aspects associated with R&D (financial perspective)
- The extent to which R&D identifies and satisfies the needs of its internal and external customers (customer perspective)
- The efficiency with which specific tasks and processes are carried out (business process perspective)
- The extent to which R&D contributes to generate new knowledge and innovation opportunities (innovation and learning perspective).

A study of how the four balanced scorecard clusters were used in R&D found the following (Kerssens van Drongelen and Bilderbeek 1999):

- The innovation and learning perspective is almost totally absent in team performance measurement. This supports the assumption that teams are only held accountable for the proper execution of a single project, and not for long-term issues such as the generation of ideas for future business.
- The internal business perspective scores high for performance measurement, with measures such as 'agreed milestones/objectives met'. This supports the view that metrics ought to be aligned with the objectives and responsibilities of the measurement subject.
- Companies do not use a balanced set of metrics from all four perspectives to measure performance.
- Most companies use broad, unsophisticated concepts such as 'quality' and 'behavior' in performance measurements. These concepts are difficult to measure and interpret unambiguously.

Chiesa et al (2009) found that most of the companies in their study evaluated R&D performance based on balanced scorecard perspectives. Their model also suggested that firms use performance measurement in R&D to pursue different types of objectives. In particular, two distinct clusters of firms emerged, one that used performance measurement with the main purpose of exerting control over R&D activities and support critical management decisions ('diagnostic'

objectives) and the other that conceived performance measurement mainly as a mean to improve the motivation of researchers ('motivational' objectives).

Table 9 shows the emerging archetypes for performance measurement in R&D, as discovered by Chiesa et al (2009). In particular, 'diagnostic' objectives, which are typically important to new product development projects, are pursued mainly through the use of financial- and customer-related measures. Indicators associated with the innovation and learning perspective, which are typically used by basic and applied research projects, are the most widespread among companies pursuing 'motivational' objectives. Business process perspectives were present in both objectives.

Table 9: Archetypes of performance measurement in R&D (Chiesa et al 2009).

Objective	Balanced scorecard perspectives	Mainly used by
Diagnostic	Financial Customer Business process	New product development Large firms and R&D units High tech industries
Motivational	Innovation and learning Business process	Basic and applied research Small firms and R&D units Science based industries

Christensen, Kaufman and Shih (2008) found that financial tools creates a systematic bias against innovation.

- Discounted cash flow (DCF) and net present value (NPV) causes managers to underestimate the real returns and benefits of investments in innovation.
- Fixed and sunk costs confers an unfair advantage on challengers and shackles incumbent firms that attempt to respond to an attack.
- Earnings per share as the primary driver of shareholder value creation, diverts resources away from investments whose payoff lies beyond the immediate horizon.

The main error is to assume the present 'health' of the company will persist indefinitely into the future, as the base case of not investing in the innovation. In most situations, however, the company will encounter price and margin pressure, technology changes, market share losses, sales volume decreases, and a declining stock price. Thus, the most likely stream of cash for the company in

the 'do-nothing' scenario is not a continuation of the 'status quo', it is a non-linear decline in performance. (Christensen et al 2008)

Figure 10 shows the principal that Christensen, Kaufman and Shih (2008) called 'the discounted cashflow trap'. Since the base line used in the financial measures, such as discounted cashflow (DCF) or net present value (NPV), is a 'steady' cash flow year after year (green line), an innovation will appear to need longer time before it is profitable (purple line) compared to a more realistic non-linear decline in cash flow (blue line).

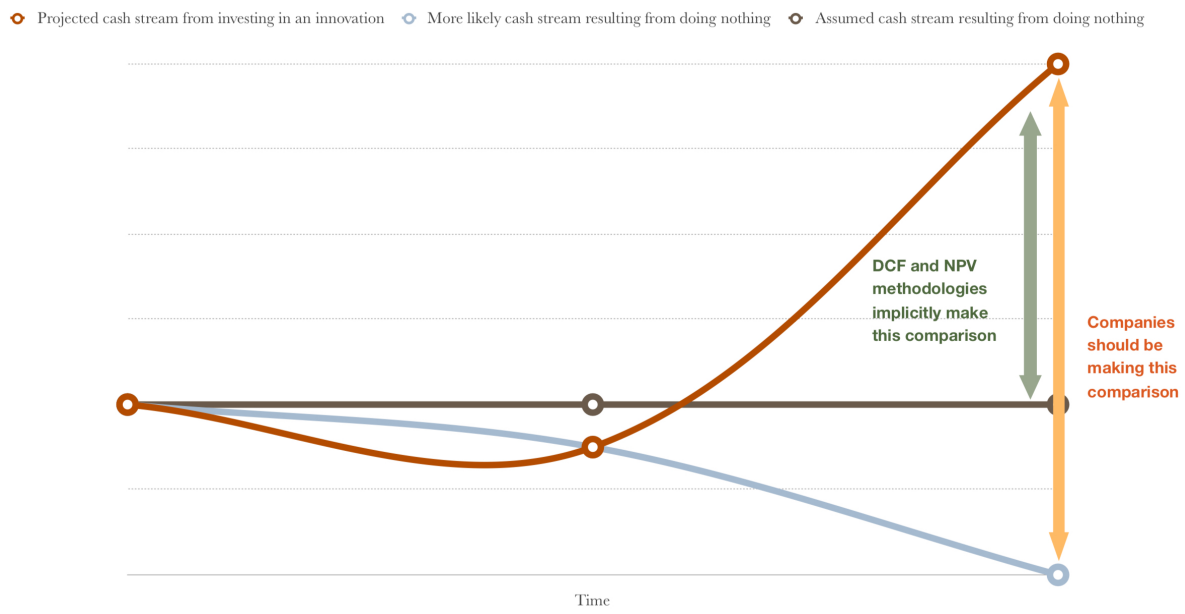


Figure 10: The discounted cashflow trap (from Christensen, Kaufman and Shih 2000)

Kaplan and Norton (2007) categorizes KPIs in two groups:

- *Leading indicators* measures activities that have a significant effect on future performance.
- *Lagging indicators* measure the output of past activity.

Parmenter (2007) found that whether an indicator is leading or lagging is related to the observers point of view. In example, a shipping company is measuring delayed departures of supply boats from shore. For the organization working on the onshore base, this is a lagging indicator. When a ship has left the base later than scheduled, it is already in the past, and they can no longer influence the result. However, for the organization on the offshore installation, the late departure can be a leading indicator for a late arrival to the rig.

Ries (2017) states that leading indicators predict future success and include customer engagement, unit economics, and repeat usage. This has been the basis for a relatively recent performance measurement system for industrial related innovation, named 'innovation accounting'.

2.4.4 Innovation accounting

The term 'innovation accounting', first coined by Eric Ries (2011), is the performance measurement system used in 'lean innovation'. The term is not related to the 'everyday' use of the term 'accounting', a synonym to 'financial reporting', as the formal records of the financial activities and position of a business to "provide information about the financial position, financial performance, and cash flows of an entity that is useful to a wide range of users in making economic decisions" (Deloitte 2019).

This thesis separates between 'financial accounting' and 'management accounting'. When the term 'accounting' is used alone it refers to solely financial performance, and the following definition will be valid:

> *Financial accounting is the measurement, processing, and communication of financial information about economic entities.* (Needles and Powers 2013)

Management accounting, however, is in this thesis be defined as:

> *Performance management is the process of supplying the managers and employees in an organization with relevant information, both financial and non-financial, for making decisions, allocating resources, and monitoring, evaluating, and rewarding performance.* (Atkinson et al 2012)

Accounting has been given the duty of defining performance since the early historical times (Lebas 1995). The traditional accounting views are based on the costing logic, which is focused on product-costing and defines performance as income (the difference between sales and costs). The costing logic consider the cost as the beginning of the calculation (Lebas 1995).

The opposing view is called ABC (Activity Based Costing), which uses the logic of causality (Lebas 1995). The cost object that the customer acquires is the

cause of the existence of processes aimed at creating the value parameters (i.e. 'timelineness' or 'quality') that the customer acquires. Thus, it is the process that causes the resource consumption, which is the cause to cost (Lebas 1995).

The ABC approach sees performance as the minimum amount of process cost to provide the customer with the desired value. This supports Drucker's (1974) view on performance with regards to effectiveness and efficiency. The causality approach rests on the description of "what people do" to achieve the goals in general and customer satisfaction in particular (Lebas 1995).

Figure 11 shows the the differences between traditional accounting principles, based on the costing logic, and the ABC accounting principles, based on the logic of causality (Lebas 1995). In the logic of causality, the customer is the root cause of the existence of cost.

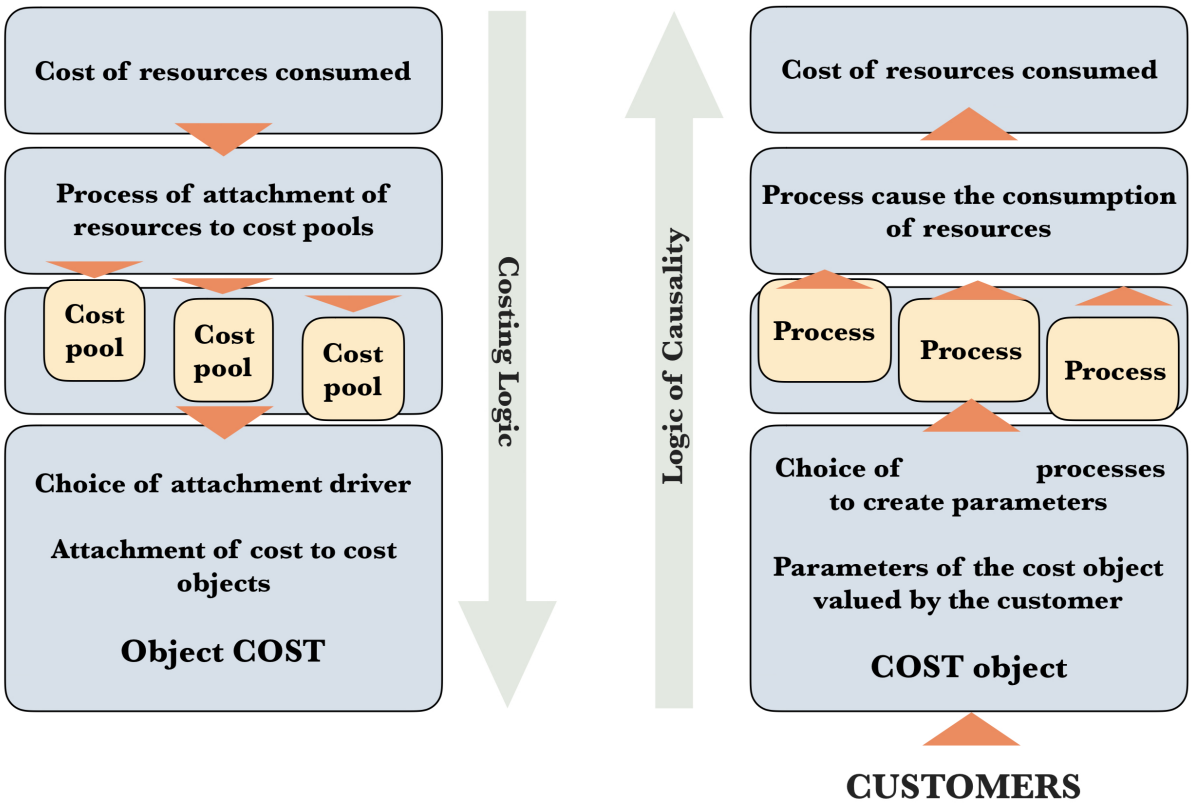


Figure 11: The costing logic (traditional view of accounting valuation) vs. the logic of causality (a completely reversed view of cost) (From Lebas 1995).

McLaughlin and Jordan (1999) introduced a logic model, which uses causal linkage or relationships for measuring performance in R&D, and stated that "what is essential is the testing of the [R&D] program hypothesis".

Lebas (1995) supports that performance can only be defined over the future and its definition is case specific, thus performance management is about evaluating and selecting possible action plans that will help the innovation achieve customer satisfaction in the future. A managerial information system can in practice be like a dashboard of a car, were all the measures that appears on its "meters" are relevant for the operation of the vehicle in the future (Lebas 1995).

Innovation accounting continue to build on the logic of cause and effect, and supports Lebas (1995), Christensen (1997), McLaughlin and Jordan (1999), Kerssens van Drongelen and Bilderbeek (1999): to solve a customer problem one must act on root cause, and to measure performance one must use a constructivist view instead of retrospective measurements. This thesis defines 'innovation accounting' as:

> *A performance management system for innovation projects, where performance measurement is performed by use of key performance indicators adapted to the innovation process.*

According to Ries (2011) only 5% of a successful innovation is the invention it self, the other 95% is the work that is measured by innovation accounting, such as product prioritization decisions, deciding which customers to target and listen to, and subject the innovation to constant testing and feedback.

Innovation accounting is still at an ideation level. Even though the principles of lean innovation has been adopted by the US governments 'National Science Foundation' (NSF) through the 'I-Corps' innovation program (NSF 2018), tangible scientific papers of its results does not yet exist.

However, innovation accounting enables R&D projects to prove objectively that they are learning how to grow a economically viable product. The assumptions that needs to be true for the product to succeed in the marketplace, are turned into a quantifiable financial model (Ries 2011).

The metrics used in innovation accounting must have all of the following three characteristics (Ries 2011):

- Actionable: Metrics must demonstrate clear cause and effect, to make the R&D team better able to learn from previous actions.
- Accessible: Metrics must be understood by the R&D team, for the metrics to guide decision-making. The metrics should be as simple as possible, and using tangible, concrete units.
- Auditable: Ensure that the metrics are creditable to everyone on the R&D team.

The innovation accounting framework consist of chained leading indicators, which is used to focus innovation teams to keep attention on the most important project assumptions. It provides a way to tie long term growth and R&D into a system that follows a process for funding innovation. An important objective of the system, is that it can be audited for the ability to drive value creation (IDEO U 2019).

Ries (2017) states that innovation accounting should comprise of three sets of KPIs, or 'dashboard levels'.

- Level 1: Designed to measure the progress of the innovation project.
- Level 2: Depending on a business plan, these metrics are used to select and test the project's assumptions. They should represent the complete interaction with a customer.
- Level 3: The learning from the first two levels is used to examine the overall performance of the innovation department within the context of the larger business.

Since this thesis will investigate performance management on project level, the level 2 and 3 metrics will not be discussed any further.

According to Viki, Toma and Gons (2017), reporting KPIs can offer insight to the progress of a R&D project, from ideation, problem-solution fit, and later product-market fit. It focuses on the number of experiments being conducted, number of customer interviews, number of prototypes (or minimum viable products), number of hypothesis validated or invalidated and time spent within each business model stage. The following KPIs are relevant (Viki et al 2017):

- Cost per learning (or cost per failure): A focus on managing the cost per learning will inspire a culture of experimentation. I.e. instead of building 1 complete product to a unit cost of 10, build 10 prototypes to a unit cost of 1 and iteratively improve the product with each release.
- Time-cost pr learning: The focus is how long time each learning cycle takes, thus, ideally reaching a continuous learning state where market input is immediately converted into a customer deliverable. The idea is to "fail fast, fail cheap and fail often", and thus "learn fast, learn cheap and learn often."
- Validation velocity: The goal of industrial innovation is to reach product-market fit. To reach this goal, assumptions and hypothesis requires validation.Thus, measuring the validation velocity will ensure that an optimum time to market is reached. Validation velocity is defined as the amount of validated business assumptions the project has completed over a given time frame. Validation activities will over time gradually lower the investment risk in a project, which is important for the governance KPIs.
- Knowledge-to-assumption ratio (may also be a governance KPI): The number of non-validated vs validates assumptions. The ratio is found by dividing validated assumptions by total assumptions. A ratio of 1 means that all assumptions within the project has been validated. However, this ratio does not account for different degree of uncertainty in various assumptions, and that some assumptions will have a bigger impact than others. Each project must find and prioritize its critical assumptions.

An important aspect of innovation accounting is that metrics are chosen by the innovation team itself, however, the KPIs must be simple and actionable, and allow the project to look at numbers over time with regards to a planned performance.

2.4.5 Short theory summary

The literature review has set forth tools for performance measurement in an industrial R&D project, using a customer focused cause and effect logic. This includes:

- R&D projects must set concrete, specific objectives.
- The project teams need to concretize the innovation activities needed to reach the objectives. The activities leading to goal attainment should be performed as effectively and efficiently as possible (reduce 'waste').
- The projects need to measure performance often to understand how well they are actually doing and to facilitate continuous learning.

Based on this, the R&D managers will be able to meet accountability requirements and present a logical argument for the project.

This thesis will in the following chapters attempt to understand how performance management and measurement is performed by the development projects in the the DEMO2000 portfolio, and evaluate whether the plan for objectives and measurements is a sheared vision with clear and shared expectations of success.

3 Methodology

This chapter will describe the research performed. Firstly, the thesis' research design is presented, which include an explanation of why this design was preferred in order to test the research questions thoroughly. The survey sample is then introduced, with information regarding how the sample was collected. At last, the research instrument (the questionnaire) is discussed, including where the questions were sourced from, and explanations to why the questions were regarded as important to fulfill the research aims.

3.1 Research design

The literature review stated that performance management is built on a combination of goals and KPIs. In order to better understand the practical use of performance management models in R&D, a quantitative survey was chosen as the research approach. The survey was aimed at performance objectives and measures at the project (team) level, since separating the function performance from department performance appears to be appropriate (Kerssens van Drongelen and Bilderbeek 1999). The survey was designed to understand goals and metrics at an overall level, by using predefined objectives and measurement perspectives. Even though the respective groups of goals and metrics contained relevant examples, the micro level targets and metrics were not part of the survey objective. However, the 32 micro KPIs which formed the basis for the survey example KPIs can be found in Appendix 3.

This thesis is addressing corporate innovation in the later phases of the R&D process where new technology is closer to commercialization. Therefor a R&D program meant for the industry with solely development projects were chosen as the survey sample.

3.1.1 The survey sample

The DEMO2000 R&D program of the Research Council of Norway was chosen as the sample for this thesis. The program presents it self as follows (Research Council of Norway 2019):

> *The aim of the DEMO2000 programme is to demonstrate and qualify innovative products and systems in close collaboration between the supplier industry, petroleum companies and research institutes. Demonstration and qualification activities are to be carried out under realistic conditions offshore or in suitable facilities on land.*

The DEMO2000 program provides funding for upstream oil and gas activities, and focuses on four thematic priority areas (Research Council of Norway 2019):

- Reducing greenhouse gas emissions, energy efficiency and the environment
- Exploration and increased recovery
- Drilling, completion and intervention
- Production, processing and transport

The program is targeted towards supplier companies and subcontractors that, together with petroleum companies or other end-users, have a need for pilot testing and demonstration of new technology. Thus, the projects must be in the experimental development or project development phase to qualify for funding from the program. The projects are typically large scale prototypes or system demonstration.

Technology readiness level (TRL) has in recent years become an often used method for estimating technology maturity during an innovation process (Mihaly 2017). This method examines program concepts, technology requirements, and demonstrated technology capabilities. TRL is normally based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology (Mihaly 2017). This thesis will use the Horizon 2020 definition of the TRL scale (European Commission 2014):

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant
- environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies)

The DEMO2000 projects will typically be at a at a level between TRL 5 and TRL 8. This places the DEMO2000 projects late in the R&D process, and close to commercialization. Figure 12 shows DEMO2000 in the context of figure 5 from the literature review.

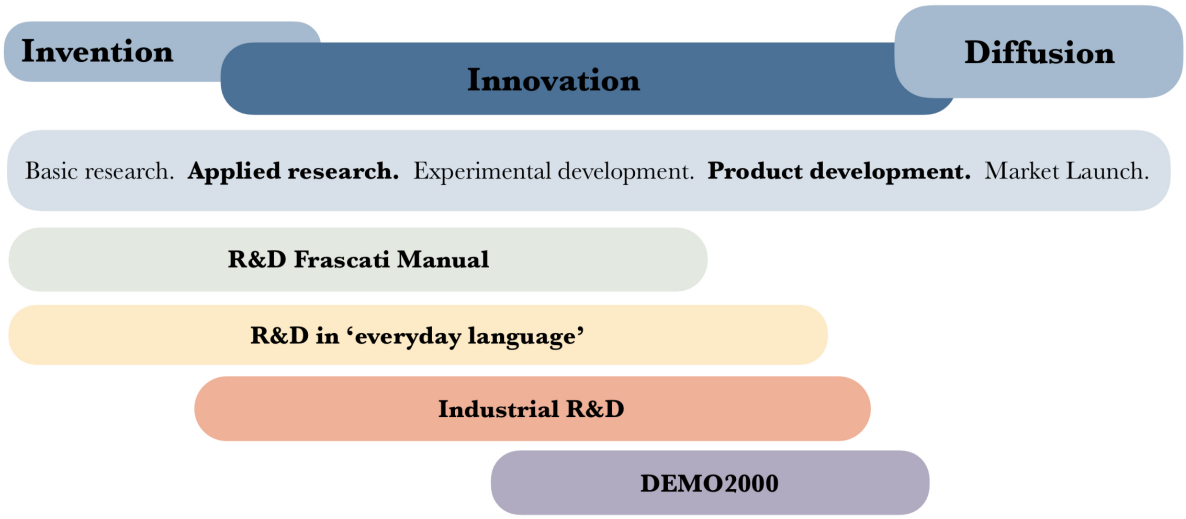


Figure 12: The DEMO2000 program in the context of R&D lifetime.

The author applied to the The Research Council of Norway for access to information on the currently active projects. The right to access was obtained, which provided a list of 63 actively supported projects as of December 2018. From the total of 63 projects, 57 unique project managers were found. The remaining six projects had the same project manager as another project on the

list. Thus, the sample approach was limited to the 57 project managers in active development projects in the DEMO2000 research program of the Research Council of Norway (as of December 2018). A complete list of projects can be found in Appendix 1.

3.2 Research Instrument

The questionnaire consisted of three sections:

- Part 1: Project specifications
- Part 2: Project goals
- Part 3: Performance measurement

Part 1 asked six basic questions about each project in order to categorize responses. The classifications were partly chosen based on experience from previous research on the subject, especially Chiesa et al (2009) and Samsonowa (2012). In addition input from supervisor and discussion with the DEMO2000 project contact person was used to decide the various distinctions. Table 10 shows the six questions listed with the associated multiple choices.

Table 10: The questions asked in part 1 of the questionnaire including the respective multiple choices.

Questions	Multiple choices
Which technology area group does your project belong to?	- Energy efficiency and environment - Exploration and increased recovery - Drilling, completion and intervention - Production, processing and transport - None of the above
What development stage is your project in at the moment?	- Small scale prototype - Large scale prototype (including system prototype) - System demonstration - First of a kind commercial system - None of the above
What is the total funding of your project? (In million NOK)	- 0-20 - 21-50 - More than 50 - I don't know
How many partners participate with funding to your project? (Including your own company and Forskningsrådet)	- 2 - 3-5 - 6 or more - I don't know
Does your project collaborate with academia?	- Yes - No - I don't know
How many employees are working in your entire company?	- 1-50 - 51-250 - More than 250 - I don't know

In Part 2, the project managers were first asked if specific goals had been set for their project. If this question was answered 'yes', a follow up question was raised. The respondents were then asked the to select project relevant goals from five predefined groups of goals. The goal groups used in the questionnaire had been classified, consolidated and condensed from individual facts into generic groups on a more abstract level, based on both the DEMO2000 project description and the relevant performance management literature.

The DEMO2000 project description sets forth objectives that should be reached within the R&D project lifetime. Listed below is the objectives from the project description, which were used to construct the goal groups in the questionnaire (the full DEMO2000 project description can be found in appendix 2):

- Level of innovation: Describe the major new elements that the planned innovation entails, and how this represents something new for the company/ companies and the users.
- Potential value creation: Describe in concrete terms the potential for value creation of the planned innovation for the participating company/companies
- Key milestones for project activities: Estimate the dates for milestones (M1, M2, etc.) that are seen as crucial to achieving the objectives of the project activities.
- Distribution of costs between each partner: Provide an overview of the distribution of project costs among each of the partners.
- Plan for realization of the innovation: Describe the plan for realization of the innovation, e.g. in the form of an outline for a business plan for new products. The plan must incorporate measures to be carried out in conjunction with the activities (e.g. for utilizing results underway) as well as plans for further realization after the activities are concluded.
- Risk factors: Explain any risk factors that may have a significant impact on the realization of the innovation, e.g. risk elements relating to industrialization, commercialization and implementation, market risks, financing risks, or organizational risks.

Table 11 shows the goal groups used in the survey, and how the respective groups relate to the project description of the DEMO2000 program.

Table 11: The five goal groups used in the questionnaire, with example goals and description for each goal group.

Goal group	Example goal(s)	DEMO2000 project description context	Relevance to Samsonowa's goals
Proof of technology	- Achieve qualification of the innovation - Prove reliability of the innovation	The planned innovation - Level of innovation	Alignment with and transfer to other (business) units (1) Create and protect intellectual property (2)
Value-adding potential	- Explore business opportunities for the innovation	The planned innovation - Potential for value creation	Generate and evaluate future business opportunities (4)
High standard of operational excellence	- Reach project milestones - Deliver within budget time og cost	Project activities: - Key milestones - Distribution of costs between each partner	Achieve a high standard of operational excellence (6)
Reduce actual and/or perceived risk for future customers	- Reduce customer risk - Cooperate with potential customers or end-users	Realization of the innovation and utilization of results - Risk factors	Establish and maintain strategic partnerships and/or collaborative research (7)
Final outcome	- Innovation succeeding in the market	Realization of the innovation and utilization of results - Plan for realisation of the innovation	Drive technology innovation and technology leadership (8)

This classification of goals were in the next step verified with regards to relevant research on the subject. Samsonowa (2012) performed a large study of goals used in industrial research departments of major European companies in the ICT (Information and Communications Technology) sector. The example goals used in the questionnaire (shown in table 11) was chosen mainly based on Samsonowa's (2012) findings, which was summarized in eight goal classes:

1. Alignment with and transfer to other (business) units
2. Create and protect intellectual property
3. Improve image (Not applicable for the project level)
4. Generate and evaluate future business opportunities
5. Recruit and develop excellent talent (Not applicable for the project level)
6. Achieve a high standard of operational excellence
7. Establish and maintain strategic partnerships and/or collaborative research
8. Drive technology innovation and technology leadership

Part 3 of the questionnaire dealt with performance measurement in general, and KPIs especially. Firstly, the respondents were asked if their project used performance measurement. If answered 'yes', the respondents were redirected to four follow up questions.

The project managers were first asked witch measurement class their KPIs belonged to, quantitative or qualitative. This was followed by a question on measurement technique, which asked wether the KPI assessment was done subjectively or objectively. These two questions, regarding metrics class and assessment type, are shown in table 12.

Table 12: The two questions in the questionnaire concerning KPI classes and assessment type, with corresponding choice alternatives.

Questions	Multiple choices
Your project´s KPIs are best described as:	- Quantitative - Qualitative - A combination of quantitative and qualitative - I don't know
The score on your project´s KPIs are mainly based on:	- Subjective assessment by supervisor(s) - Feedback from customer(s) - Objective score on quantitative criteria - None of the above

The question regarding measurement class was sourced from Samsonowa (2012), while the question about assessment technique was sourced from Kerssens van Drongelen (2000). These two questions reflects the complexity of measuring innovation, where quality often resists quantification.

The questionnaire then moved on to measurement perspectives. The respondents were asked to select how their project measures its performance. Four KPI groups was made available for selection, and more than one answer was allowed. Table 13 shows the available KPI groups, with the associated KPI examples.

Table 13: The four KPI groups (perspectives) used in the questionnaire, with the associated KPI examples.

KPI group (perspective)	Example KPI(s)
Financial	- Internal rate of return (IRR) - Return on investment (ROI)
Customer	- Number of interactions with customers during the project - % of budget dedicated to customer analysis or verification
Innovation and learning	- Number of publications - Number of patents
Business process	- Milestones met - Quality of documentation or output

The KPI groups were based on the four perspectives of the balanced scorecard (Kaplan and Norton 1992) which have proved useful in R&D project performance measurement by a survey performed by Kerssens van Drongelen and Bilderbeek (2000). The relevance of the KPI groups and examples was verified against the industrial R&D KPIs found by Samsonowa (2012). A complete list of the 37 specific KPIs which has been evaluated in this thesis can be found in appendix 3.

As found in the literature review, performance management should be a continuous process, following cycles from setting goals, via measurement (PI) and analysis (KPI), to result review and improvement (Atkinson 2012, Samsonowa 2012 and Ries 2017). The last phase forms a basis for revising the project's goals, and thus complete the cycle. This implies that the time spent on each cycle is of importance for the effectiveness of the R&D project's performance management system. Thus, after choosing their relevant KPI groups, the respondents were asked to specify how often their KPIs is assessed. The timing question with its multiple choices is shown in table 14.

Table 14: The question regarding assessment intervals, with the associated choices.

Question	Multiple choice
How often are your project´s KPI results assessed?	- More than once a month - Monthly - Quarterly or six monthly - Yearly - At the end of the project - Never

The question about assessment intervals was deliberately placed towards the end of the questionnaire, to empower respondents to impartially answer the questions about 'how' they measure their projects first. With regards to timing, both Kerssens van Drongelen and Bilderbeek (1999), Parmenter (2007), Viki et al (2017) and Ries (2018) have stressed the importance of shorter measurement cycles.

To conclude the survey, the project managers were asked to give their personal opinion on performance measurement, with the following multiple choices:

- Performance measurement in industrial R&D projects is an obvious need.
- Performance measurement in industrial R&D projects is necessary, but the measured results should not influence management decisions too heavily.
- Performance measurement in industrial R&D projects is not necessary.
- None of the above.

The topic of performance measurement in R&D has been controversial, and has been heavily discussed in the literature (McLaughlin and Jordan 1999, Kerssens van Drongelen et al 2000, Chiesa et al 2009 and Samsonowa 2012). Even though the more recent research have found broad acceptance for performance measurement among R&D managers, this thesis included the question as a verification of the findings made by Samsonowa (2012)

A copy of the full questionnaire, as presented on the Google Forms web page, can be found in appendix 4.

4 Results

The questionnaire was answered anonymously, and received 33 responses out of the 57 project managers, which gave a relatively high response percentage of 57.9%. In this chapter the data from the survey will be presented. The data findings are presented in the same chronological order as they were yielded:

- Part 1: Project specifications
- Part 2: Project goals
- Part 3: Performance measurement

At the end, the quality of the data is discussed, with regards to the specific application for data analyze in the subsequent chapter. A complete list of responses can be found in appendix 5.

4.1 Project specifications

In Part 1 of the questionnaire the project managers were asked some basic questions about their project in order to categorize responses. Table 15 summarizes the specifications of the 33 projects who responded to the survey.

Table 15: Project specifications (background) of the 33 respondents to the questionnaire.

Technology area	Development stage*	Total funding	Funding partners**	Employees in company	Collaboration w/ academia
Drilling, completion and intervention **27,3%**	System demonstration **48,5%**	0-20 mill NOK **42,4%**	2, 3 or 4 **57,6%**	More than 250 **48,5%**	No **69,7%**
Production, processing and transport **27,3%**	Large scale prototype **21,2%**	21-50 mill NOK **39,4%**	Single **21,2%**	1-50 **45,5%**	Yes **27,3%**
Energy efficiency and environment **24,2%**	First of a kind commercial system **15,2%**	More than 50 mill NOK **18,2%**	More than 4 **21,2%**	51-250 **6,1%**	Don't know **3,0%**
Exploration and increased recovery **12,1%**	Small scale prototype **9,1%**				
Others **9,1%**	Others **6,0%**				

* Small scale prototype = TRL 4, Large scale prototype = TRL 5, System demonstration = TRL 6-7, First of a kind commercial system = TRL 8

** The Research Council of Norway not included

4.2 Project goals

All of the 33 respondents reported that their project had set specific goals. Each project manager was allowed to select from zero, if none of the groups were applicable for the specific project goals, to all of the groups, if all five were matched by the projects specific goals. No project manager selected none of the predefined groups. Neither did any of the projects use the possibility to add project specific goals who did not meet any of the predefined categories. Four of the projects reported to have goals related to all of the five predefined groups.

While the respondents were allowed to select multiple goal groups, the questionnaire did not give the project managers the possibility to indicate the importance of each goal for their overall achievement.

Goals related to 'proof of technology' was definitely most common, being present in 87.9% of the projects. 60.6% of the projects had goals related to 'customer risk reduction', which made this group the second most selected. Then followed the groups 'value-adding potential' with 48.5% presence and 'final outcome' with 45.5%. The least used group of goals was 'operational excellence' which were present in only 36.4% of the projects. Figure 13 shows the number of selections of each goal group.

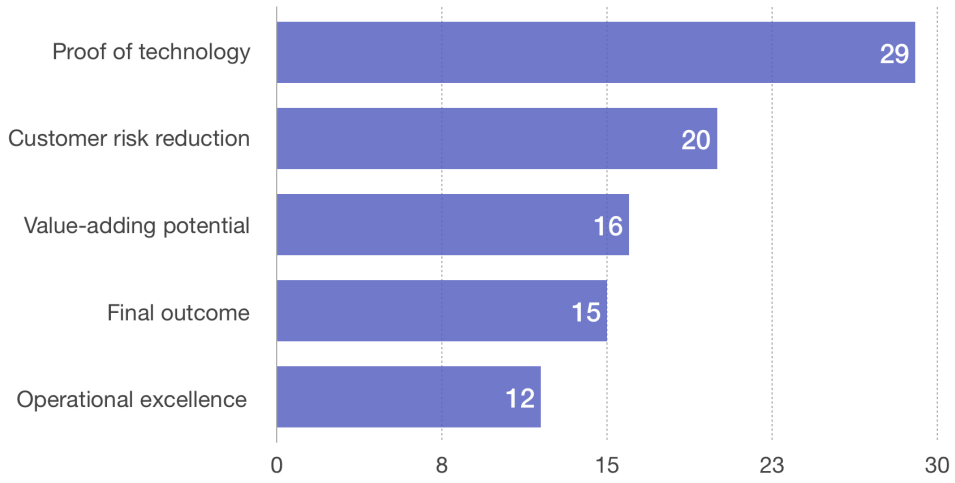


Figure 13: The groups of goals by the number of times selected.

The amount of funding seems to be decisive for the diversity of goals selected by the projects. The projects with relatively low total funds (0-20 million NOK) in average selected 2.4 goal groups from the five available options. This number increased to 3.2 for the projects with a total funding of 21-50 million NOK. While for the most heavily funded projects (more than 50 million NOK) the number increase even further, to an average of 3.5 goals selected. This tendency is shown in figure 14.

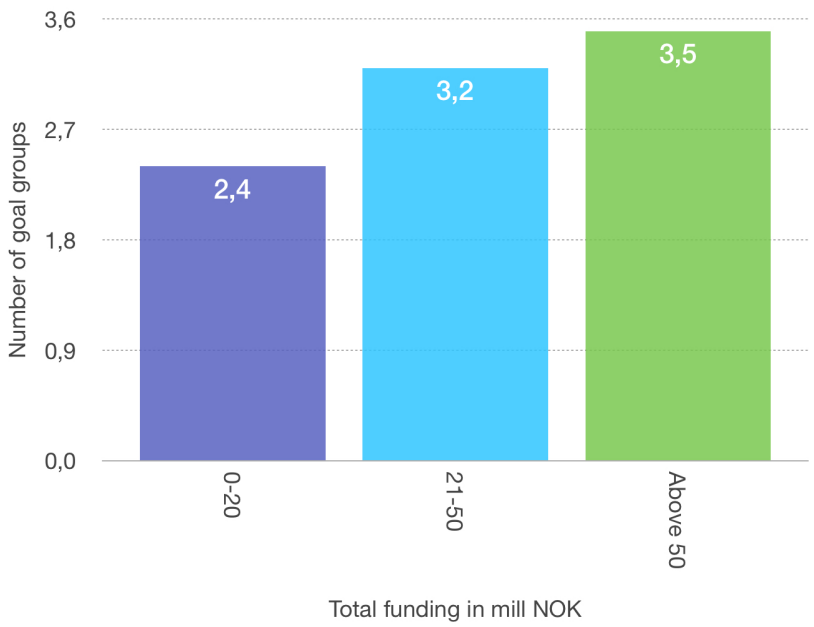


Figure 14: Number of goal and KPI groups selected in order of total project funding.

It was also found that projects with relations to academia in average selected more groups of goals (3.1) than the ones without academic collaborations (2.8). However, the difference is barely statistical significant.

4.3 Performance measurement

From the sample of 33 respondents, 27 project managers (81.8%) were measuring performance in their projects.

Within the 27 projects with performance measures were all of the nine projects with an academic collaboration. Also all of the nine projects within the 'drilling, completion and intervention' area measures performance, while the other three

technology areas are all represented in the group of 'non-measurers'. The projects with most funding partners (more than six including The Research Council and the project responsible company) are all measuring performance. No correlation was found for the current development stage or the total funding of the project, nor the size of the project responsible company in terms of number of employees seem to influence wether the project is measuring performance.

Regarding measurement class, more than half (15 out of 27) of the projects who measure performance use a combination of quantitative and qualitative metrics. From the remaining 12 projects, seven use mainly qualitative metrics and five use mainly quantitative metrics. The most used measurement technique is 'feedback from customer(s)' which were selected by 10 out of the 27 project managers. 'Objective score on quantitative criteria' was selected by eight of the projects, and 'subjective assessment by supervisor(s)' was used by seven. Figure 15 shows the distribution of respectively measurement class and measurement technique among the 27 projects with performance measures.

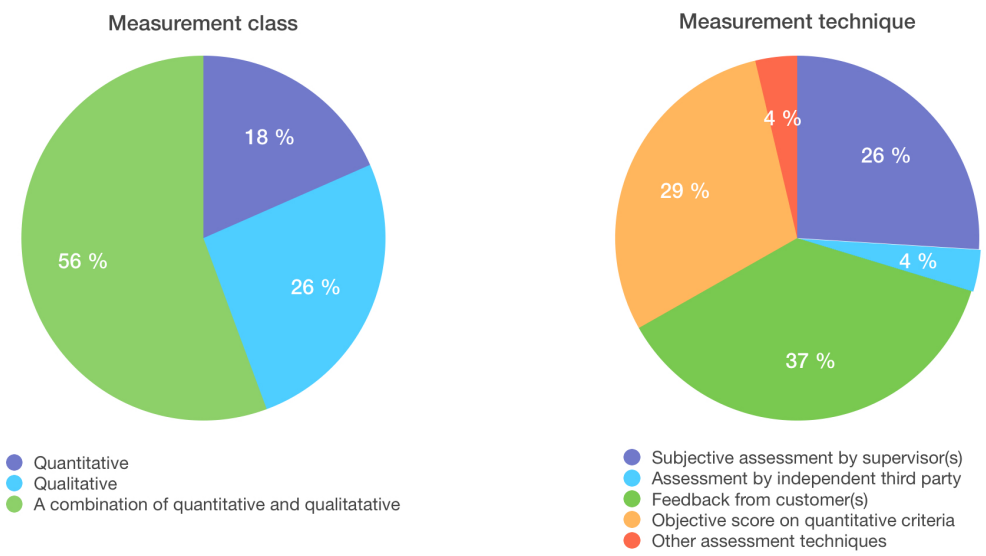


Figure 15: Measurement class and technique distribution among the projects.

From the 27 'performance measurers' an interesting pattern emerged when analyzing measurement class vs. assessment technique. The projects using quantitative metrics are assessed 60/40% by 'objective score on quantitative metrics' and 'feedback from customer'. While, for the projects that uses

qualitative metrics, 71.4% are scoring their metrics by 'subjective assessment by supervisor', in addition both 'independent third party' and 'feedback from customer' got respectively 14,3% each.

However, looking at the 15 projects who report to use a combination of quantitative and qualitative metrics, 46.7% is scoring their KPIs based on 'feedback from customer' and 33.3% use 'objective score on quantitative metrics'. Only 16.7% uses mainly 'subjective assessment by supervisor' to score their combinational metrics. Thus, it seems like the projects who uses a combination of metrics, score their KPIs by the same pattern as the projects using quantitative metrics. Figure 16 shows this pattern in a diagram.

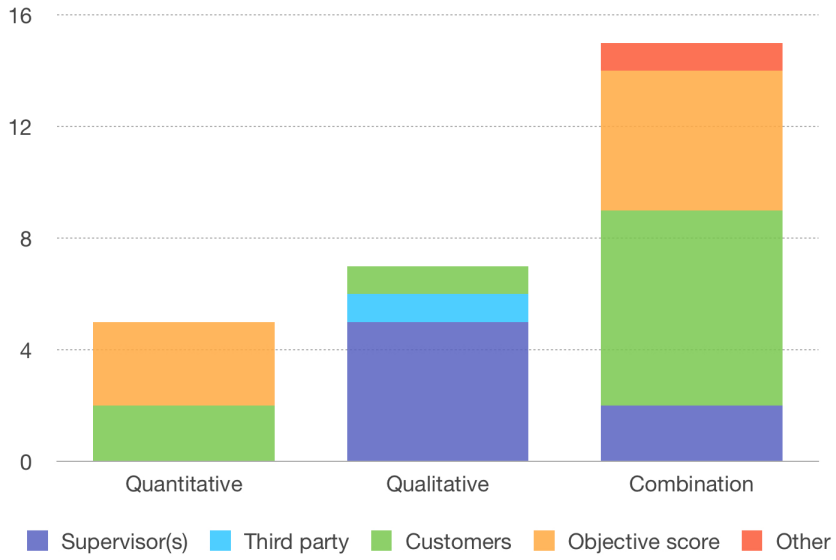


Figure 16: Context for projects using different type of metrics (quantitative, qualitative, or a combination of the two) and methods for scoring their KPIs (Subjective assessment by supervisor(s), Independent third party assessment, Feedback from customers, Objective score on quantitative criteria, or other assessments).

Moving on to the measurement perspectives, it was found that KPIs related to the 'business process' were clearly the most selected. 15 project managers reported to use KPIs in this group. In addition, three answers were given under the question "If your project has KPIs that do not fit into any of the groups above, please feel free to specify your KPI(s)", which after a semantic evaluation by the thesis author all were placed in the 'business process' category. Thus, the total count for the 'business process'-perspective was 18, as selected by 66.7% of

the projects. The three goals added by project managers, and included in the 'business process' group by the author, were:

- "Technical performance of pilot test"
- "Measurement/evaluation of Product/system/solution performance"
- "Technical progress, financial control, on time delivery"

The other predefined KPI groups was used as follows: 'customer'-perspective selected by 37%, 'financial'-perspective by 25.9%, and 'innovation and learning'-perspective by 18.5%. The respective counts are shown in figure 17.

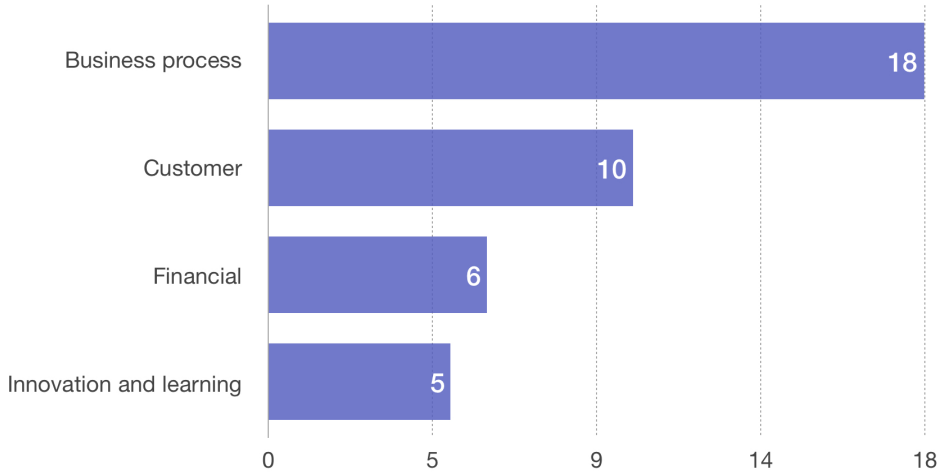


Figure 17: Number of selections for each KPI group.

As for the goal groups, the project managers were allowed to select from none (no match between predefined KPI groups and project KPIs) to all four KPI perspectives (all KPI groups matched by project KPIs). 19 projects selected only one group, five selected two groups, two selected three groups, and only one projects selected all four KPI perspectives.

The projects with the lowest funding (0-20 mill NOK) stands out by generally selecting fewer KPI groups, only 0.9 KPI groups per project, compared to the projects with higher total funding (more than 20 mill NOK), which on average selected 1,4 KPI groups per project. This is coherent with the findings related to goal groups, that higher funding seems to generate more goals and KPIs. However, the six largest projects (more than 50 mill NOK total funding) on average selected just one KPI group per project (figure 18).

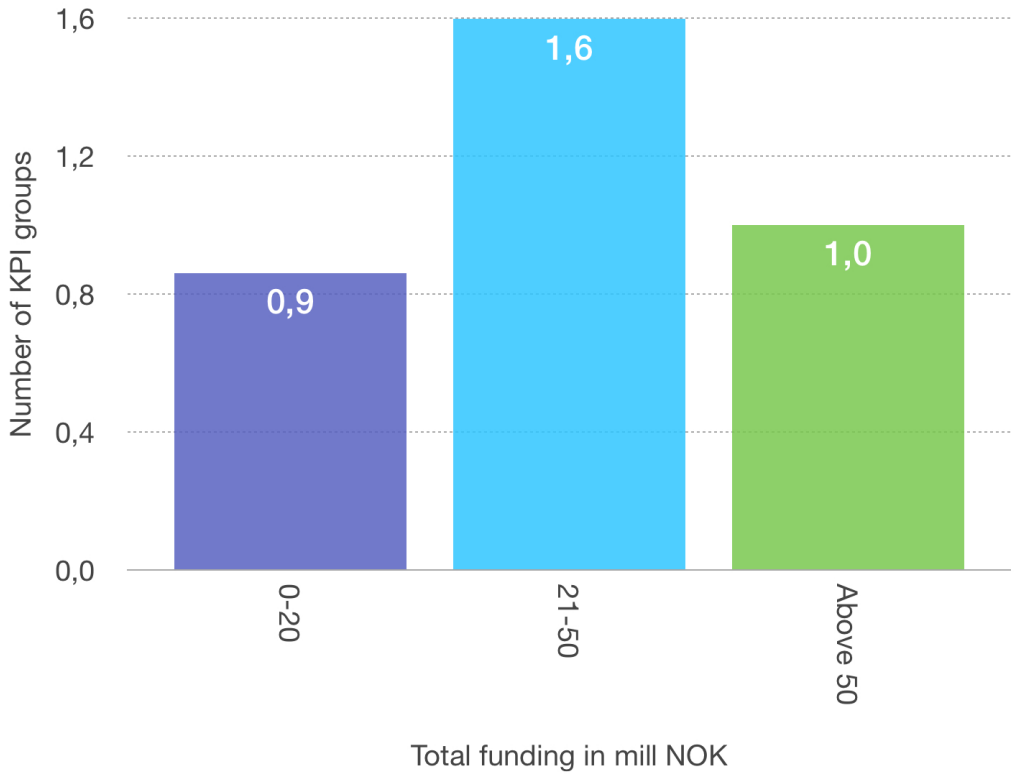


Figure 18: Number of goal and KPI groups selected in order of total project funding.

As previously discussed, the projects with collaborations with academia tended to have more diverse goals than the sample average. The same pattern was seen in the number of selected KPI groups, however, the difference was this time statistical significant, since the projects with a collaboration with academia on average selected 1.7 KPI groups, while their counterparts selected only 0.9 KPIs

The 27 project managers who measured performance, were finally asked how often they assess their KPIs. The most common assessment interval was every three to six month, which was selected by 11 of the respondents, followed by monthly assessments, selected by 7, assessment only at project end date, selected by 5, and yearly assessments, selected by 3. Only one project out of the 27 assessed their KPIs more than once a month. Figure 19 shows the distribution of measurement timing between projects.

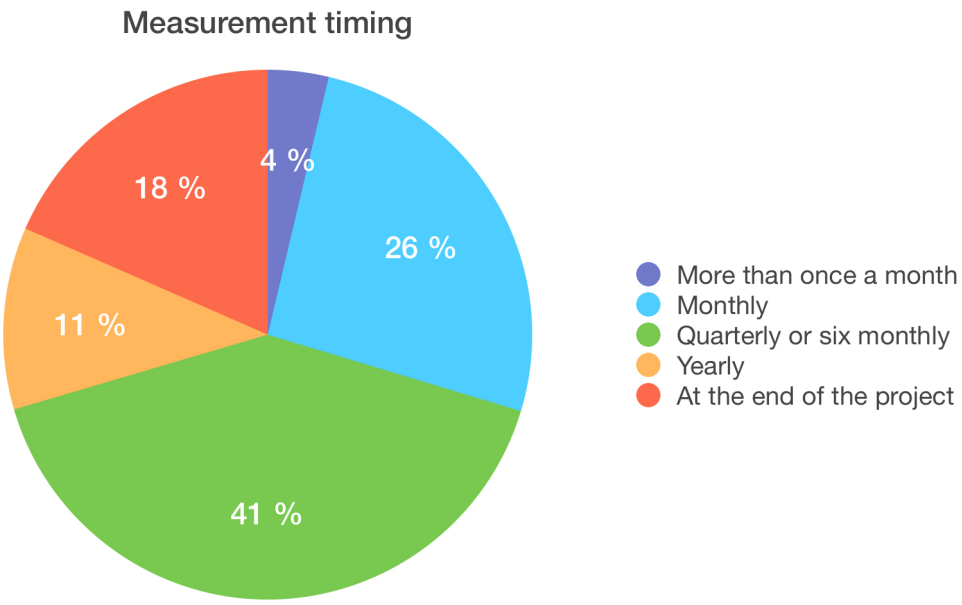


Figure 19: Distribution of time interval between each KPI assessment.

The projects who scores their KPIs often (once a month or more) are differentiating from the sample average in some key areas:

- 75% use a combination of quantitative and qualitative metrics, significantly higher than the sample average at 55.6%.
- 62.5% mainly assess their KPIs by objective score on qualitative criteria, which is more than the double of the sample average at 29.6%.
- 62.5% collaborate with academia, which is significantly more than the sample average at 30.3%.
- There is only one small project (12,5%) with funding below 20 mill NOK, while the total sample consist of 42,4% small projects.

To conclude the questionnaire, all the 33 project managers were asked for their personal opinion on the use of performance measurement in industrial R&D. The following alternatives were given:

1. Performance measurement in industrial R&D projects is an obvious need.
2. Performance measurement in industrial R&D projects is necessary, but the measured results should not influence management decisions too heavily.
3. Performance measurement in industrial R&D projects is not necessary.
4. None of the above.

More than half of the respondents, 18 out of 33, were unequivocal to the need for performance measurement in R&D, by choosing alternative 1. One third (11) of the respondents uttered some degree of skepticism to performance measurement, by selecting alternative 2. Four of the project managers did not agree with any of the statements, and chose alternative 4. None of the respondents expressed explicitly that performance measurement is unnecessary in R&D (alternative 3). Figure 20 shows the distribution of responses with regards to project managers personal opinion on performance measurement.

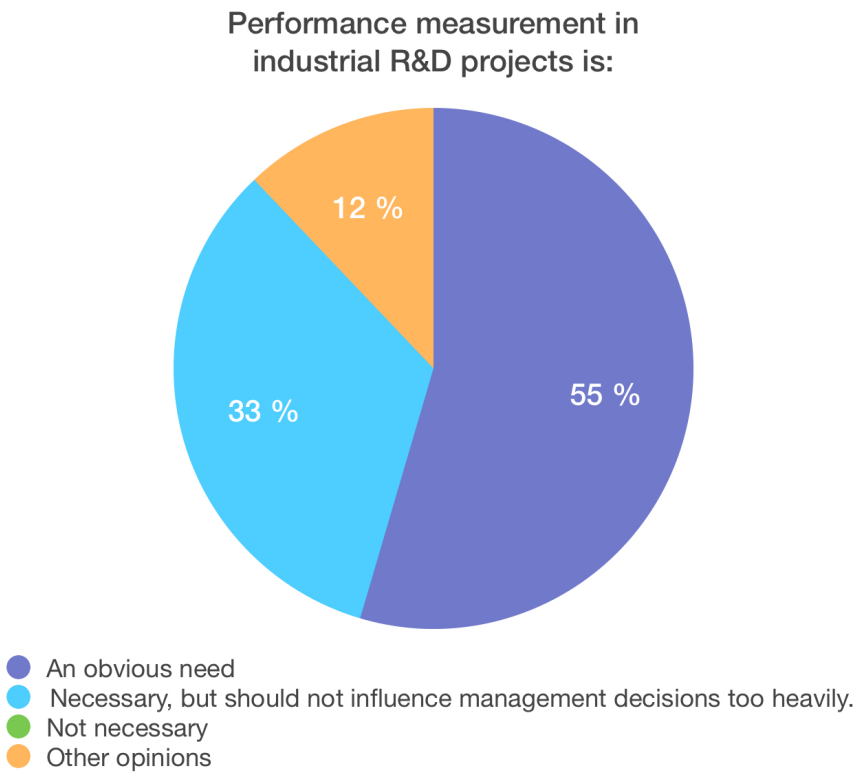


Figure 20: Distribution of project managers personal opinion on performance measurement in industrial R&D

4.4 Data quality and limitations

The data obtained by the survey is raw, due to some deliberate characteristics of both the sample and the questionnaire:

- The sample was small and specific, consisting of solely new product development projects, excluding other R&D phases, such as basic and applied research.
- The questionnaire was short and simple in its form. None of the questions used 'rating scales', which could have given the answers more nuances, but would also have made the questionnaire more complex. Neither were similar near repeat questions (Likert items) used to verify internal consistency of the answers.
- The purpose of the survey was performance measurement at the project (team) level, and neither the questionnaire, nor the thesis, make any attempt to evaluate context between the R&D projects and their respective company strategies or department objectives.
- The alternatives in the questions related to 'goal groups' and 'KPI groups' were deliberately chosen as non-conforms to avoid direct context between the groups. This was important to ensure the respondents were answering both questions impartially, without trying to match their answers between goals and KPIs. However, it may have been perceived as confusing, since one of the respondents gave the following feedback: "I am not sure if the reply alternatives had the right content, but I don't know the plans for the research."
- The survey provides a 'snapshot' of how the DEMO2000 projects measure performance. Thus, the results are specific for the currently active projects, and may not be applicable for more overarching evaluations. This is supported by a comment made by one of the project managers, who specified that: "Different projects require different measures".
- The survey was answered anonymously, thus the data can not be used for correlations against the currently most prosperous projects, nor for later evaluations against which projects does eventually succeed.

These quality limitations in the data means that the data set is not easily transferable to other research. However, the raw data were well suited for the specific application in this thesis. The high respond percentage was important since the total sample size, of only 57 project managers, were relatively small.

The 33 responses provided the necessary high respond rate of 57,9%, sufficient for being statistical viable to this thesis.

The multiple choices given seems to be appropriate and fit for the sample. A spread in answers was obtained, while the data still provided clear patterns with statistically significant results.

5 Discussion

In this chapter the data will be discussed in relation to emergent themes and how the data answered the research questions.

5.1 Performance objectives

> **SRQ1**: *Which measurement objectives are currently pursued by the DEMO2000 projects?*

The first sub-research question aimed to examine pre-set project goals within the performance measurement system. All of the 33 respondents reported to have set concrete, project specific goals.

The clearly most used goal group was 'proof of technology', which were selected by 29 managers (87,9%). This was not unexpected, given the fact that DEMO2000 is a program for demonstration of new technology. The research phase is over at this stage, therefore actually building and proving the technology is of high importance. While research is not a scope for the DEMO2000 projects, there are still uncertainty linked to both output and outcome.

The demonstration phase is normally associated with significantly larger capital investments and risks than the previous research phases, while also representing the transition into the commercial phase for the technology. Therefore, a business case with a solid foundation and strong partnership becomes even more important (Rystad Energy 2016). This is supported by a comment from one of the project managers: "[DEMO2000] projects normally has a description of a final delivery, which is more or less measurable. [...] It is hard to anticipate if the road you choose will lead to the target, or just be a 'dead end' ".

A sole focus on materializing the technology may, however, lead the project team into the 'product trap' (Ries 2017). This is typically a result of a situation were the funders are depending on the project to reach a project milestone related to finalization of the product. In product development projects, as for other business units, the project team get appraised if a product is launched on schedule. However, as described by Christensen et al (2016), the excitement may

wane, if it is realized that the customer does not care for the product that has been built. The output can be strong, but the outcome may still be a failure.

A combination of goals related to both 'proof of technology' and 'high standard of operational excellence' can be described as 'build-mode' goals for a product development project. In the survey, 12 out of the 33 respondents (36,3%) reported to have this combination. However, only two projects selected these two groups as their sole goals.

The problem with focusing too heavily on 'build-mode' may be that the team will lack information on how the customers will respond to the product. Building a product may than become the easy part of the product development process, while building a product that customers actually want to use is considerably more difficult. This is supported by the study by OG21 (2018) which confirmed that the reason for the slow technology adaption on the NCS is not related to a lack of available new technology, but rather "that the enterprises invest considerable effort in reducing technology risks, whereas value adding opportunities related to the application of new technologies receive less attention".

From the five predefined goal groups, the opposite to 'build-mode' goals, would be the 'customer-centered' goals related to 'customer risk reduction' and 'value-adding potential'. This combination of goals can provide a foundation for a deep understanding of customer needs. However, only 11 of the respondents (33,3%) reported to have this combination of goals.

While both 'build-mode' and 'customer-centered' goals are useful to guide projects in their day to day progress, they should all point in direction of a overarching objective, namely a 'final outcome' goal. This fifth predefined goal group in the questionnaire points directly towards the innovations success in the marketplace. Given that the DEMO2000 projects are all in the later stages of the R&D chain, one would anticipate that the imminent commercialization phase would be on the project managers agenda. However, less than half of the projects (45,5%) reports to have goals related to the 'final outcome' of their innovation.

One possible explanation may be the inherent traits of the innovation process in the oil and gas industry, where it often takes many years from the technology has been proven (output) until the product is actually commercialized (outcome). The Menon-report (2017) on the DEMO2000 program found that 86% of the R&D projects who had received support through the program between 2011 and 2016 were still not commercialized, however, 76% of the projects expected to become commercial within the next five years. Thus, given the long time from project start to commercialization, concrete and specific goals related to 'final outcome' may be difficult to evaluate with regards to goal attainment.

To conclude on the sub-research question number 1, the projects in DEMO2000 seems to actively be setting project specific goals. The relatively high average number of goal groups selected per project (57%) provides a diversified portfolio of goals, which is suitable for ensuring both project excellence and creative freedom. However, given the fact that creativity is an indispensable feature in the search for innovation (Samsonowa 2012), and creativity is a 'team sport', it would have been preferable with an even higher number of goals who support customer interactions and collaborations.

5.2 Performance measurement approaches

> **SRQ2**: *Which approaches to R&D performance measurement are currently used by the DEMO2000 projects?*

One of the main areas that the thesis wanted to examine was how the R&D projects measure performance with regards to measurement class (quantitative or qualitative) and perspective (financial, customer, innovation and learning, or business process), and assessment technique (objective or subjective assessment) and time interval.

Samsonowa (2012) found it was easier to analyze goals than the indicators that assess the goal achievement, because it is common practice to prioritize goals, compared to performance measures. That is supported by this thesis, which found that while all project had set goals, six of the projects did not measure performance. On average the sample selected more than half (57%) of the five goal groups as relevant. However, the projects who measured performance only selected just over a third (36%) of the possible four KPI groups as relevant.

To answer the research question related to performance measurement, the thesis will use the characteristics shown in table 16 to distinguish between hardly and highly effective measurement procedures in R&D projects in the development stage, which is based on the literature review with emphasis on Kerssens van Drongelen and Bilderbeek (1999), Chiesa et al (2009) and Samsonowa (2012).

Table 16: Summary of the literature review on differences between 'highly effective' and 'hardly effective' performance measurement.

	Highly effective measurement	Hardly effective measurement
Measurement class and technique	Combination of qualitative and quantitative Objective measurement with customers involvement	Subjective measurement by higher level managers
Measurement perspective	A balanced set of metrics, with emphasis on metrics reflecting customer demands	Emphasis on financial and business process metrics
Assessment time interval	Measurement on monthly basis	Measurement on a half-yearly or more seldom basis

5.2.1 Measurement class and technique

The survey found that the development projects in DEMO2000 seem to prefer quantitative and objective metrics. This support the findings of Chiesa and Frattini (2007) who discovered a tendency for the use of qualitative subjective measures in research and quantitative objective metrics in development. A possible explanation is that this reflects the specific degree of uncertainty and complexity that characterizes the activities of respectively research and development.

Kerssens van Drongelen and Bilderbeek (1999) found that to frequently ask customers to evaluate R&D activities during the project process, and measure their satisfaction in general, seemed to produce better performance than occasional assessments by R&D managers. 'Feedback from customer(s)' is the most common method of KPI assessment for the DEMO2000 projects (37%), which is regarded as beneficial according to the literature. However, a weakness of the survey is that it does not go into detail on how the customer feedback is obtained. The R&D projects should run experiments that measure customer behavior to demonstrate the value of a product, instead of merely asking for "feedback" about a solution idea (Ries 2017).

How the request for feedback is presented, will profoundly determine the likelihood of its relevance (Thiel 2014). Henry Ford explained this: "If I had asked people what they wanted, they would have said faster horses" (Seba 2014). Thus the challenging part of 'customer focused' product development is to find out what customers want without directly asking (Thiel 2014). The importance of such a understanding were neither explored in the survey, nor by the thesis in general.

A significant share of the projects, 26%, still uses 'subjective assessment by supervisor(s)', which according to the literature is not favorable for development projects. A possible explanation may be, as found by Samsonowa (2012), that many companies does not separate the functions of research and development, and thus will respectively research projects and development projects be assessed by the same measurement technique.

5.2.2 Measurement perspective

The survey found that only five projects (18,5%) uses 'innovation and learning' KPIs. This is consistent with the study done by Chiesa et al (2009) who found this perspective less suitable for development projects. However, the perspective can be important in other R&D contexts for example basic and applied research projects. Kerssens van Drongelen and Bilderbeek (1999) also found an almost total absence of measures from the innovation and learning perspective in team performance measurement, since teams are only held accountable for the proper execution of a single project, and not for long-term issues such as the generation of ideas for future business.

Only six projects (22,2%) selected the 'financial-perspective', which is in line with the literature in general, where financial KPIs are regarded as unhelpful to R&D, especially at the project level (Christensen et al 2008).

It was no surprise that the 'business process-perspective' is the most used KPIs, with 18 selections (66,7%), since this perspective is the most generally applicable for all types of R&D (Chiesa et al 2009). Business process KPIs are probably the the easiest to measure, since they are typically readily quantifiable and often related to objective criteria. Thus, if the company has standardized its performance measures for R&D, it would most likely be heavily business process oriented.

The literature has in general found that a focus on control, which is typically the result measuring only business process, is a less effective system. However, according to Chiesa et al (2009) business process KPIs are important to reach both the 'diagnostic' and 'motivational' objectives, even though motivational objectives were less important for development projects than research projects.

The customer perspective is by the literature regarded as high on the list of success factors in new product development processes (Kerssens van Drongelen and Bilderbeek 1999). However, only ten of the DEMO2000 projects (37%) uses these KPIs. However, the objectives of the most effective systems are broader than being either business process oriented or customer oriented. The 'highly effective' measurement system should be aimed at a balanced set of metrics, to

enable both improvement and strategic adaptation (Kerssens van Drongelen and Bilderbeek 1999).

The DEMO2000 projects have, to some degree, obtained a diverse range of performance measures. However, the use of metrics are less diverse and 'balanced' than what was the case for goals. It also becomes clear, that the customer focus is even less present in the metrics than it was in objectives.

5.2.3 Measurement time interval

The actual usage of the measurement system output seems to be decisive for the effectiveness of performance measurement. Performance can only be improved if the information gathered is actually used as input to improve and adapt. While older studies, such as Kerssens van Drongelen and Bilderbeek (1999) claimed that three-monthly assessment could be sufficient for the R&D measurement to be effective, more recent studies, such as Samsonowa (2012), suggest that KPI assessment must be performed at least once a month. This is supported by the innovation accounting performance measurement system, which highlights the need to constantly measure the innovation project's progress (Ries 2017).

The DEMO2000 projects seems to be widely spread with regards to assessment intervals, from more than once a month to solely at project ending. Kerssens van Drongelen and Bilderbeek (1999) found that team performance measurement is often considered to be the same as project progress measurement, and thus often takes place at milestones or project progress meetings with no fixed frequency. This seems to be of relevance for the DEMO2000 projects since 41% of the projects reported to measure performance on three- or six monthly basis. As shown in table 16, assessments every month (or more) seems to be most effective, and 30% of the projects reported to be in this category. Measurements once a year (or less) hardly gives any effect, while this is still the case for 29% of the respondents.

An interesting observation is that none of the projects with qualitative metrics are assessed often (monthly or more), compared to the 30% of the sample

average, which may reflect that it is more time consuming to score quality compared to quantity, thus managers will often choose to do the evaluation more seldom. The ability to measure and assess KPIs more often, will be in favor of using quantitative metrics instead of qualitative metrics.

5.2.4 The project managers personal opinion

None of the 33 project managers were of the perception that performance measurement was not needed in R&D, which is encouraging, since the need has been heavily discussed in literature for more than 40 years (Samsonowa 2012). However, there is still a significant part (45%) with some form of reservation towards performance measurement. One of the respondents gave the following explanation:

> *"[My experience] has shown me that for performance measurement systems the cost to benefit ratio is often more than one. That does not mean projects should not be planned, nor followed up, however, the detailed measurement will often cost more than it benefits the project."*

This observation is relevant for the broader performance measurement specter, and not solely for R&D applications. However, in the future, the question will probably not be 'if' R&D should measure performance, but rather 'how' R&D most effectively can measure its performance. With this in mind, the 'keep it simple' kind of metrics will be preferable. This will probably direct a shift towards more quantifiable metrics also for R&D applications, as has become the norm for most other business units. Hopefully, the new smart collaboration solutions, such as Slack, Facebook Workplace and Microsoft Teams, can in the future enable more simplified ways to measure customer interactions, and thus reduce the transaction cost for performance measurement.

5.3 Performance management effectiveness

> **SRQ3**: *How effective is the current performance measurement systems in the DEMO2000 projects on the basis of relevant performance measurement literature?*

Table 16 provided the characteristics of 'highly effective' and 'hardly effective' performance measurement systems based on the literature. To evaluate the effectiveness of the performance management systems currently in use by the DEMO2000 projects, the given characteristics was quantified, by awarding points to the possible answers in the questionnaire. Points were also awarded for the projects use of goals. The discussion in chapter 5.2 formed the basis for the point value of each goal, giving the highest score to 'value-adding potential' and 'customer risk reduction'. The maximum achievable score was 24 points. The complete 'point scoring system' and the associated ranking of all the projects can be found in appendix 6.

The 'performance management' ranking found that none of the survey respondents met all the favourable criteria. Figure 21 shows the distribution of samples on a scale from 'hardly effective' to 'highly effective' performance measurement systems.

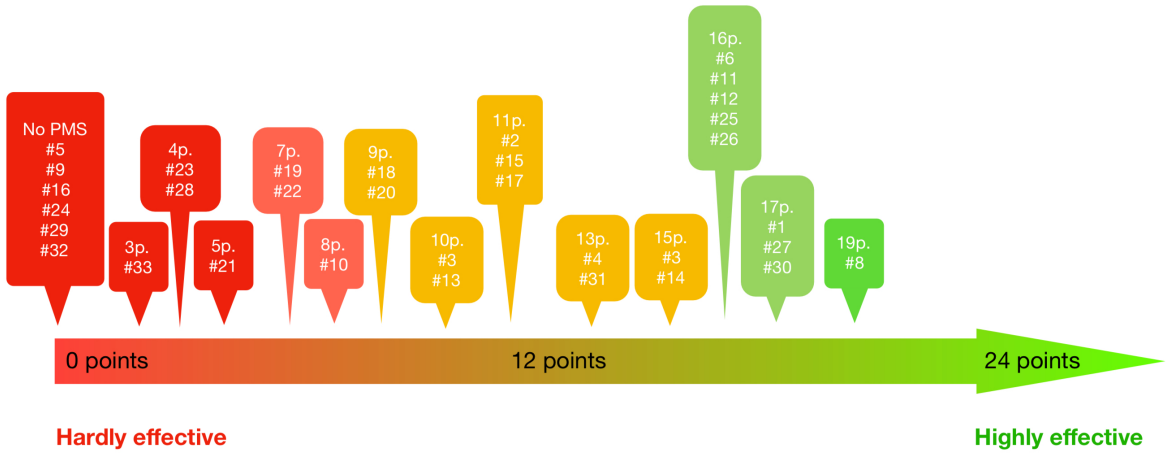


Figure 21: The performance management system (PMS) effectiveness score for the 33 sample projects.

One of the projects came close to using a 'highly effective' performance management system. Sample no. 8 got a total score of 19 points for its use of

goals and measures. This project uses a combination of quantitative and qualitative metrics, which is assessed objectively, with a customer-perspective once a month. The project has goals related to both reducing customer risk and adding potential value, in addition to providing proof of technology. The main criteria where sample no. 8 falls short is by not using 'a balanced set of metrics', since only customer KPIs were selected.

An interesting correlation regarding 'project control' versus 'customer focus' in relation to academic participation, was found in the dataset. The business operation focused projects, which selected both the 'high standard of operational excellence' goals and the 'business process-perspective' KPIs, had 42.9% participation from academia. This is significantly more than the sample average of 27.3%. While, the customer focused projects, which selected both the 'customer risk reduction' goal group and the 'customer-perspective' KPI group, had solely 14.2% academic participation. Based on this observation alone, the projects who collaborate with academia, seems to have a reduced customer focus. Academic institutions are, by definition, professional hypothesis testers. However, these institutions will to a limited degree deal with customers, and especially technology end-users, on day to day basis. Therefore, academic participation in corporate innovation projects may actually effect the customer focus in negative direction. That being said, when looking at the 'top three' on the performance measurement ranking, two of the projects reported to be collaborating with academia, and the last project manager was not sure if academia participated in hers or his project.

More than half of the projects (14 out of 27 projects with a performance measurement system) scored less than half of the possible points (maximum 24 points). Thus, as a concluding remark to sub-research question number three, it seems like the industrial R&D in oil and gas today is in lack of a clear framework for measuring innovation. This is supported by one of the DEMO2000 project managers, who made the following comment in the survey: "A research project in the industry should measure performance, but it is extremely difficult to do. Metrics are not well defined in this area."

5.4 Innovation accounting in industrial R&D

> **SRQ4**: *How relevant are the emerging performance measurement system 'innovation accounting' of 'lean innovation', for deployment in industrial R&D in the Norwegian oil and gas industry?*

Using Samsonowa's (2012) framework for R&D performance measurement, the applicability of innovation accounting in industrial R&D will be assessed from a perspective based to the dimensions marked with a red ring in table 17.

Table 17: The basic dimensions of R&D performance measurement. Innovation accounting is assessed towards the marked dimensions.

Perspective	Purpose	Level	R&D type	Process phase
FOR WHOM?	WHY?	WHERE?	WHAT?	WHEN?
Customer	Strategic control	Industry	Basic research	Input
Internal	Justification of existence	Network	Exploratory research	Activity
Financial stakeholders	Benchmarking	Company	Applied research	Output
Other stakeholders	Resource allocation	Department	Product development	Outcome
Learning	Development of activities	Process	Product improvements (incremental)	
Others	Motivation, rewarding	Project, team		
		Individual		

Innovation accounting metrics are characterized by being actionable, accessible, and auditable. Thus, the metrics must show clear cause and effect, being easily understood by using tangible, concrete units, and creditable to everyone the team. In more traditional performance measurement terms, the metrics should be quantitative (concrete) and objective (creditable), assessed often with the objective of learning (actionable), and finding causality based on customer feedback.

In table 18, the 'best practice' measurement system found in literature is compared to the corresponding performance measurement techniques of

innovation accounting (Ries 2017 and Viki et al 2017). The two sets of metrics are coinciding, with only two discrepancies. Firstly, while general R&D performance measurement supports both quantitative and qualitative metrics, innovation accounting focuses on simple and easily understandable metrics, which normally means quantification. Secondly, while a balance in metric perspectives have been found favorable in effective performance measurement systems, innovation accounting uses customer focused KPIs in a more determined manner.

Table 18: The characteristics of a 'highly effective' performance measurement system compared to 'innovation accounting'.

	Highly effective measurement	Innovation accounting principles
Measurement class and technique	Combination of qualitative and quantitative Objective measurement with customers involvement	Mainly quantitative and objective measurements
Measurement perspective	A balanced set of metrics, with emphasis on metrics reflecting customer demands	Customer focused KPIs. Business process KPIs if in the agile development phase.
Assessment time interval	Measurement on monthly basis	Continuously, and at least once a month

In order for innovation accounting to be applicable for use in oil and gas R&D, some adjustments must be done. The measurement system was originally designed for purely digital innovation projects, typically software start-up companies. The methodology has later been adapted for more general purposes, first from start up's to established companies, and thereafter for industrial application, such as in GE (Ries 2017).

The petroleum industry, defined as a low-tech industry (Hernandez 2018) and struggling with slow technology adoption (OG21 2018), can be considered the fundamentally opposite of high tech, software start up companies. This is reflected in the differences between the two industries regarding development cycle times, total project costs and the consequences of launching a product before the technology is reliable. However, these limitation are not necessarily true for several of the current DEMO2000 projects. The project portfolio is changing towards more innovations related to digitalization, which is according to the prioritization made in the DEMO2000 "program plan

2018-2022" (Research council 2018). The capacity to master ICT-related technologies is critical to improve the competitiveness of the oil and gas industry.

As per December 2018 there were 28 development project related to digitalization among the 63 active DEMO2000 projects. The so-called fourth industrial revolution, that brings together ICTs and traditional industries, yields major opportunities and challenges for the re-industrialization of the Norwegian oil and gas sector, such as automation, flexible production processes, remote and unmanned operations or the sharing of data.

Table 19 shows eight of the 28 digital DEMO2000 projects, which would be suitable candidates for using a innovation accounting performance measurement system. These projects are solely software related, and have a max funding from DEMO2000 of 5 mill NOK, which make them relatively small[1].

Table 19: DEMO2000 projects with solely software related scope of work, combined with a relatively low funding.

No.	Project title	Project responsible	Start	End	Fund*
269119	AlarmTracker - Demo2000	ELDOR TECHNOLOGY AS	2017	2019	5
282101	LedaFlow model accuracy improvements required for tighter design to help lower project development and operations costs	KONGSBERG DIGITAL AS	2017	2019	2,4
269268	LedaFlow Slug Capturing 10X	KONGSBERG DIGITAL AS	2017	2019	3,6
259155	Cost effective management of hydrates and wax with LedaFlow	KONGSBERG DIGITAL AS	2016	2018	3,3
272139	Drilling Data Hub Demonstration	NORCE NORWEGIAN RESEARCH CENTRE AS	2017	2019	3
281998	Advanced Lower Completion Tool	PETRELL A/S	2017	2019	2,1
281939	HD-technology for Steeply Inclined and Vertical Flow: Production Optimization for Wells, Risers and Pipelines	SCHLUMBERGER INFORMATION SOLUTIONS AS	2017	2020	4,8
269440	Demonstration of data-driven software for daily production optimization	SOLUTION SEEKER AS	2016	2019	5

*** The funding given by the DEMO2000 program.**

[1] DEMO2000 can maximum participate with 25% of the total development costs, these projects will therefore typically range from 8 to 20 mill NOK in total funding.

To conclude on sub-research question number 4, it appears that the innovation accounting performance measurement system resembles what literature has revealed as favorable characteristics of a highly effective measurement system, with just minor differences. The metrics are focused on assumption testing and customer interaction, which is found to be favorable attributed for new product development project. Eight current DEMO2000 project were found suitable for for being 'test runners' of the innovation accounting performance measurement system, based on their new product under development being both fully digital (no hardware), relatively small scale, and without safety critical applications offshore. However, the methods of lean innovation, such as building rapid prototypes, and launching 'rough' products to the market, should be used with caution in the oil and gas industry. The industry's high barriers against technology adoption is partly caused by the comprehensive technology qualification procedures (OG21 2018). These procedures are in place to safeguard the offshore personnel and installations, and they must not be relaxed without a thorough evaluation.

5.5 Answer to the main research question

The main research question which has been tested in this research was:

> ***RQ:*** *Are industrial product development projects in the oil and gas industry currently using adequate performance measurement systems to facilitate an accelerated technology adoption on the Norwegian Continental Shelf?*

Obviously, no R&D project's performance measurement system, no matter how effective it is, can ever prove that new product will become a market success. Neither can it accelerate a technology adoption rate on its own.

In innovation there will always be an uncertainty and a need for creativity, which no management system can fully overcome, nor control. However, as the literature review revealed, there is possible to reduce the uncertainty by using practically useful and theoretically sound performance measurement. The opposite, measurements who drive efficiency while neglecting effectiveness, will only be frustrating for the product development team. As Peter Drucker said: "There is nothing quite so useless as doing with great efficiency something that should not been done at all" (Ries 2011).

A performance measurement system for R&D projects should preferably be based on objective measurements with customer involvement, a balanced set of metrics with an emphasize on customer demands, and a frequent assessment (minimum once a month). However, the survey of the DEMO2000 projects showed that the actual measurement practices were generally only to a limited degree corresponding with the literatures views on a 'highly effective' measurement system. The survey found that the business process-perspective was by far the most used metric (66,7%). The standard rule of business units is "as long as the plan is executed well, hard work will yield results" (Ries 2017). However, that rule is not necessarily true in R&D.

In addition, the DEMO2000 project portfolio consists of 44% projects with a digital technology as a significant part of the innovation. Recent literature have indicated that different performance metrics may be beneficial for such projects, compared to the traditional, equipment focused, product development.

Through-out this thesis the need for customer-involvement in all types of innovation, with the associated measurements, has been stressed. In digital technologies, the need for end-user usability is even more profound. Thus, based on the lack of a clear framework for performance measurement in DEMO2000 portfolio, combined with the increased amount of digital innovation projects, an update of the projects performance measurement procedures seems to be necessary.

The difficult part, of course, is not to reach this conclusion. In stead, that is where the real challenge begins. The projects will need to both develop and implement enhanced performance measurement systems. While it is tempting to say "just ask the customer!", the answer is of course far more complex. Generally, the more 'radical' the idea is, it will be less likely that asking a potential customer will yield accurate results. This is why many traditional market research techniques, such as focus groups and surveys, are also less likely to yield useful data or insights for more innovative ideas (Thiel 2014). The 'visionary' Steve Jobs phrased it this way: "It's really hard to design products by focus groups. A lot of times, people don't know what they want until you show it to them" (Isaacson 2013).

A performance measurement system based on innovation accounting techniques, may form a part of the solution to enhance the measurement procedures, at least for som types of R&D projects. However, in the 'bigger picture' the choice of which performance measurement system to use is probably of less importance. Significantly more important is the actual interplay between the various stakeholders in a innovation process, and how they together are able to verify the projects critical success 'assumptions'.

A close collaboration between the project responsible company and the project partners is a absolute necessity. One of the project managers gave the following comment to the survey, which sums up the importance of these relations:

> *"In my experience from working on R&D projects for more than 40 years, both as principal and executor, [I have found] what seems to be facilitating the best results is [...] the frequent contact between principal and executor. And maybe most importantly, ensure qualified personnel on both sides, who are 'hands on' the project. With this in*

place, 'dead ends' may be averted at an early stage, and thus avoid the unnecessary use of time and money."

Also other potential customers, especially end-users, should have an obvious presence through out the product development phase. Researcher have another viewpoint to the innovation process, they are 'hypothesis testers' by profession, which can provide a valuable resource for any industrial R&D project. The importance of building strong relations between researcher, developers, and customers, is supported by Rystad Energy (2016) which recommended the DEMO2000 projects to "think all the way from demonstration to commercialization, building a solid business case with a strong partnership". With the innovation 'scene' trending towards more open innovation processes, an enhanced collaborations between the various stakeholders, with a multi-disciplinary approach, should become the new norm.

Industry case examples has shown that both operators and technology companies often fail to understand the entire technology value proposition (Rystad Energy 2016). To respond to this challenge, industrial product development projects need to keep a holistic view on the value of their technology proposition, have a realistic plan and ensure that people with the right competence are involved. This interplay both can and should be measured by a balanced set of goals, with an focus on value-adding potential and customer risk reduction, and KPIs that both ensures the project is delivering according to plan (business process perspective) while asking the right questions to the right people (customer perspective). However, currently, only a handful of the survey respondents seem to capture these aspects in their performance measurements.

5 Conclusion

This thesis has reviewed a number of issues related to performance measurement in industrial R&D, observed through the lens of the Research Council of Norway's DEMO2000 project portfolio.

The R&D projects were found to have set a broad range of project specific goals, which were generally suitable for fostering both project excellence and creative freedom. However, it would have been preferable with an even higher number of goals who supports customer interactions and collaborations. The performance measurements used by the projects were according to literature not perceived as 'highly effective' measurements. The actual usage of the measurement output is decisive for the effectiveness of performance measurement. However, only 30% of the projects assess their KPIs within the frequency which in the literature is considered to be sufficient (monthly).

To better understand the entire technology value proposition of new product development, the projects needs to build strong relations between researcher, developers, and customers, with a multi-disciplinary approach. This interplay both can and should be measured by KPIs that both ensures the project is delivering according to plan (business process perspective) while asking the right questions to the right people (customer perspective). However, currently, only a handful of the survey respondents seem to capture these important aspects in their performance measurement procedures. A holistic performance measurement system, which captures both the potential value proposition and the project progress, while the right competence is involved, is considered to make innovation teams more effective. The lack of effective measurement systems in the DEMO2000 projects, may increase the risk of the 'wrong' products being built. In that case, optimizing the product will not yield significant results.

I will let this quote on the importance of human interplay in innovation, by Walter Isaacson (2018), conclude this thesis:

> *"Genius starts with individual brilliance. It requires singular vision. But executing it often entails working with others. Innovation is a team sport. Creativity is a collaborative endeavor."*

6.1 Limitations

The main limitation of this study is that that its findings can not be correlated towards actual performance of the R&D projects in the sample as the questionnaire was answered anonymously. The results of the survey are evaluated solely based on what in literature is regarded as 'highly effective' measurement systems. The sources that were used as input to the thesis are international, with an emphasis on European research. However, these studies, mainly from Germany, Italy and Holland, may have minor differences compared to Norwegian performance measurement conditions.

The thesis has explored performance measurement at the project level specifically, and did not discuss the varied approaches in other areas, such as for the R&D department or for the organization as a whole. The thesis recognizes that the uses of performance measurement tend to be different based on application.

Lastly, the survey was designed to understand performance management at an overall level, by using predefined objectives and measurement perspectives. Thus, the thesis has not explored neither the specific goals nor metrics which belong to the respective groups. While it is widely recognized that different metrics within a measurement perspective can be of varying effectiveness, the author is of the opinion that the choice of macro level KPIs are more important than the micro KPIs.

6.2 Future Research

A topic that could be further explored can be one that during the work on the thesis emerged as important and interesting, but beyond the scope of this work: to evaluate the actual performance of petroleum research projects in relation to their performance measurement procedures. The performance measurement system of a project can be evaluated against actual project output and outcome.

Also, moving the research into micro level metrics evaluations could be valuable, to further manifest the characteristics of a 'best practice' performance measurement system in industrial R&D.

Lastly, since "what you measure is what you get", further research should evaluate the potential drawbacks of the proposed shift in performance measurement procedures towards favoring a customer focused, more rapid, technology development. Will project control be suffering? May it lead to an increased focus on 'sustaining innovations' instead of finding the 'radical technology' changes? In the far fetched long run, could it lead to an increased total risk level on the Norwegian Continental Shelf?

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Appendices

Appendix 1

List of active R&D project in the DEMO2000 portfolio as per 1. December 2018.

No.	Project title	Project responsible	Fund*
220928	Subsea Power Grid System Integration Test	SIEMENS AS	4,5
225828	Full scale verification of float steering and positioning system for seismic gun arrays	PARTNER PLAST AS	2,7
245292	Joint Industry Project for Improved MEG Regeneration Systems	NOV PROCESS & FLOW TECHNOLOGIES AS	3
248844	System Integration Pilot and Qualification of New Subsea Products	AKER SOLUTIONS AS	12
248854	Offshore Pilot of Drill Floor Robot at North Sea Semi-Submersible	CANRIG ROBOTIC TECHNOLOGIES AS	4,9
248871	Demo av Selvtestende Optisk H2S Punktdetektor	SIMTRONICS AS	1,4
256460	Drilling Mud Process Control	HUISMAN NORGE AS	3,4
256472	Aptomar multi-sensor Oil Spill Detection tracker (AOSD) for TCMS	NORBIT APTOMAR AS	0,75
256489	Remote Drill floor Operation	NATIONAL OILWELL VARCO NORWAY AS	15
256553	eSpring - electrically powered actuator for fail-safe-close applications	FMC KONGSBERG SUBSEA AS	6,4
256588	Building and testing of a fully qualified subsea system prototype for production of Sulphate free or low salinity water.	SEABOX AS	15
258925	Demonstration of technology for cost efficient and reliable operation of electrically driven gas compressors	ABB AS	8,3
258937	SwarfPak On/Offshore Pilot	WEST PRODUCTION TECHNOLOGY AS	6
258943	Demonstrate CMR superior drilling performance and value case (cost reduction by 30-50%)	WEST DRILLING PRODUCTS AS	15
258997	Technical Qualification of the next generation subsea control and auxiliary system - Joint Industry Project	ABB AS	10
259014	Pipeline Inspection using Underwater Hyperspectral Imager - UHI	ECOTONE AS	1,6
259095	Demonstration of Automated Drilling Process Control	NORCE NORWEGIAN RESEARCH CENTRE AS AVD STAVANGER	20
259145	Continuous Shooting, Recording and Imaging of seismic data	PGS GEOPHYSICAL AS	12,5
259155	Cost effective management of hydrates and wax with LedaFlow	KONGSBERG DIGITAL AS	3,3
259186	Project DOWSES: Development Of Water Spray Explosion Suppression	DNV GL AS	1

No.	Project title	Project responsible	Fund*
259190	Enhanced Subsea Hydrocarbon Leak Detection with Broadband Active Acoustic Sensor System (L-BAS)	METAS AS	5
259195	Produksjonsoptimalisering og integritetsovervåkning av gassløft-brønner.	SCANWELL TECHNOLOGY AS	7,5
259235	Subsea Hydraulic Power Unit	INNOVA AS	1,5
259245	Utvikle en brønnbarriere for bruk i forbindelse med permanent nedstengning av brønner (P&A) som kan realiseres uten en boreinnretning.	INTERWELL P&A AS	15
259250	Kostnadseffektiv, miljøvennlig og kontrollerbar subseakjøler - FSCC	FUTURE TECHNOLOGY AS	3,8
269066	DEAL med Smartmoduler - Automatiserte og samhandlende kontrollsystemløsninger for økt bore-effektivitet	MHWIRTH AS	10,8
269102	Offshore pilot test of Choke valve	SCI AS	2,8
269119	AlarmTracker - Demo2000	ELDOR TECHNOLOGY AS	5
269188	Unmanned ocean vehicles, a flexible and cost-efficient offshore monitoring and data management approach	AKVAPLAN NIVA AS	9
269225	Subsea CFU Pilot	AKER SOLUTIONS AS	7,5
269252	Broadband Acoustic Seismic Source (BASS)	WESTERNGECO AS	18
269257	Towing a seismic source over the seismic spread	CGG SERVICES (NORWAY) AS	5
269268	LedaFlow Slug Capturing 10X	KONGSBERG DIGITAL AS	3,6
269300	CHEmical Control Knowledge demonstration project: Monitoring And Treatment Enhancement	NORCE NORWEGIAN RESEARCH CENTRE AS	5
269314	AutoViscosity	NATIONAL OILWELL VARCO NORWAY AS	12,8
269317	Superior Well Caliper	WELL ID AS	4,5
269324	Omnirise Singlephase Boosting Pump, without Barrier Fluid and with internal Variable Speed Drive	FSUBSEA AS	14
269339	Prototype Development and Testing of Internal Drilling Device for ICS	COREALL AS	2,4
269360	Assessing the Influence of Real Releases on Explosions (AIRRE)	GEXCON AS	1,8
269440	Demonstration of data-driven software for daily production optimization	SOLUTION SEEKER AS	5
271975	Vision People Detection	NATIONAL OILWELL VARCO NORWAY AS	4
272003	Downhole Swarf Collection Tool	NORSE OILTOOLS AS	4
272012	3D inspection camera	VISION IO PRODUCTION AS	2,4
272088	Development of a modular compact subsea pump	VETCO GRAY SCANDINAVIA AS	17
272095	Subsea Power System Integration and Shallow Water Testing - Joint Industry Project	ABB AS	10

No.	Project title	Project responsible	Fund*
272123	KESS-Demonstration of an innovative high-efficiency Kinetic Energy Storage System for sustainable powering of offshore jack-up drilling rigs	SIEMENS AS	15
272124	Advanced non-invasive subsea and topside flow meter	XSENS AS	6
272126	RDM-C Reelwell Liner- and Casing Drilling	REELWELL AS	5,7
272128	Firesafe Energy - Next level cable and pipe fire sealing	FIRESAFE ENERGY AS	1
272129	Geomechanical software for multi-well injection optimisation of complex fields	GEOMEC HOLDING AS	10
272135	Variabel oppdrift	IKM TECHNOLOGY AS	3,6
272139	Drilling Data Hub Demonstration	NORCE NORWEGIAN RESEARCH CENTRE AS	3
281894	PowerPipe Pilot	REELWELL AS	10,1
281939	HD-technology for Steeply Inclined and Vertical Flow: Production Optimization for Wells, Risers and Pipelines	SCHLUMBERGER INFORMATION SOLUTIONS AS	4,8
281998	Advanced Lower Completion Tool	PETRELL A/S	2,1
282016	PowerBlade Hybrid	NATIONAL OILWELL VARCO NORWAY AS	10
282027	HV Wet Mate Connection System (WMCS)	BENESTAD SOLUTIONS AS	5
282036	Digitized Fluid Transport	KONGSBERG DIGITAL AS	5,1
282085	Development of a Field Gradient Sensor (FiGS®) for autonomous subsea vehicles	FORCE TECHNOLOGY NORWAY AS	4,7
282101	LedaFlow model accuracy improvements required for tighter design to help lower project development and operations costs	KONGSBERG DIGITAL AS	2,4
282115	Kinetic Hydrate Inhibitor Removal, Recovery and Reuse from Produced Water and Rich MEG Streams	NOV PROCESS & FLOW TECHNOLOGIES AS	2,4
282122	Pilottest av undervanns elektrisk aktuator	SCI AS	2
282158	Completion time saving tool	TOOLSERV AS	5

*** The funding given by the DEMO2000 program (The Research Council of Norway can contribute with maximum of 25% of the total project funds)**

Appendix 2

The DEMO2000 project description

These guidelines explain how to use the template for the **project description** for *DEMO2000*. The project description must be submitted using the template described below.

NOTE: This template must be used for grant applications submitted for the october 11th 2017 deadline. Previous versions of the template are not to be used.

Project description for *DEMO2000* General instructions

The Research Council's support applies only to the project activities to be performed related to piloting/demonstration. Other activities and measures that are necessary to realising the innovation must also be described, and will be assessed during the grant application review process. *The project description is divided into four parts:*

• PART 1: The planned innovation

This is where you describe the innovation concept, the opportunities for value creation this entails and the anticipated potential for such value creation. You must also provide an overview of the project participants and their roles and interests in the project.

• PART 2: Project activities

This is where you provide a more detailed description of the activities for which funding is being sought, with reference to the project objectives, tasks, budgetary framework and timeframe which are to be listed in the grant application form.

• PART 3 Realisation of the innovation and utilisation of results

This is where you describe the plans for how the results will be utilised, and other measures that are required to ensure that the potential for value creation and benefit to the Norwegian continental shelf can be realised.

• PART 4: Other information

This is where you provide additional information that may be of significance in the Research Council's application review process.

Please note that there is a page limit, maximum 10 pages, and formatting requirements.

The project description is a mandatory attachment to the electronic grant application form to be completed and submitted via "My RCN Web", referred to in the following as "the grant application form".

The designated template provided below must be used, and all items of information must be completed. Delete the instructions and fill in the information for each item on the template.

TEMPLATE (must be followed):

Project description

PART 1: The planned innovation

1. Underlying idea

Describe the underlying idea for value creation (innovation concept).

2. Level of innovation

Specify what the planned innovation involves:

- new or improved products/services;
- new or updated methods of production/delivery/distribution;
- new or updated structures for management/organisation/working conditions/competence;
- new or updated business models.

Describe the major new elements that the planned innovation entails, and how this represents something new for the company/companies and the users.

Describe the significance of the planned innovation in a national and international context (industry/market).

3. Potential for value creation

a) Norwegian continental shelf (NCS)

Describe in concrete terms the potential for value creation of the planned innovation for the participating company/companies.

Specify whether this is related to:

- Increased resource base – extended production/life;
- New production
- reduced costs (investments or operational);
- upholding levels of competitiveness;
- other aspects of value creation.

b) Export – market outside of NCS

Describe the potential for value creation with regards to export of the technology to other applicable areas outside of the NCS.

c) Climate- and environmental impact

Describe whether the implementation of the demonstration project and/or the utilisation of project results will entail any significant environmental impacts (energy efficiency, reduced emissions to sea or air - positive and negative).

4. Project participants and constellation of partners

a) Participating and financing partners

Provide an overview of the companies/institutions that will be participating in the project, and briefly describe each partner's role and interests in the project. All project participants that will be performing and/or financing tasks on a significant scale must be included, and these must be entered in the grant application form under "Project Owner" or "Partners".

Quantify the number of people employed in the project (directly & indirectly).

b) Other forms of collaboration

If the project entails collaboration on activities with actors other than those listed under item 4 a, e.g involvement of specific subcontractors for performing specific tasks beyond the assistance from the partners, provide further information about these here.

Part 2: Project activities

(This portion of the project description provides supplementary information about the activities, as it is described in the grant application form.)

5. Objectives – Pilot / Demonstration

Describe the primary objective for the projectactivities.

Describe verifiable secondary objectives that will lead to the achievement of the primary objective.

Describe the planned pilot/demonstration in details (where & what to be done).

6. Project challenges

Describe the project's central challenges.

Identify and describe the question that will be addressed. This should be presented in the context of already known or available state-of-the-art knowledge/technology so as to indicate your knowledge of the technological front.

State whether a search in literature, patent databases or the like has been conducted.

Explain the planned approach and choice of methodology.

What is the level of ambition established for the objectives, and are there any special factors (risks) that may make it difficult to achieve these objectives in full?

7. Project plan

a) Main activities ("work packages") under the project

The specific objectives and deliverables with appurtenant costs for all the *main activities* of the project are to be presented in the table below, cf. the item "Main activities and milestones in the project period" in the grant application form. The sum of all expenses for the main activities must correspond to the total costs for the project, cf. the item "Cost plan" in the grant application form. Specify the name of the partner that is responsible for each activity and any other participating partners. *(New lines and sub-items may be added to the table as needed.)*

Project plan: Main activity, objectives and deliverables

No.	Main activity, objectives and deliverables	Cost	Responsible partner	Participating partners
H1				
H2				
…..				
Sum				

b) Key milestones for project activities

Describe and estimate the dates for milestones (M1, M2, etc.) that are seen as crucial to achieving the objectives of the projectactivities, as these are described in item 5 above. Decision-making points which may be important in determining the course to pursue in subsequent project activity must be included.

-The main activities (H1, …) and milestones (M1, ...) must be entered in the table "Main activities and milestones in the project period" in the grant application form.

8. Distribution of costs between each partner (in NOK 1 000)

Please read the information on the website pertaining to costs and budgets carefully, cf. the guidelines to filling in the grant application form.

Provide an overview of the distribution of project costs among each of the partners. Use the table below to specify the distribution of payroll and indirect expenses, expenses for equipment, other operating expenses and total expenses for each partner. *(Lines may be added to the table as needed.)*

Partner	***Name of partner***	***Payroll and indir. expenses***	***Equipment***	***Other operating expenses***	***Total costs***
B1					
B2					
…					
F1					
F2					
…					
…					
Sum	**Entire project**				

• Only costs for company partners (B1, etc.) are to be distributed by cost category. For other types of partners, only the total amount of their costs is to be entered in this table above.

• The sum of "Total costs" must correspond to the total cost of the project as entered in the table "Cost plan" in the grant application form.

• The sum of "Payroll and indirect expenses" for the company partners (B1, etc.) must correspond to the sum of payroll and indirect expenses as entered in the table "Cost plan" in the grant application form.

• The sum of the costs for the partners from the R&D sector (F1, etc.) must correspond to the sum for the cost category "Procurement of R&D services" as entered in the table "Cost plan" in the grant application form.

9. Financial contribution from each partner (in NOK 1 000)

Provide an overview of the type of financing the company partners (B1, etc.) will contribute to the activities. Use the table below to specify the individual contributions from the partners by in-kind R&D activities and/or cash financing. If the project will be receiving funding from other partners or from other sources than the Research Council, enter the amount under "Other funding" and provide further details under the table. *(Lines may be added to the table or deleted as needed.)*

Partner	Name of company	In-kind R&D activities	Cash	Total
B1				
B2				
…..				
Net sum	**All company partners**			
	Other funding			
	Sought from Research Council			
Sum	**Total funding amount**			

• The "Total funding amount" must correspond to the total cost of the project entered in the table under item 9.

• The total of "In-kind R&D activities" and "Cash" in the row for "All company partners" must correspond to the total amount of "Own financing" entered in the table "Funding plan" in the grant application form.

• The amounts on the rows for "Sought from the Research Council" and "Total funding amount" must correspond to the amounts entered in the table "Funding plan" in the grant application form.

PART 3: Realisation of the innovation and utilisation of results

10. Plan for realisation of the innovation

Describe the plan for realisation of the innovation, e.g. in the form of an outline for a business plan for new products/services or an outline for a launch plan for new business models or production processes.

The plan must incorporate measures to be carried out in conjunction with the activities (e.g. for utilising results underway) as well as plans for further realisation after the activities are concluded.

The following are examples of relevant information to include:

• The company's/companies' plan for introducing products/services to the market.

• The company's/companies' plan for implementing new methods, new organisational structures or new business models.

• The company's/companies' plan for improvement or introduction of new processes or products.

• Beyond the project activities, what other kinds of measures are being planned to realise the potential for value creation? This may, for example, comprise investment in production equipment, market profiling, establishing industrial or commercial cooperation, strengthening of capital.

• Which resources will be essential to enable the company/companies to implement the plans?

11. Risk factors

Describe and explain any risk factors that may have a significant impact on the realisation of the innovation.
(Note: Risk factors related to the project activities are to be described under Part 2, item 6.)

Please comment on the following:

- risk elements relating to industrialisation, commercialisation and implementation;
- market risks;
- financing risks;
- organisational risks;
- Other risks.

Part 4: Other information

12. Health and safety

Describe whether the implementation of the project and/or the utilisation of project results will entail any significant impacts on the health and safety in the operations or the industry.

13. Additional information

Describe other information that might be of relevance in the evaluation process.

Describe which thematic priority area in DEMO2000 for which the grant application is targeted.

Appendix 3

The specific KPIs which was evaluated by this thesis and found relevant for the team level in development projects.

- achieved business impact of an idea in terms of its economic value
- alignment of research activities with the IP strategy of the company
- adherence to budget
- adherence to timelines (phases, gates)
- discounted cash flow
- economic value of the transfer activity or transferred research results
- external perception or external recognitions
- implementations of the roadmaps and the quality of contributions from research projects
- intensity of input into the innovation process
- internal perception or internal recognitions
- internal rate of return
- net present value
- number of ideas moved to a certain or the next phase of the innovation process
- participation in scientific events beyond publications
- percentage of budget dedicated to customer analysis or verification
- quality of collaboration with academia
- quality of collaboration with partners and customers
- quality of project management
- quality of publications
- quality of the people in the research department
- quality of the research results transferred
- quality of the risk management in place
- quality of the transfer process or transfer activities
- quality of the working environment
- return on investment
- roadmaps to achieve the visions and their quality
- significance of the transferred research results for the receiving unit
- structure and quality of the research (i.e., certain technology areas)
- visions related to the individual parts of the research portfolio and their quality
- volume of collaboration with academia
- volume of collaboration with partners and customers
- volume of external investments into the research project
- volume of first filings out of the IP pipeline
- volume of patents granted
- volume of publications
- volume of technology transfer activities to other business units
- volume/quality of development measures undertaken

Appendix 4

The full questionnaire, as presented on the Google Forms web page

Performance measurement in R&D projects in the Norwegian oil and gas sector

*Må fylles ut

Project specifications

Which technology area group do your project belong to? *

- Energy efficiency and environment
- Exploration and increased recovery
- Drilling, completion and intervention
- Production, processing and transport
- None of the above

What development stage is your project in at the moment? *

- Small scale prototype
- Large scale prototype (including system prototype)
- System demonstration
- First of a kind commercial system
- None of the above

What is the total funding of your project? (In million NOK) *

- 0-20
- 21-50
- More than 50
- I don't know

How many partners participate with funding to your project? (Including your own company and Forskningsrådet) *

- 2
- 3-5
- 6 or more
- I don't know

Do your project collaborate with academia? *

- Yes
- No
- I don't know

How many employees are working in your entire company? *

- 1-50
- 51-250
- More than 250
- I don't know

TILBAKE NESTE

Performance measurement in R&D projects in the Norwegian oil and gas sector

*Må fylles ut

Goals

Do your project have specific goals? *

- ◯ Yes
- ◯ No

TILBAKE NESTE

Performance measurement in R&D projects in the Norwegian oil and gas sector

Project goals

Below you will find 5 groups of goals for industrial R&D projects.
Please select the group(s) that best reflect the goal(s) of your project.

If your project have goals that do not fit into any of the groups, please use the text box at the bottom of the page to specify.

Which of the groups below do your project have goals related to? (Multiple answers allowed)

	In use
High standard of operational excellence (I.e. "Reach project milestones" or "Deliver within budget time og cost")	☐
Proof of technology (I.e. "Achieve qualification or prove reliability of the innovation")	☐
Valueadding potential (I.e. "Explore business opportunities for the innovation")	☐
Reduce actual risk and/or perceived risk for future customers (I.e. "reduce customer risk" or "cooperate with potential customers or end-users")	☐
Final outcome (I.e. "innovation succeeding in the market")	☐

If your project have goals that do not fit into any of the groups above, please feel free to specify your goal(s):

Svaret ditt

TILBAKE NESTE

Performance measurement in R&D projects in the Norwegian oil and gas sector

*Må fylles ut

Performance measurement

Do your project measure performance? *

- ◯ Yes
- ◯ No

TILBAKE NESTE

Performance measurement in R&D projects in the Norwegian oil and gas sector

*Må fylles ut

Project KPIs

Your project´s KPIs are best described as: *

- ◯ Quantitative
- ◯ Qualitative
- ◯ A combination of quantitative and qualitative
- ◯ I don't know

The score on your project´s KPIs are mainly based on: *

- ◯ Subjective assessment by supervisor(s)
- ◯ Assessment by independent third party
- ◯ Feedback from customer(s)
- ◯ Objective score on quantitative criteria
- ◯ None of the above

Which of the groups of KPIs below are used to measure performance in your project? (Multiple answers allowed)

	In use
Financial (I.e. "IRR" or "ROI")	☐
Customer (I.e. "number of interactions with customers during the project" or "% of budget dedicated to customer analysis or verification")	☐
Innovation and learning (I.e. "number of publications" or "number of patents")	☐
Business process (I.e. "Milestones met" or "Quality of documentation or output")	☐

If your project have KPIs that do not fit into any of the groups above, please feel free to specify your KPI(s):

Svaret ditt

How often are your project´s KPI results assessed? *

- ◯ More than once a month
- ◯ Monthly
- ◯ Quarterly or six monthly
- ◯ Yearly
- ◯ At the end of the project
- ◯ Never

TILBAKE NESTE

Performance measurement in R&D projects in the Norwegian oil and gas sector

*Må fylles ut

Your personal opinion regarding performance measurment

Please select the following statement that best matches your opinion: *

- ◯ Performance measurement in industrial R&D projects is an obvious need.
- ◯ Performance measurement in industrial R&D projects is necessary, but the measured results should not influence management decisions too heavily.
- ◯ Performance measurement in industrial R&D projects is not necessary.
- ◯ None of the above.

TILBAKE NESTE

Appendix 5

The survey responses (chronological)

Part 1: Project specification

#	Technology area	Development stage	Total funding	Funding partners	Employees	Academia
1	Drilling, completion and intervention	First of a kind commercial system	21-50 mill NOK	3-5	1-50	Yes
2	Drilling, completion and intervention	System demonstration	21-50 mill NOK	3-5	More than 250	No
3	Energy efficiency and environment	System demonstration	0-20 mill NOK	3-5	More than 250	Yes
4	Drilling, completion and intervention	System demonstration	21-50 mill NOK	3-5	More than 250	No
5	Others	Large scale prototype	0-20 mill NOK	3-5	51-250	No
6	Exploration and increased recovery	Large scale prototype	More than 50 mill NOK	6 or more	1-50	No
7	Production, processing and transport	Large scale prototype	More than 50 mill NOK	3-5	More than 250	No
8	Drilling, completion and intervention	First of a kind commercial system	21-50 mill NOK	2	More than 250	Don't know
9	Energy efficiency and environment	System demonstration	More than 50 mill NOK	3-5	More than 250	No
10	Energy efficiency and environment	Large scale prototype	21-50 mill NOK	2	More than 250	No
11	Drilling, completion and intervention	System demonstration	0-20 mill NOK	2	More than 250	No
12	Production, processing and transport	System demonstration	21-50 mill NOK	3-5	1-50	No
13	Drilling, completion and intervention	System demonstration	21-50 mill NOK	6 or more	1-50	No
14	Energy efficiency and environment	Large scale prototype	0-20 mill NOK	2	1-50	No
15	Energy efficiency and environment	Small scale prototype	0-20 mill NOK	6 or more	1-50	Yes
16	Others	First of a kind commercial system	0-20 mill NOK	2	1-50	No
17	Production, processing and transport	System demonstration	21-50 mill NOK	3-5	1-50	Yes
18	Production, processing and transport	Large scale prototype	21-50 mill NOK	3-5	More than 250	No
19	Production, processing and transport	System demonstration	More than 50 mill NOK	6 or more	More than 250	No
20	Drilling, completion and intervention	System demonstration	0-20 mill NOK	6 or more	More than 250	No

#	Technology area	Development stage	Total funding	Funding partners	Employees	Academia
21	Drilling, completion and intervention	System demonstration	More than 50 mill NOK	6 or more	More than 250	Yes
22	Drilling, completion and intervention	First of a kind commercial system	21-50 mill NOK	3-5	1-50	Yes
23	Production, processing and transport	System demonstration	0-20 mill NOK	3-5	1-50	Yes
24	Energy efficiency and environment	Large scale prototype	0-20 mill NOK	3-5	1-50	No
25	Production, processing and transport	System demonstration	21-50 mill NOK	3-5	1-50	Yes
26	Energy efficiency and environment	Others	0-20 mill NOK	3-5	More than 250	No
27	Energy efficiency and environment	Small scale prototype	21-50 mill NOK	6 or more	51-250	Yes
28	Exploration and increased recovery	Small scale prototype	0-20 mill NOK	2	1-50	No
29	Production, processing and transport	System demonstration	0-20 mill NOK	3-5	1-50	No
30	Others	Others	More than 50 mill NOK	3-5	More than 250	No
31	Exploration and increased recovery	System demonstration	0-20 mill NOK	2	1-50	No
32	Exploration and increased recovery	First of a kind commercial system	21-50 mill NOK	3-5	More than 250	No
33	Production, processing and transport	System demonstration	0-20 mill NOK	3-5	More than 250	No

Part 2: Project goals

#	High standard of operational excellence	Proof of technology	Value-adding potential	Reduced risk for future customer	Final outcome
1	X	X	X	X	X
2		X			
3		X	X		X
4		X		X	X
5				X	
6	X	X		X	X
7		X	X		
8		X	X	X	

#	High standard of operational excellence	Proof of technology	Value-adding potential	Reduced risk for future customer	Final outcome
9	X	X	X		X
10	X	X	X	X	X
11	X	X	X	X	X
12		X	X	X	X
13	X	X		X	
14	X	X		X	
15		X			
16	X	X			
17		X		X	X
18		X		X	
19		X		X	X
20		X			
21	X	X			X
22		X	X	X	
23		X	X		
24		X	X	X	
25		X	X	X	
26			X	X	X
27	X	X	X		X
28		X			
29			X	X	
30	X	X	X	X	X
31	X	X			
32					X
33		X		X	

Part 3: Performance measurement

#	PM	Measurement class	Assessment technique	Assessment timing	Personal opinion
1	Yes	Combination	Customer feedback	Project end	Should not influence decisions too heavily
2	Yes	Quantitative	Customer feedback	Three or six monthly	Obvious need
3	Yes	Combination	Customer feedback	Monthly	Obvious need
4	Yes	Quantitative	Objective score	Project end	Obvious need
5	No				Other
6	Yes	Combination	Objective score	Monthly	Obvious need
7	Yes	Combination	Objective score	Three or six monthly	Obvious need
8	Yes	Combination	Objective score	Monthly	Obvious need
9	No				Other
10	Yes	Qualitative	Subjective by supervisor	Three or six monthly	Should not influence decisions too heavily
11	Yes	Qualitative	Customer feedback	Three or six monthly	Obvious need
12	Yes	Combination	Customer feedback	Yearly	Obvious need
13	Yes	Combination	Objective score	Project end	Should not influence decisions too heavily
14	Yes	Combination	Customer feedback	Three or six monthly	Should not influence decisions too heavily
15	Yes	Quantitative	Customer feedback	Three or six monthly	Obvious need
16	No				Obvious need
17	Yes	Combination	Subjective by supervisor	Monthly	Should not influence decisions too heavily
18	Yes	Combination	Subjective by supervisor	Monthly	Obvious need
19	Yes	Combination	Other assessment	Project end	Obvious need
20	Yes	Combination	Customer feedback	Three or six monthly	Other
21	Yes	Qualitative	Subjective by supervisor	Three or six monthly	Obvious need
22	Yes	Qualitative	Subjective by supervisor	Three or six monthly	Should not influence decisions too heavily
23	Yes	Qualitative	Subjective by supervisor	Yearly	Obvious need

#	PM	Measurement class	Assessment technique	Assessment timing	Personal opinion
24	No				Should not influence decisions too heavily
25	Yes	Quantitative	Objective score	More than once a month	Obvious need
26	Yes	Combination	Customer feedback	Three or six monthly	Should not influence decisions too heavily
27	Yes	Combination	Objective score	Monthly	Obvious need
28	Yes	Qualitative	Independent third party	Yearly	Obvious need
29	No				Other
30	Yes	Quantitative	Objective score	Monthly	Obvious need
31	Yes	Combination	Customer feedback	Three or six monthly	Should not influence decisions too heavily
32	No				Should not influence decisions too heavily
33	Yes	Qualitative	Subjective by supervisor	Project end	Should not influence decisions too heavily

Measurement perspectives

#	Financial	Customer	Innovation & learning	Business process
1	X	X	X	X
2		X		
3			X	
4		X		X
5				
6				X
7	X			X
8		X		
9				
10	X			X
11		X		
12		X		
13				X
14		X		

#	Financial	Customer	Innovation & learning	Business process
15		X		
16				
17	X		X	X
18	X			X
19				X
20	X		X	X
21				X
22				X
23				X
24				
25				X
26		X		
27			X	X
28				X
29				
30				X
31		X		
32				
33				X

Appendix 6

Point scoring system (The short form used in the ranking in parenthesis)

Goals:

High standard of operational excellence (OE)	1p
Proof of technology (PT)	1p
Value-adding potential (VA)	2p
Reduced risk for future customer (RR)	2p
Final outcome (FO)	1p

Measurement class (MC):

Combination of quantitative and qualitative	3p
Quantitative	2p
Qualitative	1p

Assessment technique (AT):

Feedback from customer	3p
Objective score	3p
Independent assessment by third party	1p
Other assessment techniques	0p
Subjective assessment by supervisor	-1p

Measurement perspectives:

Financial (FI)	-1p
Customer (CU)	4p
Innovation and learning (IL)	1p
Business process (BP)	1p

Assessment interval (AI):

More than once a month	5p
Monthly	4p
Three or six monthly	1p
Yearly	0p
At project end	-1p

Performance measurement system ranking

Maximum possible score: 1+1+2+2+1+3+3+4+1+1+5 = 24p.

#	OE	PT	VA	RR	FO	MC	AT	FI	CU	IL	BP	AI	Sum
8		1	2	2		3	3		4			4	19
1	1	1	2	2	1	3	3	−1	4	1	1	−1	17
27	1	1	2		1	3	3			1	1	4	17
30	1	1	2	2	1	2	3				1	4	17
25		1	2	2		2	3				1	5	16
6	1	1		2	1	3	3				1	4	16
11	1	1	2	2	1	1	3		4			1	16
12		1	2	2	1	3	3		4			0	16
26			2	2	1	3	3		4			1	16
14	1	1		2		3	3		4			1	15
3		1	2		1	3	3			1		4	15
31	1	1				3	3		4			1	13
4		1		2	1	2	3		4		1	−1	13
2		1				2	3		4			1	11
15		1				2	3		4			1	11
17		1		2	1	3	−1	−1		1	1	4	11
7		1	2			3	3	−1			1	1	10
13	1	1		2		3	3				1	−1	10
18		1		2		3	−1	−1			1	4	9
20		1				3	3	−1		1	1	1	9
10	1	1	2	2	1	1	−1	−1			1	1	8
22		1	2	2		1	−1				1	1	7
19		1		2	1	3	0				1	−1	7
21	1	1			1	1	−1				1	1	5
23		1	2			1	−1				1	0	4
28		1				1	1				1	0	4
33		1		2		1	−1				1	−1	3

#	OE	PT	VA	RR	FO	MC	AT	FI	CU	IL	BP	AI	Sum
5				2		0	0					0	0
9	1	1	2		1	0	0					0	0
16	1	1				0	0					0	0
24		1	2	2		0	0					0	0
29			2	2		0	0					0	0
32					1	0	0					0	0