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Preface

This master thesis is my final task of my master program Energy Management at Bodo Graduate School of Business. This course gave me a unique opportunity to study foreign experience in Norway. Study in Bodo gave extra knowledge and another vision of the energy management. Last semester was busy with good study and job experience.

I would like to thanks to everybody who has helped me during the process of writing this thesis. A special thanks goes to my supervisor Elena Dybtsyna. Your constructive advises allow me to create the whole picture of my thesis, formulate my ideas in the right way and finish this thesis. Without Your help, I would have been lost in a jungle of my ideas and information.

Finally, I want to say thank for all experts that answer on my questions and gave for me helpful feedbacks.

Vladimir Dutov

Bodo, April 17, 2017

Abstract

This thesis is exploring the factors that influence on the process of decision making of radical and incremental implementation of subsea technologies in Russia. Huge reserves of oil and gas and sanctions stimulate the development of own Russian technologies. Artic zone is the main area of subsea complex appliance in Russia. However, this area creates additional difficulties in technology implementation. Harsh climate conditions and remoteness from the land complicate the usage of the complex. The objective of the study is to explore the drivers and barriers for implementation radical and incremental innovation in subsea complex in Russia. Five factors model involving technological transfer, technological paradigm shift, exploration and exploitation approach, uncertainties and cost of technology development was created and analyzed during research to estimate the drivers and barriers for technology modification. Norwegian experience of technology management was studied to estimate the challenges of innovation creation and the ways of their overcoming. The main conclusion of this study is that Russia is on the stage of subsea complex development. To penetrate the market with this technology, radically improved subsea complex is needed. All the factors that were add to the model nowadays are the barriers for technology modification in Russia. The reason of this fact is the lack of scientific development in R&D institutes and low oil prices. Currently the development of innovative technologies in upstream industry is difficult in Russian companies. However, the analysis of Norwegian experience can bring ideas of improving current situation in Russia.

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Abbreviations

E&P- Exploration and production.
API – American Petroleum Institute
ISO – International standard organization
CAPEX – Capital expenditures

1. Introduction

Nowadays, with the rapid development of the World economy and continuous increase in energy consumption and population, oil and gas industry holds the position one of the most powerful industry in the world (BP, 2012). This position was achieved with the help of innovation management that created technological advantage. The oil and gas is truly global with the operations performed in every corner of the globe, from Australia to Alaska, from China to Peru, and every habitant from desert to Arctic, form mangrove to offshore (UNEP, 2015). However, according to Urstadt (2006), new trend is that “easy oil” or conventional oil and gas already consumed and big producers increase the usage of sophisticated technologies to explore and extract tomorrow’s hydrocarbons. In order to maintain the level of production, companies are switching to the offshore production (Lord, 2007 and Tillerson, 2006).

According to Dr. Andrew Leonard (2014), technologies play the critical role in the offshore production. The deep offshore contains more than 5% of estimated 300 billion barrels of world’s liquid hydrocarbon resources. Moreover, this area has the share of 12% from the total conventional reserves and 6% liquid reserves of global production (TOTAL, 2013). According to TOTAL (2013) the forecast share will rise to 9 million barrels per day or 11% of conventional oil output. Nowadays the offshore activity takes 30% from the global production of oil and gas (Planet Energies, 2016). Moreover, this activity increased with creation of new technologies which allows to move further and further from the coast and drill at ever deep water depth, of up to 3000 meters below the ocean surface (World Economic Forum, 2008, Tillerson, 2006). Such technology as subsea complex made revolution in offshore oil and gas producing sector. Opportunities of deep water depth production and cost effectiveness of Subsea technology help to open new horizons in offshore hydrocarbon development (Urness and Hillegeist, 2012). Nowadays, technology of subsea complex spread among big oil and gas producers and service companies. For gaining competitive advantage, it is necessary to manage this complex in innovative way to achieve maximum of effectiveness from technology usage and as a consequences profitability.

Russia has the biggest reserves of oil and gas in the offshore area of the Arctic region (USGS, 2008). One of the biggest projects in offshore area in Russia is Sakhalin. In this project, proven reserves include 1.2 trillion cubic meters of gas and 5 billion tons of oil (Sisgeo, 2016). Shtokman gas and condensate field is also one of the biggest gas fields in Russia. The reserves of the field account for 56 million tons of gas condensate and 3.9 trillion cubic meters of gas (Gazprom, 2017). All these projects with huge reserves of hydrocarbon and a close location to potential consumers make attractive the development of offshore fields. However, energy boom cycle with high oil prices and then, since mid-2014, rapid declining of oil prices settling at a very low level has created new challenges for oil and gas producers (Gevoryan and Semmler, 2016). Russia as a main producer of oil and gas also suffers from this crisis. Moreover, sanctions, which were implemented against Russia, stopped the collaboration with foreign-service companies. Russian petroleum industry with lack of technologies is dependent from foreign technologies and innovations. The lack of technologies and recent oil crisis makes production complicated (Sliwinski, 2015). Low prices on hydrocarbons force Russian companies stop the big new projects and reduce the investments in existing projects (Analytical Center under the Government of Russian Federation, 2015). Nevertheless, sanction forces Russian industry start to develop its own technologies. National petroleum companies together with government have developed a plan to reduce the dependence from foreign technologies. One of the main point of this plan is creation of subsea complex. However, how this complex should be managed to resist such situations as oil crisis and other barriers in the future? What are the drivers that stimulates implementation of innovation? This thesis seeks to investigate which factors influence on implementation of radical and incremental innovation in subsea complex.

1.1 Technology as an advantage.

The main endeavor of energy around the world companies is a cost reduction in hydrocarbons production. According to such innovations as horizontal drilling, subsea technologies and hydraulic fracturing of shale gas, companies can keep the level of costs as low as possible. Moreover, it enables them to increase the level of production and make the production ecologically friendly. Innovative technologies give an access to unrecoverable oil and gas fields (OGRC, 2005).

However, some scientists argue that the pace of development and implementation of innovations in petroleum industry is slow (Perrons, 2014; Acha, 2002 and Sharma 2005). Most companies in the upstream industry is equity shared of oil and gas assets and it denies an opportunity to keep new technologies proprietary (Perrons and Watts, 2008). This problem can negatively affect competitive advantage. It is risky for developing and being a first user of innovation associated with the high cost. Most companies prefer to be the “fast followers” (Daneshly and Donnelly, 2004). From the concept to real technology innovations takes approximately 16 years (NPC, 2007). Some scientist characterized petroleum industry as “Low- and medium-tech” (von Tunzelmann and Acha, 2006) and “slow clockspeed” (Fine, 1998).

The industry seems to be changing. During the evolution of oil and gas industry, the companies became targeted at the development and management of innovative technologies (Chazan, 2013). It is the core of the industry that gives the competitive advantage and the size of the market share (Veasna, 2016). Spending on R&D for national companies and international oil companies has increased rapidly over the past few years (Thuriaux-Aleman, et al., 2010). However, there is difference between developed and developing countries, which have oil and gas resources. Developed countries such as Norway, the USA and the Great Britain produce technologies that provide them with technological advantage. They have a well-developed system of innovation and technological management. These countries have developed R&D activity in special hubs and universities. In addition, they invest a lot of money in R&D and as a result, they have many cutting-edge technologies in energy industry. These technologies are the foundation for service companies and the producers of hydrocarbons. Based on these technologies these companies can offer their services to developing countries and companies (KPMG, 2016). By this reason, companies with strong developed system of R&D management dominant in their local market and have an access to foreign markets.

Russia lacks such a progressive system of R&D (Gupta et.al 2013). Applied science in Russia is less developed rather than in developed countries. After the Soviet Union times the system of innovation and technology management is in stagnation. Unwillingness to make investment in R&D generates a critical crisis situation. However, Russia has huge reserves of oil and gas. It is the world’s largest producer of crude oil and second largest producer of dry gas (EIA Beta Russia 2015). Due to the lack of its own technologies, Russia mainly prefers to import technologies from companies that are more progressive. There are two ways of importing hi-tech technology. The first one is when a partially state- run company buys the technologies from abroad. The second way is when international companies come to the Russian market. They can be service companies or international oil and gas producing companies with subsidiaries in Russia. The technological gap and the existence of enormous oil and gas reserves attract service companies and international hydrocarbon producing companies. These two types of foreign companies allow to increase the profitability of the field by cost cutting technologies, innovations and engineering of process. In other words, they can provide their customers with all range of service to cover all upstream, midstream and downstream activity.

Nowadays the Russia Federation lives under sanctions. Foreign companies are denied to run business on its territories. Lack of foreign technologies and services decrease the production of hydrocarbons especially in the offshore area. It also reduces the market share of the Russian companies in the world market. In this case, it is necessary to elaborate own equipment for the production of non-conventional oil and gas on the shelf and develop our own system of innovation and technology management. The accomplishment of such a task can be challenging. The technological level of foreign-service companies is too high and competition in this field is tough. A system of close interaction between Government and private research centers to create big R&D projects is still under the development. Foreign-service companies have vast experience of creating technologies and this gives them advantage. In Russia, technological development in oil and gas industry has started recently. Before the crisis, the Russian companies have chosen not to invest much in R&D because of its CAPEX increasing. It was cheaper to sign a contract with a foreign-service company and get the whole cycle of upstream activity or just the technology like a drill or pumping station. However, some steps for creating own technology for offshore production were undertaken. The example, Gasprom's project "Prirazlomnay". Nowadays, the Russian companies such as Gasprom and Rosneft are trying to create their own technologies. In particular, they are focusing on subsea technology. However, the creation of innovative technology is only half way of efficient innovation and technology management. Different external factors in oil and gas market which influence on a company's performance force innovation managers to respond to market calls. It is also important to provide effective innovation and technology management. This topic is relevant for nowadays situation especially for Russian oil and gas producing companies. These companies have enough financial assets and government support for creating such technologies. However, the level of innovation and technology management is quite low.

Since the technology plays such an important role in oil and gas production and market demand, notwithstanding unsustainable oil prices, one could be lead to think that it would be important for the companies to develop technological and innovation management. However, these technologies also have to be modified and standardized. The main trend on the market is cost cutting. New technologies allow reducing the cost of production and making production of expensive reservoirs economically viable. Nowadays instability of oil prices makes this trend of cost reduction very important for companies around the world. The rate of technological management especially in Russian oil and gas sector seems not high (Deloitte, 2016). In this case, I want to study subsea technology development in Russian oil and gas sector from the innovation and technology management point of view to describe and analyze factors that influence on technological improvement of subsea complex in the Russian context. In addition, oil crisis creates an uncertainty that impedes the performance of a company. Based on that my research question for this thesis is as following:

What are the factors that influence on radical and incremental innovation implementation in subsea complex in Russian oil and gas sector?

2. Background

2.1 Subsea Processing Evolution

The first subsea well was brought into production in Gulf of Mexico in 1961 (Watson, 2013). After that event, in the 90's Norway became a leader in development of subsea technology moving forward with great strides. The first project with subsea technology was launched in Gulfaks field in 1982. Decision was made to develop this field by installing subsea complex on the seabed (Christie and Kishino et. al., 2000).

After that experience, it was admitted that the production of hydrocarbons on the seabed was realistic option. Engineers tried to create more cost-effective solutions and less complicate solution. The main purpose was a subsea complex to be fully integrated with existing technology and infrastructure. Moreover, that complex was connected with a platform (Urness and Hillegest, 2012).

In the end of the 90s, Norway was the leader in subsea technology (IFE and Sintef, 2016). In addition, Statoil started to penetrate with this technology into other markets and areas of the world. Firstly, Statoil tested off subsea in the cost of Western Africa. As a result, several large international companies became interested in this technology and subsea became more and more common. This technology radically reduced costs, increased recovery level and improved functionality (Statoil, 2017).

Subsea technologies allowed to get an access to new fields. However, new fields presented major challenges, temperatures and higher pressures associated with longer remoteness from shore (Rentcome, et al., 2011). During the period from 2002 to 2007 the major breakthrough was made in the modules of water removal and water injection (Abreu Farinha, 2015). The first seabed separation facility was installed in Tordis field in Norway (FMC technologies, 2017)

From 2007 until today, technological progress in oil and gas sector has grown exponentially. International companies implemented new technologies in offshore activity. For instance, in 2009 Shell for the first time implemented gas/liquid separation and boosting system in BC-10 project (Shell, 2017). In 2012, a compression project was implemented, where gas is to be exported and compressed to shore, with offshore operations in Gullfaks project in Norway (Mode Ramberg and Davies, 2016).

Nowadays, a subsea complex is not so rare, it is spread around the world and used by big international companies. It is not a unique technology but for every separate field subsea technology is developed. There are a lot of service companies that offer subsea processing equipment. Among the leaders there are such companies as FMC Technologies, Cameron, Akers solution and Schlumberger (Amadi-Echendu, et al., 2014).

The main advantage of subsea processing is not only the possibility for development of deep-water reservoirs, but the increase of the rate of hydrocarbon production. Moreover, subsea technology reduces the CAPEX (capital expenditure) by excluding topside equipment and deck space from the production process (Salgado Gomes and Barata Alves, 2007). The evolution of subsea technology can be seen in **Figure 1.**

As it can be seen from the figure below, subsea complex with the time changed radically and it continues to change. A lot of improvements were implemented. Modern subsea complex is complicated with various complicated components and systems (Piciaccia, et al., 2004). In this case innovation management plays important role in estimating in which way the technology will be modified.

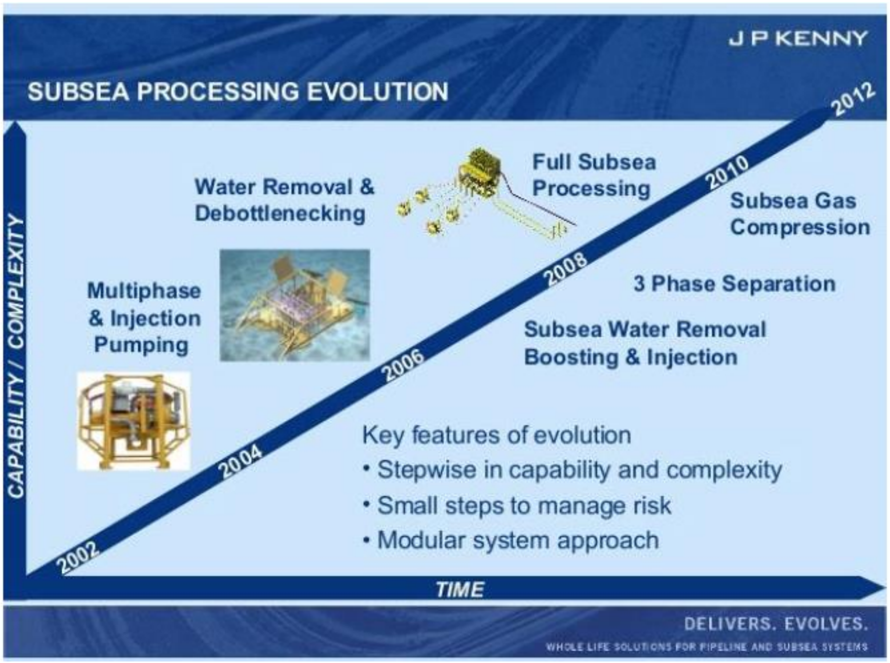

Figure 1 Evolution of subsea technology (Abreu Farinha, 2015)

2.2 Subsea complex

Subsea technology is a complex of submerged ocean equipment, operations or applications, especially at some distance offshore, in deep ocean waters, or on the seabed. Mainly, this equipment includes the "Christmas tree", the wellhead, drain risers and pipelines, interfaces connecting the drain system, control systems and operation of the well with sub-distribution system (umbilicals) (Cook and Graham, 2008). Subsea production systems can range in complexity from a single satellite will with a flowline linked to a fixed platform or an onshore installation, and to several wells on a template or clustered around a manifold production via subsea processing/commingling and transferring to a fixed or floating facility, or directly to an onshore installation. Additionally, one of the main component of subsea complex performance is power supply function (Bai and Bai, 2012).

According to what was saying above, the components of subsea system are:

- Drilling systems of subsea
- Wellhead and Christmas tree
- Risers and Umbilicals (communication subsea flow and interfaces – topside)
- Connections systems of subsea and manifolds
- Disposal systems and tie-in
- Control systems

A subsea production system can be used to develop reservoir, or parts of reservoir, which require drilling of the wells from more than one location. It is possible to be made through creating structure, especially of aggregating physical template or alternatively, generating a cluster and lying individually that is connected through flow lines to a common structure. In these both situations, transpiration of raw materials to the surface is performed by risers (huge flow lines) discharged into floating platforms Floating, Production, Storage and offloading (FPSO) or Floating, Storage and Offloading (FSO). Such kind of floating entities may have additional power for processing of hydrocarbons. Deep water conditions can dictate the development of the field by means of a subsea production system, since traditional surface facilities such as installed on a steel-piled jacket, might be either technically unfeasible or uneconomical due to a water depth. An additional function of subsea technology is that equipment may also inject water into various formations for disposal and it provides a pressure maintains in the reservoir. There are fast of subsea configurations with production and injection systems (Speight, 2015).

This technology made the process of oil and gas production less complicated and more cost effective (Underwater technology foundation, 2016). Moreover, it maximizes the recovery of hydrocarbons and extends the life of the oil and gas field (FMC technology, 2016). According to Jeff Spath (2014) the president of SPE, nowadays it is approximately 9000 operating platforms currently used and their quantity will increase. For efficient production producers cover reservoirs with much wider area, tying back subsea wells both to floating infrastructure in deepwater and to fixed platforms into shallow water.

2.3 Norwegian experience of innovation management in oil and gas industry

The cornerstone of Norway's resource management is the development of new technology and knowledge. Ever since oil and gas production began in Norway, the main purpose was to find the most efficient solutions for exploration. Innovative technologies have been an essential part for achieving a sound utilization of resources and a value creation on the Norwegian continental shelf. Basing on Norwegian experience, innovation management plays a vital role for a value creation and competitive advantage in oil production sector (Engen, 2007).

A major step forward in a subsea technology development was made by Norway and Norwegian oil and gas producing companies. For 30 years, Norwegian Continental Shelf was a laboratory for developing of innovative technologies. Cost reduction, insurance of sound environmental solutions and increasing recovery growth are the main aims of R&D in Norway. An extensive usage of subsea complex has revolutionized the way projects are generated and have made new solutions for development more cost-effective way (NPD, 2005). A subsea technology is an important milestone in the history of Norwegian R&D.

Nowadays, petroleum industry of Norway has state-of-the-art mastery and expertise of a wide range of innovative technologies and is capable of creating complex projects, especially in subsea creation and implementation. Moreover, positive effect from innovation capacity and competitiveness influence on other technological industries in Norway. Technological progress for the Norwegian shelf has created competitive advantage for the Norwegian supplier industry at the global stage (Stoltz, 2009).

The system of technological transfer is highly developed in Norway. Favorable framework conditions have given companies opportunities to develop technologies and conduct research (Engen, 2007). The success of technological development in Norway was achieved by close collaboration between the R&D institutes and oil companies that enables to develop of totally new technological solutions and projects (Thune and Gulbrandsen, 2014).

Moreover, new challenges and conditions like the IOR/EOR (improvement of oil production/enhance of oil production) of mature fields force companies to implement new technologies. Nowadays, there are fewer large discoveries and it becomes more demanding to develop remaining hydrocarbons from old fields. In addition, it is difficult for individual projects to cover all spending on technological development.

To guarantee a competitive advantage and a value creation for the future, it is necessary for Norwegian government, service companies, oil companies and other businesses continue to investing in R&D. These investments will support stable development of technologies and maximize safe recovery of hydrocarbon resources. However, it is very difficult to find funding for such expensive projects for oil production. Norway's government created the strategy "Oil and Gas in 21st Century" (OG21). This strategy has helped R&D institutes, universities, supplier industries, oil companies and government to agree on a joint national strategy for oil and gas. OG21 is flexible strategy and it changes according to a situation on the market and other conditions. Figure 2 demonstrates the organizations which take part in the creation of OG21 and its work. Norwegian Ministry of Petroleum and Energy establishes OG21. Legislation and other forms of regulations are the primary tools which are used by the government to encourage R&D activity. The Research Council of Norway also stimulates research and technology development through receiving direct allocations from the government. These allocations are distributed mainly between DEMO 2000 and PETROMAKS 2 research programs and to Stavanger and Troms ø research institutes. These organizations play a vital role in achieving aims that was set up in the OG21 strategy (NPD 2, 2017).

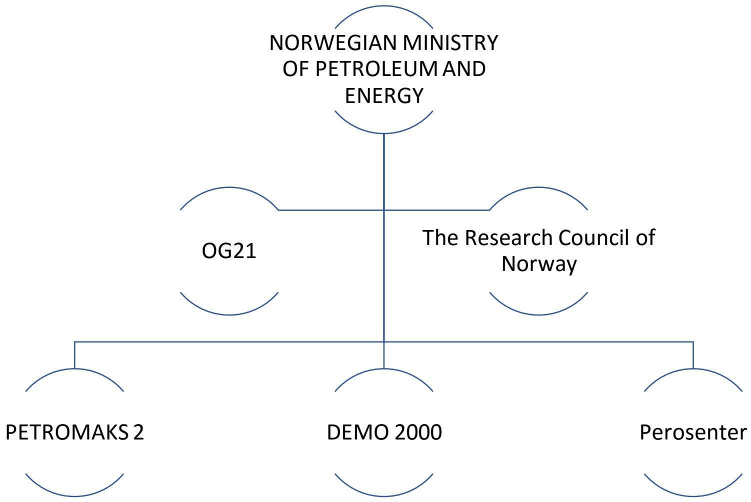

Figure 2 System of establishing OG21(NPD 2, 2017)

PETROMAKS 2 is the program that provides funding to a wide range of projects, from basic research in institutes and universities to innovation projects from private companies. This program takes the whole responsibility for the research activity that facilitate and optimize future-oriented development of the business and management of Norwegian petroleum resources. The PETROMAKS 2 program is vital tool for funding and promoting competence-building and long-term research. The program is mainly focused on education during the program period. The PETROMAKS 2 has large international interface with foreign countries such as North America, Brazil and Russia.

DEMO 2000 program is a vital funding tool for testing innovative technology solutions in oil and gas industry. The main aim is to reduce the risks and costs of industry by sponsoring pilot projects and demonstrating projects. In other words, this program is a collaborative arena for supplier and petroleum companies. Moreover, DEMO 2000 is open for any business that creates technologies and solutions for oil companies on the Norwegian shelf. However, DEMO 2000 covers just 25% of total costs of any given project.

PETROSENTER is research centers for petroleum activities. These centers are characterized by broad objectives and long-term prospect in order to solve estimated challenges for the production of Norwegian oil and gas:

- **ARCEx**- Research Center for Arctic Petroleum Exploration. This center was established in UiT the Arctic University of Norway. This center solves the challenges of relevance to the oil production in Arctic.

- **The National IOR Center of Norway** is aimed to improved oil recovery. It was opened in Stavanger. The center help to conduct relevant research, long-term competence-building and research training. It also facilitates cooperation between research communities and industry so that new technologies and solutions can be rapidly implemented.

The creation of new technologies or improvement existing ones is a costly and very risky activity (Rao and Rodriguez, 2005) Such structure of government and industrial cooperation facilitates the creation of innovative solutions and technologies. In other words, Norway's government stimulates private companies to invest money in R&D by helping them create technologies or improve technologies that they need. Moreover, the government takes some part of risk by covering expenditures on development and tests of the technologies. Thus, the creation of innovative technologies or improvement for existing ones becomes less expensive for private companies. This system of governmental innovation management makes it easier for private companies to manage their own technologies by creating innovative technologies and improving technologies that they have. All these facilitate innovation management in private companies. Modern subsea technology is a bright example of this interaction in action.

2.4 Russian experience of innovation management in oil and gas industry

Subsea technology is under the development in Russia. An interaction structure between government assistance and industrial investment is also in the stage of development. In most cases, big oil and gas producers have their own applied institutes or R&D hubs but their performance is at low level. Huge tests of innovative technologies are very expensive and risky for companies and this make it unprofitable for the Russian petroleum producer to fund new technologies. However, the imposed sanctions force Russian oil and gas producers to develop their own technologies and especially, subsea technologies. Mature fields onshore with decreasing level of production and attractive huge reserves of offshore make this subsea creation vital for Russian petroleum industry. In this respect, Norwegian experience is important for innovation management in Russia. It can be a good opportunity to use Norwegian experience of innovation management in Russia. Technological management is also essential because the creation of subsea technology is just the question of the time. Gazprom, the biggest gas producer in Russia, is now in process of developing subsea complex. The next step is management and improvement of this technology. For that purpose, companies should create their own model of technological development which might meet the market situation and demand.

3. Theoretical framework

3.1 Types of innovations

The term “innovation” is much easier to characterize rather than to define. Shumpter (1911) argues in his “Theory of Economic Development” that entrepreneurs brake stable situation on the market by creating innovations. Thereby, market stability changed to new economy cycles which depends on new innovation on the market. According to Kay (2007), Shumpert believes that success of the market economy depends on innovations of entrepreneur and not on accumulation of capital. Thereby, Shumpert estimates innovation as a new quality of product or a new commodity, opening of a new market, introduction of a new method of production, control of new source of supply and new organization of an industry. Shumpert understands innovation as something big and revolutionary. However, Witzel (2005) defines innovation not as a breakthrough or radical. He states that innovation consists of small incremental improvements to existing production *processes* or *products*, management and organizations and so on. Witzel argues that the main function of innovation is improve service or product and keep the business flexible with shifting needs of the market. However, the most beneficial innovations are gradual, slow and incremental.

For the purpose of this thesis, to discuss process of innovation as type of innovation that involves technological development, I consider subsea technology as the process of oil and gas production (Berg Aasen, 2009).

3.1.1 Process innovation

Innovation of processes creation for products production and innovations in product range are vital for industrial companies. Mainly, in most cases researchers pay more attention to the product innovation rather than process, without taking into consideration the interaction of both process and product innovation (Milling and Stumpfe, 2016).

Technology process innovation is the implementation of significantly improved or technologically modern production methods. These methods may be worked out from the use of innovative knowledge, and may include changes in production organization, or changes in technical equipment, or combination of these both. This method can be implemented to deliver technologically modern, or produce or improved products that cannot be delivered or produced with the use of conventional production methods. Moreover, this method can be implemented for increasing production and transportation efficiency of goods (OECD, 2016).

Utterback and Abernathy (1975) developed the product-process life cycle theory. This theory provides an explanation of the pattern of industrial innovation processes and products. Their model covers all mutual relationships between competitive strategy and process's stages of development, life cycles of the products. Utterback and Abernathy (1975) state that production process is a complex of process equipment, task specifications, materials input, work force, information and work flows, etc. that are recruited to produce a service or product. They developed a model where production process develops over time towards the rate of improved production output. According this model, technology improves in some patterns: becomes more capital intensive, labor productivity enhances by huge division of specialization and labor, the flow of materials is used rationally, the design of product is standardized and increase in process scale (Ettlie, 1995). Efficiency increases the result from incremental changes in these several variables, that are encouraged by the market change, within the company and external to the company (volume).

The process continues to aspire to the higher productivity statement through incremental changes in these factors. Just cumulative effect can change significantly all the nature of the process and lead to radical technology. Some stages of development that are similar in some economic sectors and industries can be determined in the specialties of production factors of wide range of processes. Process change or development may lead to the changes of internal organizational structure, technology based on capital goods and development of special materials. Utterback and Abernathy (1975) highlighted three stages of process development: uncoordinated, segmental and systematic.

Uncoordinated. Competitive environment and market expansion force company to a radically improvement of product or process. On this stage, radical innovation can be implemented. The level of process or product improvements are high and diversity of products or processes among competitors are great. Very often processes are performed manually and through unstandardized operations are performed by general purpose equipment. Thus, the production process is "liquid" with weak established relationships between process elements. This stage is flexible to the environmental changes but inefficient. However, there are certain challenges in this stage. One of them that radical innovative technology increase the costs as frequent changes in performance process of existence technology.

Segmental. Segmental stage comes after creating of the dominant design of technology or product. On this stage, specialized equipment for the production is implemented, rapidly increasing the level of innovation in production process. Operational tasks are more subjected and specialized to formal operating controls. Production process is carried out through automation and process control systems. However, in some cases can be situation where the main processes are performed manually relying on general purpose equipment, but subprocesses can be automated. This stage can be characterized by segmented quality of production. Nevertheless, production costs decrease.

Systematic. On that stage, highly integrated solutions are implemented in the company production process. Technological process is standardized. Typically, the production process become so integrated as a result   any changes in this process become costly. This means that redesign in one element of production process, will require changes in other parts of the process. Cost reduction is the main point of optimization in that stage. Redesign of one element or the whole production process comes slowly. However, cumulative shift on the market in implementing single element or the whole process can force company to introduce such technology on its production. Mainly, in this stage incremental innovation can be implemented.

Figure 3. demonstrates the pattern of process and product innovation with three stages.

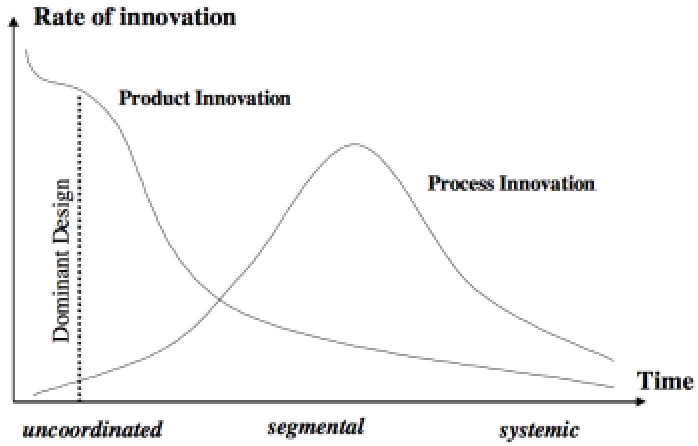

Figure 3 Utterback/Abernathy's model of process and product innovation (Utterback and Abernathy, 1975).

In 1978 Utterback and Abernathy developed more modified model of process innovation called "Pattern of innovation in technology". However, the basement for this model was the study which was written in 1975. The stages for the process development in the core are similar.

A lot of researchers differentiated collected commodities that form homogenous goods, like materials and chemicals, which are the result of performance of process industries (Piana, 2003; Robinson, et al.,2002). Abernathy states that new technology and interrelationships between process and product innovation are implausible for process-based products. In addition, he argues that the model is used directly to a unit of production in which multiple units are transformed and connected through a complex production process that gains a valued good whose features may be different. In situations where the commodity is definitely standardized (for instance, copper, sulfur, nylon or acid), the radical product innovation is restricted, in some cases impossible (Linton and Walsh, 2007). Oil and gas can be included in the list of products which are difficult to improve.

However, other scientists such as Nelson (1994), criticizes the model of Utterback and Abernathy. He argues about six or eight models that are more appropriate for explanation of differences between product and process innovation. However, Utterback in his paper in 1994 demonstrates that his model with small improvements has a value for homogenous or process-based products. Subsea complex is the process innovation which produces homogenous products. That was the reason why this theory was chosen for study. Moreover, the model above will help determine at which stage located subsea complex. It enables to establish which innovation should be implement in the complex according to the development of this technology.

3.1.2 Radical and incremental innovations

According to the literature and recent studies on innovation, there are some differences in the nature of innovation adopted. For the improvement of effectiveness or efficiency of a company performance, companies may implement product or process innovation, or both. There are two types of innovation that may be implemented: radical or incremental (Gersick 1991; Ettlie, Bridges and O'Keefe, 1984; Tushman and Romanelli, 1985). The former introduced the linear, cumulative change in product or process, representing simple or small adjustments or minor improvements in current technology (Dewar and Dutton, 1986). While the latter, nonlinear changes in paradigm, demonstrated significant departure from existing knowledge and practice. According to Dewar and Dutton (1986), incremental and radical innovation determine as the ends of continuum exposing the level of new knowledge included in innovation, and not as the separate categories. However, Dewar and Dutton argues that it is difficult to interpret the middle value of this continuum. Some researchers offer finer-grained distinctions in types of innovation (Henderson and Clark 1990; Meyerson and Martin, 1987).

According to Dewar and Dutton (1986), it is very difficult to find the distinction between incremental and radical innovation, and it is much easier to intuit than to measure or define them. Due-to the fact, that individuals rely on their experience in classification of innovation, individuals can differ in their perception of types of innovations because of their experience, position and expertise. Definitions of radical and incremental innovations can be seen in Table 1

Radical innovation	Implementation of fundamental changes in the company's products or processes, technologies and methods	Song and Montoya-Weiss, 1998; OECD, 2015; Meyers and Tucker, 1989
Incremental innovation	Refinement and improvement of existing technologies, products, processes and methods	Chandy and Tellis, 1998; Dosi 1988, OECD 2015

Table 1 Radical and incremental innovation.

As the study is focused on the process innovation especially in technology process, there are several features that characterized radical innovation in technology:

- Fundamentally new skill sets (Afuah, 1998)
- This type of innovation adds entirely new technological features that increase the performance rate or reduce the costs (Leifer, et al., 2000)
- Dramatically change the world around them by creating new lines of business (Bozdogan et. Al., 1998; McDermott, 1999 and Gilbert, 2003).

Incremental innovation for technologies and processes offer feature improvement or comparatively modest costs. This type of innovation saves the status-quo (Leifer, et al., 2000). Prior studies about upstream oil and gas industry explain that inherent riskiness stimulated incremental innovations (Daneshy and Donnelly, 2004). Nevertheless, radical innovations such as horizontal drilling and 3D seismic happened from time to time (Martin, 1996 and Yegin 2011; Managi et. Al., 2005). However, information about technology in upstream industry is lacking. Moreover, the understanding of both radical and incremental innovation in different companies and researches can be different. There is no strict scale by which it is possible to relate the technology to radical or incremental innovation, especially for individual companies (Antonelli, 2012). Some companies can interpret their breakthroughs as radical innovations, but for others it will be incremental changes and vice versa (Sen and Ghandforoush, 2011). This is a disadvantage. According to lack of literature concerning upstream industry, it becomes problematic in some cases to strictly determine radical or incremental technology in upstream industry. Nevertheless, subsea complex can be improved by radical innovation and incremental. The decision-making concerning which types of innovation should be implemented depends from the range of factors that influence on that decision making.

3.1.3 Radical innovation in subsea

Subsea technology is still a corporate secret of the companies who develop such technologies. In this case, it is very problematic to find any information or literature concerning the modifications of the system.

However, Santos (2015) developed a radical trajectory for innovations development in a subsea complex in Brazil. Technological development in oil production and exploration started to boost when pre-salt reserves in Brazil were opened. “Subsea-shore” is a radical trajectory including large scale offshore equipment and specialized technologies, transporting gas and oil through pipelines to floating platforms or shore. In other words, this trajectory is a radical innovation that consists of different technologies. This innovation allows to remote-control the transportation of hydrocarbons, to perform the task conducted on the surface. The term “trajectory” is one of three scenarios for technological development in upstream industry for Petrobras company (Oliveira, Ribeiro, & Furtado, 2014). Nowadays, Petrobras is the biggest oil producer in Brazil invest 153.9$ US billion in E&P underwater facilities (Economia Rio, 2014). The main aim of this scenario is to develop radical improvements for subsea complex by eliminating the need for the surface platform. The program was named “subsea to shore”. These radical innovations represent large uncertainties in technologies but can lead to an outstanding position on the market. However, there are a lot of scientific and technological challenges that need to be overcome.

The first challenge represented by the flow assurance arises from the various regimes of performance which can be combined with different fluids at low temperatures or low pressures. Second, flowlines (SURF) and risers and big amount of subsea umbilicals are under constant stress because of harsh conditions of the sea. In this case, it is necessary to cope with the economic viability and sea challenges. Another one more challenge is the facilities used to transmit power to a subsea complex. Modern technology can transmit only limited amounts of power and this is not enough for stable performance of a subsea complex.

According to research of Santos (2015), solutions for these challenges will be radical innovations which will bring fundamental changes in a company performance. Nevertheless, radical innovation is problematic for development and implementation. Radical innovation involves a lot of risks such the costs for development. In the process of development, it can be found that technology is very expensive or the end of R&D can fail (Keizer, 2013). Radical innovations in upstream technology can also suffer from these risks. This is a disadvantage. However, the result form the successful implementation of radical innovation can cover all spending for R&D and get competitive advantage. Radical innovations in subsea is still under research topic. Since it has the practical use, most companies make it confidential. Therefore, to find information or available research can be very challenging.

3.1.4 Incremental innovation in subsea

In petroleum industry, incremental innovations are more prevalent than radical ones. For the Campo's basin and pre-salt reserves Petrobras company, developed incremental technologies for a subsea complex. More precisely, the company developed subsea separation and subsea boosting. For that purpose, 3 projects were conducted: 1 in the sector of subsea separation, Marlim's 3-phase Subsea separation system and 2 in subsea boosting, Albacora's Subsea Raw Water Injection System (SRWI) and Barracuda's subsea Helico-Axial Multiphase Pump (SHMPP). These projects are the core of Petrobras new technology strategy for several years which aim is to improve and develop the basis for future innovations in subsea processing. According to De Abrau Farinha (2015), all these three innovations are incremental due-to the reason that some solutions in that technologies were used earlier and they not new.

Subsea boosting technologies were chosen for Helico-axial project. This technology has a long track record of successful implementations in a subsea complex (Lawson, et al., 2015). The most important challenge during the development of Barracuda-Multiphase Helic-axial pump was reducing the axial pressure on the bearings. The implemented solution was to re-qualify, for multiphase pumps, a very spread solution for gas compressors and monophase pumps, the balance piston. According to subsea boosting system, it is possible to argue that Perobras implemented incremental technologies (De Abrau Farinha, 2015a).

The main disadvantage of this type of innovation is that it is problematic to get big competitive advantage and become dominant on the market. However, such type of innovation doesn't require big investments in R&D comparing with radical innovation. The chance of successful implementation of incremental innovation is higher rather than radical improvement (Globerman and Lybecker, 2014). Such type of innovation allows to maintain competitive advantage. In upstream industry, this type of innovation is more spread rather than radical one (Kim and Maborgne, 2005).

Incremental innovation in subsea is still the question of further research too. Any information concerning this issue is closed from the public usage. However, using research above from De Abrau Farinha (2015) it is possible to argue that subsea complex can be improved incrementally in a various ways. It means, that there are a lot of opportunities of improving such complex.

3.2 Factors that influence implementation of radical and incremental innovation.

3.2.1 Uncertainties in innovation choice

Modern companies face a number of barriers and challenges when investing money in radical and incremental innovations. Nowadays literature defines four types of uncertainties when developing and commercializing radical and incremental innovations (Gassman et al., 2012). *Market uncertainties* define to what extent a customer needs are understood, to be transferred into products, and whether increased competitiveness in the market and value for superior customer is generated. Moreover, the situation on the market also influence the decision whether to invest or not. For instance, low oil prices suggest lower earnings. In this case, international oil companies are risk averse and prefer to reduce spending on R&D (Creusen and Minne, 2000). *Technological uncertainties* refer to a scientific knowledge base involving production process, maintainability and scientific knowledge base. *Organizational uncertainties* refer to a managerial conflict of stimulating radical or incremental innovations while pursuing operational activities. *Resource uncertainties* involve challenges of acquiring vital resources externally and internally to pursue radical and incremental innovation.

Companies that implement innovations in a subsea complex face different uncertainties. These uncertainties or barriers create the conditions the companies should follow while developing and implementing their innovation strategies. Decisions about subsea development has to be in correspondence with current market situation and other uncertainties. Implementation of radical or incremental innovation in subsea is defined by a company strategy and the company strategy depends on uncertainties or barriers.

3.2.2 Technology transfer.

According to Camp and Sexton (1992), for companies who implement new technologies for pursuing competitive advantage, process or product development and technology transfer are mutual processes. For understanding what is technology transfer is, it is necessary to define technology. According to Agmon and Von Glinow (1991), technology is a tool for conducting some functions. There are two types of this tool: mental model or a machine. There is a big difference between technology transfer in the high technology industry and other industries such as service, manufacturing etc. Technology process involves movement of technological innovation exchange (Eveland, et al., 1991).

Larsen et al. (1986), defines technology transfer as a process of innovation technology exchange between organizations and individuals who are involved in putting this innovation into action on the one hand and develop R&D on the other hand. Traditionally, technology transfer includes the an exchange of physical goods. However, modern technology transfer mainly relies on information exchange. So, it is possible to say that technology transfer is communication of specific information. In oil and gas sector technology transfer is communication of the information that helps to create new technology for petroleum companies and to achieve certain aim. The transfer effectiveness can be estimated through inconsistency between information received and information transmitted. However, some researchers state that it is more important to strengthrn the focus on return on investment rather than on accuracy of the effectiveness in the information exchange (Camp and Sexton, 1992).

There is two-way process of technology transfer. It is possible to determine technology process as a type of information exchange. Technology transfer should be seen as a continuous process rather than one certain event. For instance, private company should maintain close relationships with researchers from university for several years and exchange knowledge. It is necessary to have technology to exchange, or transfer from one organization to another so that technology transfer might occur. Research universities and institutes where scientist develop technologies and conduct researches plays one of the major role in technology transfer. In the USA, a lot of high-technological centers are located close to research hubs or universities (Inzelt and Coenen, 1996).

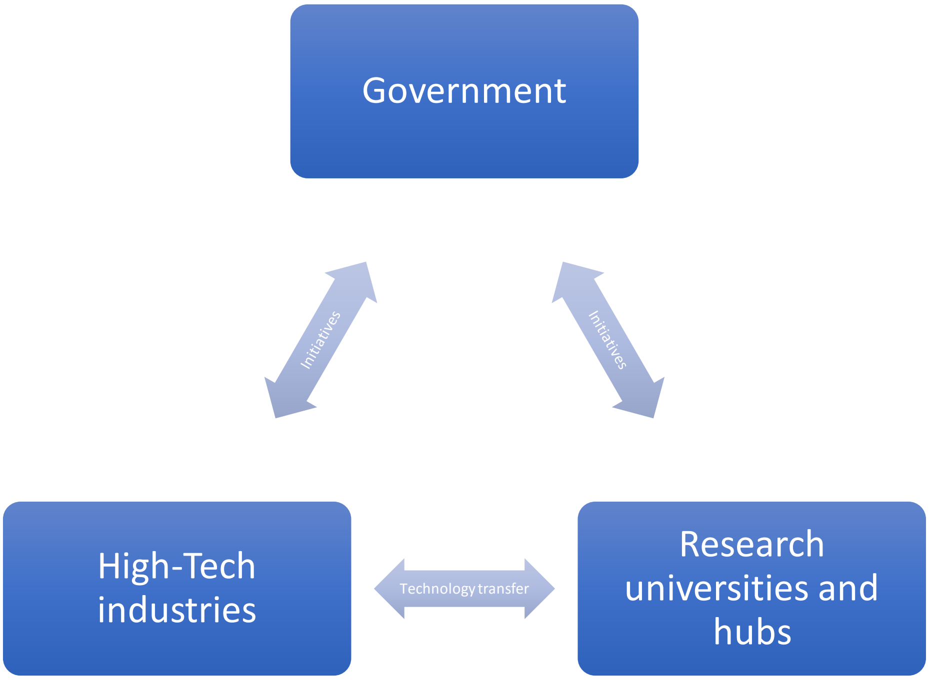

Figure 4 Technology process (Agmon, et al., 1991)

Figure 4 demonstrates how technology transfer is performed in private industry. On the top of the figure located "Government" is located. Government motivate technology transfer through investment in "Research universities and hubs". Taxes are the main source for the government to fund the applied science in universities. Government also stimulates the companies to interact with "Research universities and hubs" through open interaction platforms and incentives. The main force in universities which conduct researches and create technologies is scientists. Table 3.2.1 exposes typical mechanism for technology transfer between organizations (Agmon et al., 1991).

To achieve the gain from the technology transfer process, companies depend on the possibility to use this information or knowledge in a practical way. Without knowledge, it is impossible to create new technology. However, technology transfer can give an extra edge for the company (Camp and Sexton, 1992).

There are three stages of technological transfer. The first stage refers to obtaining of new information or knowledge. The second stage is the transformation of knowledge or information into new technology or product. The third stage is the penetration of new technology or product into the market (Camp and Sexton, 1992). In addition, there are five stages in the conventional model for developing new technology. Figure 5 demonstrates all stages and their definitions.

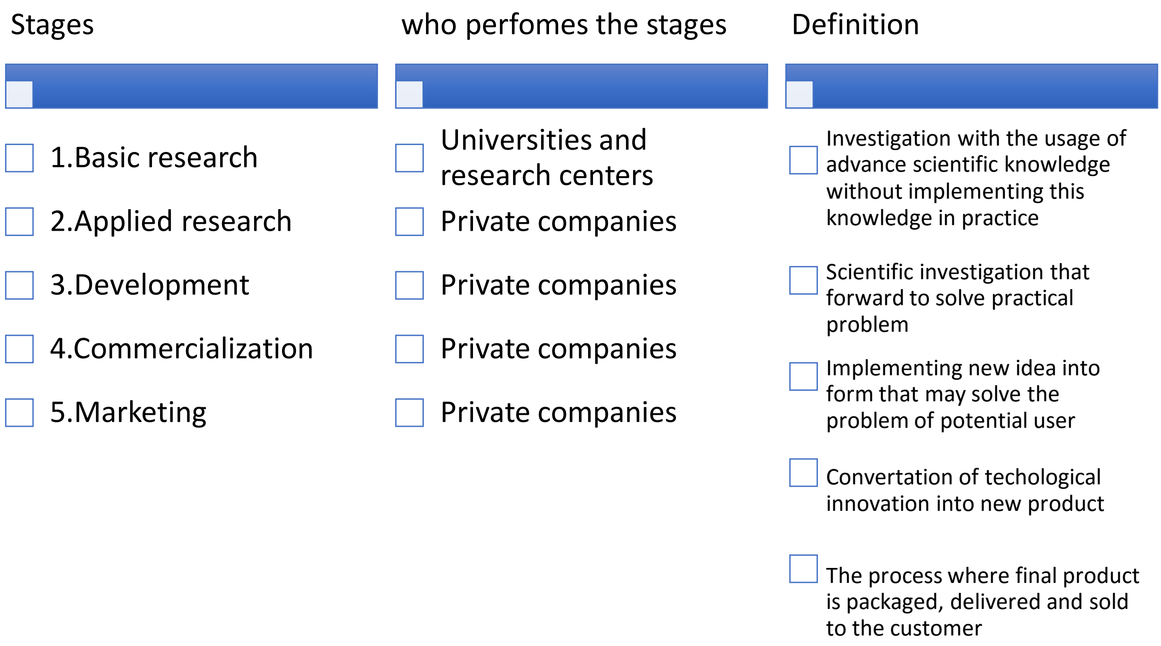

Figure 5 Stages in technology transfer process (Agmon, et al., 1991)

So, it is possible to conclude that technology transfer is a process of gaining information or knowledge from the other fields with the purpose to develop new technology. The most important part in technology transfer is cooperation between organizations. Technology transfer is performed across different industries. Usually, technological transfer is a positive thing. However, there is technological transfer between developed and developing countries and the result of such activity is ambiguous. According to Beladi, Jones and Marjit (1997), the transfer from developed countries to developing may injure the welfare of developing country. Ruffin and Jones (2007) also support this idea. They argue that low elasticity with large value for the developing country import propensity, may result in decrease of its real income. This means that for developing countries technological transfer may be unprofitable. Developing countries become dependent on foreign technologies and don't want to invest money in new technologies. However, the developed countries gain from technological transfer (Redor and Saadi, 2011). In this case, technological transfer may have negative effect.

Technological transfer is a driver for radical and incremental innovation development (Tanner, et al., 2003). Subsea technology is complicated system which is consist of different separate technologies. For this complex of technologies transfer may play important role in its development especially in Russia. R&D centers of big companies are weakly developed in Russia and can't cover development of all technologies in subsea. Moreover, there are a lot of challenges for well preforming technological transfer (Eletskih, 2013). In order to develop technologies such as subsea complex, government support is necessary for the private companies as well as interaction with governmental R&D centers in Russia. Norwegian experience in technological transfer can be studied for future development technological transfer in Russia.

3.2.3 Exploration versus Exploitation

Exploration and exploitation has an influence on the level of innovation in an organization. Exploration involves such terms as risk taking, search, experimentation, variation, discovery, innovation and flexibility. Exploitation involves such terms like choice, refinement, efficiency production, execution, selection and implementation (March, 1991). Exploitation strategy is very close to the term “incremental innovation”. Incremental innovation can be characterized as improvement, refinement and exploitation of existing technology. Exploration strategy increases the spending on R&D and simultaneously give a chance to achieve competitive advantage. Moreover, both terms describe the strategic choice of a company between using familiar technology with incremental improvements versus implementing radical innovation (Matters and Ohr, 2013). For a company, it is necessary to focus not just on one strategy. For example, companies which follow exploration strategy and avoid exploitation can understand that their spending on R&D is very high as well as risk and in the end, they may totally fail by their direction dependence from R&D technology. The companies suffer from big amount of underdeveloped ideas and the competence level of these companies in the sector is low. Other companies that focus mainly on exploitation suffer from suboptimal stable equilibrium (March, 1991). This means that they try to maintain and improve the existing level of production without any investment in radical innovations. Traditionally such type of companies fail their competitive advantage to firms that develop radical technologies or product. To sum up, it is necessary for companies to be in balance between exploitation and exploration to reach prosperity and survive on the market.

However, the main problem of balancing between exploitation and exploration is limited resources for which companies compete. Companies have limited financial resources. Their decision about investment in R&D or new technology will influence on its exist production. According to this, it is necessary for the company to make implicit and explicit choices between the exploitation and exploration. The explicit choices are defined between alternative funding and competitive strategies. The implicit choices involve such terms as customs and organizational forms. For instance, how the aims and incentive systems are achieved. Improving or maintaining the balance is important but difficult. The balance between exploration and exploitation includes challenges between long-term and short-term planning, survival strategy and decision-making (Puhan, T. and Puhan, X., 2008).

According to Winter (1997), one of exploration challenges of new technology is that it reduces speed, because of improving skills from existing technology. On the other hand, improved skills stimulate interest in learning new things. In evolutionary models of organizational and technologies types, the choice between exploitation and exploration is exposed as the process of selection and variation at balance. It is very important for the companies to select effective type, practice or routine. However, it is also important to overview modern trends and be flexible to market changes. Future orientation is one of the most important terms. Companies need to meet new requirements of future trends.

March (1991) also highlighted that the main problem of exploration is uncertainty. It is impossible to guarantee the positive result of R&D that will bring profit for the company. Exploitation is less risky. Companies already have something solid that bring them profit. Another challenge is that search for innovative technologies or ideas take a lot of time and involves a lot of uncertainties concerning the result than modifying existing technology. According to this, companies prefer to have exploitation rather than exploration. Thus, companies improve their technologies rather than generate innovations. Do petroleum companies prefer to modify their existent technologies rather than generating innovations? Do oil and gas companies prefer to modify a subsea complex rather than radically change it? If it is true, uncertainty is performing as a barrier to new technology. In addition, if a company focuses on sustaining development of exploration performance, switching performance to the exploitation will be either failure or self-destruction.

Previous experience plays a vital role in the adoption of exploration or exploitation strategy. It will stimulate implementation of new technology basing on previous knowledge (Argyris and Schön, 1996). The lack of knowledge from previous experience can be as a barrier for implementation of innovation.

What is understand under the term learning? Some people can consider learning as a process that creates a process or a "product" (something learned). The question, "What have we learned?" refers to the statement what new information was gained. The question: "How do we learn?" refers to the ability of understanding the process of learning and the ability to study badly or well. Each company draws lessons from its experience. It helps to estimate good or bad experience and the methodology, how this result was achieved. In the end the company receive more knowledge.

The process of a company learning involves a learning process that involves storing and processing knowledge or information, a learning product and a learner who involves in the process of gaining this information (Argyris and Schön, 1996). Organizational learning allows to improve the task by using new knowledge. This is the main point of organizational learning.

Achieving learning is a big field for discussion. Sagar and van der Zwaan (2005), estimated several factors for achieving benefits of learning. Inside an industry or a firm, improvements can be taken from production process learning. This point also involves learning by operating. It is about worker's implicit skills. These skills allow more efficient operation using given technology. Implementation is a part of learning. When technology is implemented simultaneously learning is achieved because of experience from this implementation (Sagar and van der Zwaan, 2005). Learning through implementation can lead to refinement and improvement of institutional structure. This structure plays a vital role in implementing new technology.

Innovative institutional functions for maintenance of technologies and getting finance is an example of such a structure. Cost reduction of execution of a project and process effectiveness are advantages of these functions. Moreover, all the knowledge from the learning process is relocated into R&D and after that relocated in improved products and technologies in the future.

To sum up, the main point of exploration is experimentation with new variants. It leads to uncertainties and may lead to negative result. It is a more risky strategy. The main point of exploitation is extension of existing knowledge, paradigms and technologies (March, 1991). The main point of exploitation strategy is that it is predictable, positive and proximate. A successful performance of a company depends on the balance between exploration and exploitation strategies. Previous experience may lead company to choose exploration rather than exploitation. There are different advantageous of exploration strategy such as decrease of production costs, and an increase of profitability. However, it will lead to the costs concerning installation, maintaining technology and operating (Sagar and van der Zwaan, 2005).

Development of subsea complex directly depends from exploration or exploitation strategy of a company. Exploration strategy defines radical improvement of subsea complex. Exploitation strategy defines incremental improvement of subsea technology. Implementation one of the two strategy will stimulate the development of certain type of innovation. These strategies can be as drivers for development and implementation innovation in subsea. According to the theory, the best way is to provide both strategies simultaneously. In the process of creation subsea complex learning process plays important role. For instance, gaining experience on the technology testing phase allows to create ideas about future incremental improvements. Learning process in the subsea complex exploitation allows to collect the experience for the future modifications. The lack of learning process of subsea exploitation can be a barrier for future improvements of the complex.

3.2.4 Costs in the industry of high technology

High technology industries require big investments in improvement technologies. Production fixed costs are very high. This statement also involves high costs of CAPEX (capital expenditure). However, the costs of an extra unit of a product is low (Hill and Jones, 2004). A good example is Microsoft with its software. In the development of Windows XP software costs 1 US billion dollars but the cost of production of one version of XP software costs close to zero. Is it possible to say that the situation in petroleum industry is the same? And do the development and production of subsea also support this point of view? Commonly exploration and drilling are expensive. However, after the installation of all equipment the cost of a barrel is virtually zero. The story with subsea complex is different. Nowadays the most of subsea projects are unique. This means, that projects that are unique cost a lot and current purpose of the oil and gas production companies is to create standardized subsea complex to reduce the costs in production.

It is vital to understand the importance of cost structure for estimating the strategy. In addition, it is also important to know that with expanding production marginal costs also will rise. With an increase of production level, it will be necessary to acquire additional machinery and employ additional staff.

Subsea complex refers to the high technology industry (UK trade and investment, 2014). Costs for creating radical and incremental innovation for subsea complex is high. Furthermore, each subsea complex is unique. It constructed for special requirements of oil field (Hereema company, 2016). Thus, it is difficult to decrease production costs of extra unit of subsea complex. This can be a barrier for investing and developing of radical and incremental innovation.

3.2.5 Technological paradigm shift

Technological paradigm shift happens when radical innovation change the industry and penetrates on the market. The technological paradigm shift change the structure of the market. It forces companies radically change their production or production process to survive on the market (Hill and Jones, 2004). The good example of paradigm shift in petroleum industry is unconventional oil and gas production. Hydraulic fracturing caused a revolution on the market (Ortiz, 2014). This technology opened new areas of production of hydrocarbons.

Each paradigm shift is based on the S-curve (see Figure 6). This curve demonstrates the maturity of technology and allows to estimate on which stage of maturity technology located. At the beginning, innovative technology faces a lot of barriers and challenges and this is radical innovation. Then new technology starts to rise reaching the point where the whole market accepts innovation. Simultaneously in the stage of growth technology improves by incremental innovation. After that market saturation of this product comes and product becomes not interesting for the market. Demand for such product decreases. Then new innovation enters the market and takes over. Company invests huge amount of money in its technology. However, with the maturing of technology the company investments become less and less. In the end the company switches its attention to better and new technology (Cvetanovic, et al., 2012).

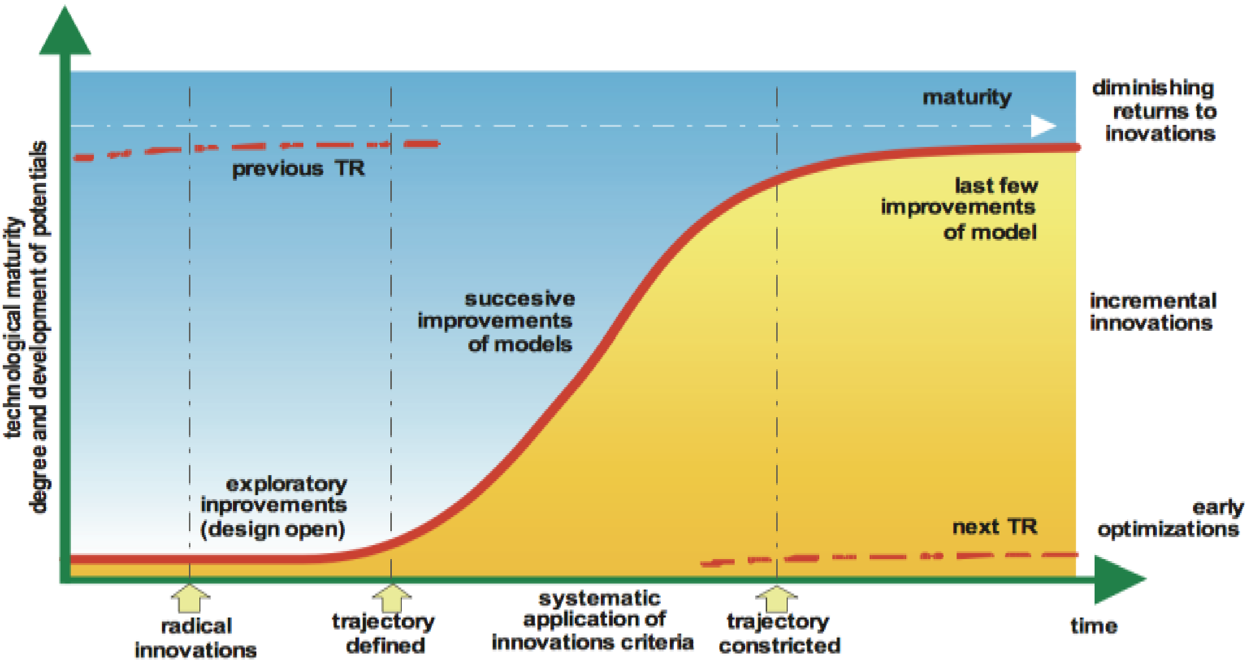

Figure 6 Technological paradigm shift (Perez, 2004).

The key of technological paradigm is complex of technological fundamental innovations. The core factor of development is innovations that represent the design of existing technological paradigm. The fields with leading role in commercial valorization of their possibilities and in the innovations, expose the most propulsive spheres. Hill and Jones (2004) by referring to Foster determines the term “natural cycle of technology”. It happens when scientists switch their attention to the new technology that can bring profit and replace the existing technology because of reaching a limit from it.

Technological paradigm shift allows to gain competitive advantage by implementing innovation in a necessary time period. Moreover, implementation of radical innovation helps company to achieve a first mover advantage and in some cases disadvantage. However, disadvantages are also opportunities for the companies to be the first in understanding mistakes.

This theory helps to identify the maturity of subsea complex. The location on the S-curve allows to make decision concerning the future technology improvement. Location of subsea technology on the bottom of the S-curve defines necessity to implement radical innovation. Incremental innovation implements when subsea complex reached the middle stage of technology maturity.

3.3. Analytical model

The discussed above theoretical framework is divided into two groups. The first group describes how subsea technology can be modified or radically changed by two types of innovations. The second one describes what factors shapes decision making about the type of innovations to be used at a subsea complex implementation.

Subsea technology can be referred to as the process innovation. Subsea complex produces oil or gas. They both are homogeneous products. Thus, oil and gas producing companies focus their attention on the process innovation. Subsea complex as a process innovation can be modified by radical or incremental innovation. Two key factors for choosing one of the innovations are the company strategy and innovation management.

Radical innovation totally changes the performance of subsea complex and radically improves the production of hydrocarbons. It allows to gain the first mover advantage on the market.

Technological competition on the market between oil and gas production companies is very high. Moreover, the companies who gain the first mover advantage establish new level of qualitative performance. It involves such issue as environmentally friendly production, effectiveness of production, lower level of vibration, etc. All these terms are under regulation of the ISO (International organization for standardization)[1] and API (American petroleum institute)[2] (Stark, et al., 2001). It means that companies adapt standards of API and ISO through their own technologies and by this win competitive advantage (Sam, 2016).

Incremental innovation is the improvement of existing technology. It is less expensive and more spread comparing with radical innovation. Incremental innovation allows to maintain existent competitive advantage by reducing costs. Improvements of some parts can make the technology easier in service. Usage of more reliable materials can improve construction of technology and prolong its life (Seligman, 2016).

Both types of innovation depend on the company strategy and innovation management. There are various factors which influence on the decision making concerning the radical or incremental innovation implementation. One of the major factor that has big influence is *uncertainties in technological choice*. As was mentioned above there are several uncertainties which influence on innovation choice, but for petroleum industry for technology choice the main driver is oil prices (PWC, 2015). Oil prices are involved in market uncertainties. This study focuses on the analysis of a subsea complex. This is a very difficult and complicated system which operates under different conditions: deep waters, low temperatures and low lightning. All these lead to technological challenges and *technological uncertainties*. Both of types of uncertainties can be a barrier for developing new technologies in subsea technology in sense that managers will limit money on R&D because of low oil prices and the lack of knowledge in subsea technology development. The main point for preparing to these uncertainties by the companies is to build model which may predict as many variants of the technology development in case of market fluctuation as possible.

Technological transfer of subsea complex is also a part of the theoretical discussion. Technological transfer plays the vital role in development technologies in petroleum industry.

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[1] ISO is one of the biggest organizations which creates norm and standards for petroleum industry. It involves 167 national standards bodies. It plays the vital role in establishing sustainable and safe technology in petroleum industry (ISO, 2017).

[2] API establishes petrochemical and petroleum equipment and operating standards (API, 2017). Another important function of API is certification of technologies. A lot of countries use these standards in the process of giving licenses for production (API, 2017b).

Technological transfer in developed countries is very progressive. It means that the connection between R&D centers and private companies is very high. In developing countries like Russia technological transfer especially in oil and gas industry is very weak. Subsea complex is very complicated technology which involve different technological innovations. Moreover, each company that produces such complexes produces unique subsea system. This uniqueness gives competitive advantage to these companies on the market. In this case, technological transfer between companies becomes very difficult. Nevertheless, the system of interaction between R&D institutes and private companies developed at a high level. In developed countries government helps home companies to achieve competitive advantage by creating a lot of programs of stimulating home business. Moreover, it stimulates the interaction between the R&D institutes and private companies. According to this, it becomes possible to create such complicated technology as subsea complex.

The lack of technology transfer can be a barrier for technological development. The low development or dysfunction of one part of Figure 4 above may lead to the lack of technological transfer at least. This dysfunction is spread in developing countries (Falvey and Foster, 2006). Accordingly, such countries prefer to import technologies and this is an additional barrier for developing their own technologies. These countries have some gaps in technology transfer process. Thus, it is very difficult to develop technologies in such conditions. However, if a company has its own R&D hubs or institutes, it adds efficiency in technology transfer. In addition, a company can control the process of technology creating and this case also adds effectiveness to further technological implementation and usage. In case of a good system of technology transfer between different organizations, it is possible to achieve competitive advantage by creating innovation. However, companies cannot totally control the process of creating such innovation and this is a disadvantage.

Exploration versus exploitation approach is an important issue to make an analysis as it defines two types of company strategy. As was mentioned above, it is necessary to be in balance between exploration and exploitation strategy to achieve success. Exploration strategy refers to radical innovation. Exploitation refers to the incremental. According to the study, subsea technology should be improved in radical and incremental way simultaneously. However, it can be difficult due to the various factors. The company’s strategy defines what is really necessary for the company and time horizon. For a short-term strategy or cost reduction strategy it will be more suitable to invest money in incremental innovation. For implementation of radical innovation, it is necessary to have long-term plans and a lot of money to invest in R&D. All the range of factors that influence on the strategy of decision making influence on exploration or exploitation strategy acceptance as well. Furthermore, if the company has a lot of money and resources, the best way is to develop both strategies to achieve maximum result.

Subsea complex as a main tool for oil and gas production in the offshore areas also follows these rules. Moreover, for developing countries or the countries which imported technologies it is important to invest money in learning process. Due-to the lack of knowledge and experience in this sphere of subsea construction, it is very important to develop own technologies to get rid of dependence on imported technologies. Subsea technology is a complex that consist of different parts. Generally, it is a complex of innovations that can perform in extreme conditions. Learning process from previous experience is vital for further development of this complex. Learning process in this case is involved in exploitation activity for the current improvement and stimulates exploration for further creating of radical innovation.

Ia stated earlier, radical innovation as well as incremental innovation involve big risks. Thus, the costs in high technology industry is necessary to discuss as risk of losing money and time can fail the innovation. Capital expenditures on radical innovation are much higher than on incremental innovation. For companies, such investments are big but the gain that they can receive is also huge. Profit and big market share after implementation technology in the process of production can cover all the risks and spending. As a subsea project is unique, the standardization of such technology will allow to significantly reduce the costs on production and exploitation.

Technological paradigm shift can help to address the estimate on what stage a subsea technology located. This estimation will help to understand which type of innovation is necessary to implement radical or incremental from the position of technological development. It is necessary to mention that subsea technology is not new. The first complex was developed in 1980-ies. Over time it was radically and incrementally modified. Nowadays, after all modifications this complex can be referred to innovation.

The analytical model for my research project consists of the factors that have influence on decision making between radical or incremental innovation implementation in subsea complex (see Figure 7).

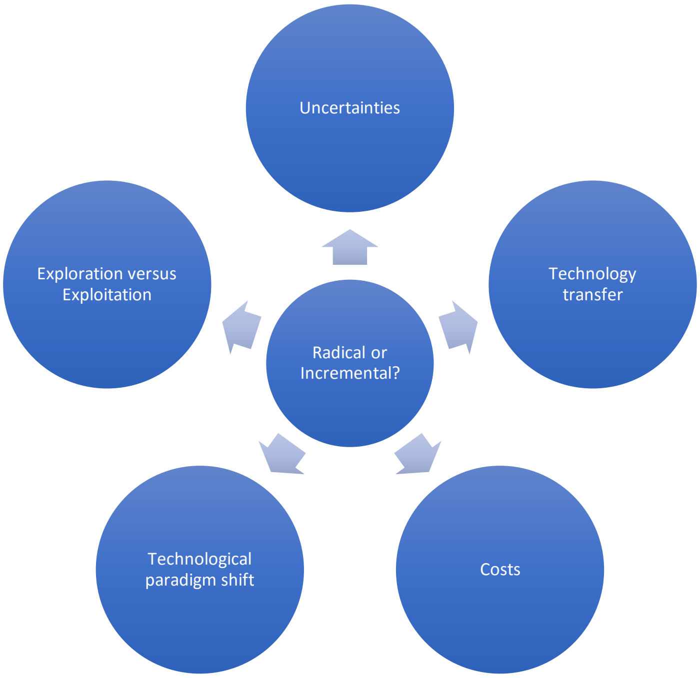

Figure 7 Factors that influence on implementation innovations

Each circle around the central one represents the analytical approach and the central circle represents two types of innovation. Each discussed approach has its own features that influence on the process of decision making from the different points of view.

4. Methodological chapter

4.1 Qualitative Method

There are two methods for research construction qualitative and quantitative method (Creswell, 2014). Implementation of the method depends on the purpose of research. Quantitative research is better when research concerns the measurements. The main advantage of this method is that it can cover wide range of situations. The main disadvantage is that quantitative method not so useful in understanding the reason that causes such an event (Sounders et al., 2009). Qualitative method is much better in understanding situations and study phenomenon. This approach is appropriate when pre-knowledge about phenomenon is unknown or phenomenon was studied but in a poor way. It is necessary for researcher to be involved in research for more deep study. It involves talk to the people and observation of society performance. It should be also mentioned that it is possible to use both approaches simultaneously. Qualitative method gives a big depth of subject understanding (Berg, 2009).

There are three types of research question which are suitable for the qualitative research (Johannessen et al., 2005). The first one is when the aim of research question is to estimate the opinion from the specialists about some event or action. The second one refer to the desire of researcher to describe something that is specific or unique and connect with specific or unique events. The third one is when the research question is mainly based on the theory and a researcher wants to estimate for what reason such events happened.

The purpose of my research is to describe what shapes decision making or what are the drivers and barriers in petroleum companies concerning development of innovative technologies in subsea complex. For this purpose, qualitative approach is implemented. It allows going in-depth with challenges and drivers that petroleum companies meet before they make a decision which innovation should be implemented. It is also necessary to establish barriers which stop development or implementation of radical or incremental innovation. This study can give an explanation which factors have the strongest influence on the decision-making process and which decisions are made under these factors influence. The chosen qualitative approach allows to collect information as much as possible in the area of a subsea complex. In this context, quantitative research is less effective. This approach is weak in mindset collation of the decision takers. Moreover, it is also difficult to understand the reason of their decision making through quantitative analysis.

4.2 Research Design

The research design involves such point as data collection and the way the data are analyzed. The data analysis should be provided in the way that best explains and answers the research question. Mainly, scientists highlight three types of objectives in research: exploration, description and explanation. For this research case study method was chosen. There are a lot definitions of case study method. However, the main point of this approach is that it looks in depth at one, or a few events, organizations, numbers or individuals over a certain time period (Easterby Smith et al, 2015). Berg (2009) argues that case study includes a systematic collection of information about particular event, person, social event to allow a researcher to estimate effectively how a subject perform. For this research project, case study fits perfectly because in this research I tried to understand what drivers and challenges influence on the subject.

For this research, explorative case design was chosen. It is appropriate for the investigation of the research question. The main aim of the case study is to generate an understanding why such phenomenon is happened (Johannessen et al., 2005). Concerning research what are the factors that influence on radical and incremental innovation implementation in subsea.

4.3 Primary data

Empirical data or primary data are gathered by researcher. It gives high level of confidence that all data will obtained and structured in the right way and fit the objectives of the study (Easterby Smith et al, 2015). Collecting data is costly thing and it consumes time. For the primary data, remote interview was taken.

Appropriate data is the main point for the data collection. For this purpose, remote interview through email was conducted. This method is asynchronous and has a lot of advantages. First advantage is that respondents have time to think carefully about their answers. As was previously mentioned, the thesis topic refers to the corporate secrets of the private companies and the answer should be carefully thought over. According to this, respondents may control their answers. The second advantage is that remote interviews allow participate at different times, giving respondents great flexibility. The third advantage is that remote interviews save time and money for a researcher. Moreover, saving time allowed to devote more time to a deeper study of the subject. It gave for me better understanding of the subject (Easterby Smith et al, 2015). However, remote interviews also have disadvantages. One of them is that a respondent in his answer can rise an interesting topic and it will require me to send to him additional questions to cover this topic. It will take additional time and disturb the respondent. In this case, questionnaire should involve the questions with maximum coverage of the topic. Nevertheless, such type of interviews may be affected by a sudden drop-out and distraction of the respondents (Tracy, 2013).

There are two reasons that forced me to implement remote interview in this thesis. The first one is that respondents are located in another town and they are too busy to give a private interview. The second reason is that the answers concerning the opinions of the respondents and all answers should be thought over. However, all respondents agreed to give additional information if there is a necessity to follow up some of their answers. This means, that I could ask additional question by email to achieve the deep answer of the respondent.

4.4 Secondary data

The primary data in the research were built upon the secondary data. The secondary data were used for constructing background of the thesis. It consists of companies reports, book and science articles. The secondary data are the resources that already exist and they can be collected through buying them in research center, institutes, etc., and free sources. This type of data involve private or public database, government papers, articles, reports, annual reports and internet sites, etc. The main advantage of the secondary data is that they save money and time for a researcher. Moreover, according to the secondary data it is possible to study previous studies and find other information which is relevant to your own research. However, the secondary data have some disadvantage. The main one is the quality of the secondary data. Some sources represent low quality information or the data on such sources can be uncertain.

For this thesis, the secondary data were chosen from official sources such as R&D institutes, science direct journals, government papers and companies reports. All the secondary data gave the valuable knowledge for constructing the research. The secondary data gave the basement of knowledge that further helped me to estimate vital research elements and relevant issues for research.

4.5 Sampling

In order to be able to make a conclusion about innovation management and technology development in subsea complex it is necessary to gather the data from people and organization who are involved in this issue and in this research population is a whole range of organizations that are involved in oil and gas production in Russia. It is possible to refer the term "population" to the whole range of entities that make decisions related to the issue. The term "sample" refers to entities' subgroup from which evidence is collected (Salkind, 2010). The main purpose of the research is to use evidence from a sample to estimate the conclusion about population (Easterby Smith et al, 2015). In Russia petroleum industry is represented by the oil and gas companies, government, service companies and research institutes. However, as was previously said Russian companies don't have their own subsea technology. All subsea complexes in Russia are the property of foreign service companies. These service companies promote the whole range of service to these complexes. Big Russian petroleum companies just develop such technology and the main R&D organizations take the major part in this development. For this purpose, Krylov State Research Center was chosen. This is one of the biggest R&D centers in Russia which develops technology for offshore production of oil and gas. Specialists in this center also provide companies with the strategies concerning technological development in oil and gas production. They create innovation of both radical and incremental type, estimate the level of technological development of technology. Moreover, this center approves the quality of technologies that elaborated by other organizations in Russia. This is the biggest center of offshore activity in Russia. The creation and modification of subsea complex is under Krylov Center jurisdiction. This organization is perfectly fits the topic of the thesis (Krylov State Research Center, 2017).

The basement for the case method is epistemology (Easterby Smith et al, 2015). Epistemology is defined as the theory of knowledge. The main focus of epistemology is nature, origin and a scope of knowledge. There are a lot of definitions concerning the term "epistemology". From philosophical point of view epistemology is the study of knowledge and nature; in particular, the study of defining components, limits of justification and knowledge of the sources and substantive conditions (Moser, 2002).

	Positivism (Yin)	Positivism and Constructionists (Eisenhardt)	Constructionist (Stake)
Design	Prior	Flexible	Emergent
Sample	Up to 30	4-10	1 or more
Analysis	Cross-case	Both	Within case
Theory	Testing	Generation	Action

Table 2 Key features of case method informed by different epistemologies (Easterby Smith et al, 2015).

My position in the research is between social constructionism and relativism. The main point of relativism is that scientific laws are created by people, there are many truths and viewpoints depend on respondents. Social constructionism also maintains the idea that reality is socially constructed (Easterby Smith et al, 2015). According to the Table 2 constructionist sample is more than one person.

	Company or organization	Position of the respondent	Experience in the industry
1	Central design bureau "Baltsudoproyekt"	Head of platform construction department	14 years
2	Krylov State Research Center	Head of oil and gas production department	12 years
3	National research University - Higher School of Economics	Head of national research department in oil and gas industry	6 years
4	National research University - Higher School of Economics	The main analyst in the field of oil and gas industry forecast	6 years
5	Rosneft	Head of technological development and innovation department	5 years

Table 3 Sampling

All five respondents were taken from different organizations: Central design bureau "Baltsudoproyekt"; Krylov State Research Center; National research University - Higher School of Economics and Rosneft. This is purposive sample. All respondents work in departments which are closely connected with technology planning and technological foresight. They have a high level of competence in the field of technologies in offshore area (see Table 3). Moreover, these specialists have big experience of interaction with such giants like Gazprom, and Novatek. These companies are the biggest oil and gas producers in Russia. Gazprom and Rosneft company are the main companies who requires subsea technology in offshore area.

4.6 Data analysis

The empirical data were gathered by a semi-structured open questionnaire. The questionnaire was structured in the same way as the progression reading themes. It makes very comfortable to read and analyze data collection. The data from all respondents were collected and compared with described theory. In other words, my empirical was explained or corrected by the theory. The theory chapter described what can be as the drivers or the barriers for innovation development and implementation. For the analysis part, I've tried to find out how these factors work in practice. Respondents were asked about their opinion concerning drivers and barriers for radical and incremental technology implementation. Informants have not been asked about theoretical questions because it would not have any purpose.

4.7 Validity and Reliability

It is very important to be concerned about validity and reliability. Delamont (2012) argues that the research procedure offer a high level of security against the mistakes, but mistakes can happen in the scientific findings. It is possible to make a mistake in executing the methods of the research. It can happen through such things as poor interpretation of data, contaminating evidence and biased samples. It is very important to look carefully to avoid such mistakes. Validity refers to how well a test is measured and what is purported to measure. There are two types of validity, they are external and internal (Huitt, et al., 1999). Relativist fashion of case study has the similar concerns as in the positivist study. Validity is less concerned in constructionist epistemology in case study, but it forwards to provide a rich picture of behavior and life of an organization (Easterby Smith et al, 2015). According to this fact, internal validity in this thesis refers to the questionnaire, researcher, respondents and their statements. Different respondents may understand the same questions in a different way. However, all respondents understood the questions in the way that I want to measure based upon preliminary discussions. I have tried that all aspects of my research question were covered. Some of the respondents commented my questions in depth and I had the possibility to follow up if something was unclear. Additionally, respondents were asked to add something more if they wanted to add something. All the respondents have big experience for the analysis of technologies and decision making concerning their improvement in petroleum industry (see Table 4.5.1). Further in the research, I will mentioned all experts through their numbers.

The term external validity refers to the statement of possibility to use the results of the research beyond the study. In other words, is it possible to generalize the results of the study to other settings? (Isaac and Michael, 1971). However, for this research generalization is not the purpose. The main aim of the study is to estimate the factors that influence on the process of decision making. A small size of sample for qualitative research like this one has low level of external validity. The usage of subsea technology in the research makes this study unique. However, other industries like mining may find common features with petroleum industry and this makes this study valuable for other industries as well.

The term “reliability” refers to the term that the study can be replicated over and the result will remain the same. I am confident that the result of this study can be implemented by other researches. If the respondents and researchers are different, the result should be the same. However, the design and theories should be the same as in this study. The answers in the questionnaire may be different. Nevertheless, the main points in the answers will be the same. Reliability can be reduced just by researchers who can interpret the answers in a slightly different way, and that is why this conclusion of the research may be changed. As was mentioned above, my sample has a high level of confidence in the area of my research. According this fact, I am sure that the answers of respondents help me to answer my research question.

4.8 Ethical consideration

Bryman and Bell (2011) discusses ten principles of ethical practice. Three of them improve lack of bias and accuracy in research other seven refers to the information and subject interest protection. There is always exist possibility that respondents put their reputation, name and job at stake when they give their opinions through interview or questionnaire for scrutiny. In order to protect respondents, it is necessary to use such tools as anonymity. It allows to shield information from the people. It is also necessary to avoid interpret information of the respondent.

Firstly, I informed personally all respondents about what kind of information I needed from them for my thesis and I would protect their information. It allowed me to avoid misunderstanding with respondents. The main advantage of my research is that all respondents answer to me by email. This allowed to them to think over their answers. They wrote the answers which did not contradict their professional ethic and rules of organizations where they work. Answers through questionnaire let avoid bias with the answers of the respondents, because they wrote their answers themselves. All the meaning of respondents were made anonymous.

5. Findings and Empirical Data

5.1 Innovations in subsea complex

In this paragraph, I will present the findings made through my secondary data and interviews. The aim of this chapter is to expose what experts from oil and gas industry see as innovation in a subsea complex by dividing description of innovations into two groups: radical and incremental.

5.1.1 Radical innovations in subsea complex

My respondents understand radical innovations in subsea as radical innovations in development of stranded hydrocarbons. In this case, radical innovation is the implementation of new project decisions for a subsea complex that considerably changes functional characteristics or separate nodes, thanks to which the possibilities of their application extend. The development of radical innovations is necessary for the development of fields with harsh climatic conditions for example: the Arctic waters, the deep fields or the fields located at a great distance from the coast.

Respondents highlighted the following directions of radical innovations development in subsea complex. The first one, is the buried subsea modules. These modules buried lower the ground level and by this they protected from the icebergs. Such modules can perform in the Arctic zone without the fear to be damaged by icebergs. Then, subsea-ice drilling and production complex. It allows to perform in Arctic conditions without help of float drilling systems. Moreover, such system makes the complex independent factory which can drill, produce and separate the hydrocarbons.

Blocks of underwater compression and separation. The increase of the separation level allows to increase the quality of product and make the complex more independent from onshore facilities. Transition to the modular scheme. Modular projection and production of subsea complex will make the process of subsea complex creation easier. Moreover, it allows to change quickly separate modules when they will break. Modular scheme has additional advantage of fast assembly.

Next thing, that all experts mentioned, is underwater factory - independent underwater processing and transportation of hydrocarbons. This type of completed innovation can perform without any additional auxiliary nodes. The whole process of oil and gas production is automatically performed. Christmas tree is the other important direction. The transition from horizontal to vertical structure allowed to apply new technologies of drilling, installation and connection of the pipeline, service of wells. Moreover, this radical innovation significantly improves production of hydrocarbons.

The new deep-water power supply system of big power installed on a seabed. Avoiding connection to the platform, including ensuring system performance of direct electroheating of subsea and the pipeline, etc.
Optical systems of communication. Improve the system of communication. Such type of system is more reliable and fast performing
The manifold with a double head. This system will increase the production rate and will provide the sustainable performance of the complex the well.
Independent (universal) systems of repair of wells. Such system will allow to exclude people in servicing the complex. It will lead to the complex automatization.
Use of the new materials increasing firmness of designs. Implementation of new materials has several advantages. It increases the level of reliability of the complex, prolong the lifetime of subsea. As a result, it will reduce the cost of production and transportation of hydrocarbons. Increasing of complex reliability will prepare it to high temperatures.
Use of independent submersibles. The usage of submersible will allow to use subsea complex at deep waters. It will facilitate the servicing of the complex and will allow to prevent accidents.

From the experts' opinion was estimated that the directions subsea modules and subsea drilling are chosen by the companies according to the huge reserves in Arctic shelf. This region is famous for its harsh conditions. Cold weather, strong wind, the lack of light, and cold waters with ice and icebergs make additional difficulties for oil and gas production. Furthermore, President of Russia established program for the Artic development. This additionally stimulates the development of technologies for the oil and gas production under harsh condition of Arctic zone (RG. Ru, 2014). President program subsidizes the technologies that will be implemented in Artic offshore (Ministry of industry, 2015). Main threat for the production is ice and icebergs. Icebergs can hit the subsea and destroy it on the shallow waters. Due to that reason, it is necessary to bury subsea complex for avoiding such accidents.

Ice is also a problem for a subsea complex performance. It limits the access to subsea in winter time and makes it difficult to service the complex. Ice and icebergs increase exploitation costs for a subsea complex. It forces to use a special vessel with ice and icebergs protection. In addition, it is necessary to use special equipment for providing services.

Other points of radical innovation in a subsea complex refer to other regions where subsea is implemented. These technologies can be implemented on each subsea complex in each region.

However, first respondent argues that the separation is incremental innovation. After the conversation with him, I found that separation technology can be both radical and incremental. It depends on the technology itself. The module that is responsible for the separation can be improved - this will refer to incremental innovation. In the case, where a separation module has totally new functions and the parameters for quality or new way of performing is radical innovation.

5.1.2 Incremental innovation in subsea complex

From the analysis of all questionnaire was estimated that incremental innovations gradually develop and improve separate functions and technical characteristics of a subsea complex with constant aspiration:

- to increase in service life
- to increase in safety
- to cost reduction

Moreover, it includes improvement of transformation technologies and electric power distribution, new management techniques, underwater storage and pumping of oil, etc. This type of innovation can be defined by the process of the fields development, testing and improvement of technology solutions during the project. Innovations arise within management of technological risks of the project.

Respondents highlighted seven directions of incremental innovation development in subsea complex.

Completely electric control system. Experts determine electric control system without hydraulics as incremental innovation in subsea complex. They state that hydraulics requires more servicing and it can be undergone with corrosion.
Compressors and pumps of the smaller sizes. Energy efficiency and easy servicing are the main task for incremental innovation in subsea. Decrease in size of compressors and pumps can lead to the energy efficiency. Furthermore, decrease in size will lead to the modular scheme of subsea construction.

Systems of fastenings on the soft deep-water soil. Experts state that this is incremental innovation because of spread implementation of this technology in floating platforms.
New technical characteristics of the estuarial equipment - decrease in loading and wear of the estuarial equipment, increase in operational characteristics of the estuarial equipment. Such incremental innovation allows to maintain admissible temperature and pressure of the well. Stable support is important factor for subsea technology. Control of such parameter is necessary to perform safely.
Deep-water power cables. This technology is incremental innovation. Radical type of innovation in electricity supply can be power generators working on associated gas. Moreover, deep-water power cables allow to avoid hydraulics tube and give increase in power supply.
New systems of measurement and control. Incremental innovations in this area allow to increase in control of the complex performance. Such systems allow to prevent accidents and give the informative data of complex performance. Analysis of such data allow to improve the performance through the complex correction. Such type of innovation involves multiphase counters and executive mechanism.
Valves construction that allows to service it without divers. As was mentioned earlies incremental innovation forwards to improve servicing of the complex. New valves construction is forward to improve such function. Making valves as modular scheme allow to service it with help of submersibles without people invasion.

Interviewees argue that the implementation of incremental innovations in the field of a subsea complex is also often connected with gradual transition to cardinally new technology solutions. It means a stage-by-stage introduction of radical innovations and their further optimization in the production process. For example, performance and increase in remoteness from the coast in the field of more high temperatures and pressure conditions.

According to third and fourth respondents, the ratio of radical and incremental innovations in oil and gas industry constitutes approximately 30%-70% that is significantly higher than in other industries, where a share of radical innovations accounts for only 10-15%. This big share of incremental innovations can be defined by gradual improvement of existent technologies that further will lead to the radical improvement. Radical innovations are necessary for companies to solve complex technological problems of hydrocarbon production on the new Arctic fields. The Arctic reservoirs are located in harsh climatic, inaccessible conditions. At the same time, high degree of uncertainty and lack of data analysis force companies to implement innovations gradually or incrementally, to test all elements of new decisions separately etc. If it is impossible to solve the problem through incremental improvement, scientist develop and implement radical solution.

Due to a growing usage of a subsea complexes by more than 5000 units and an increase in geography of possible applications by opening of new hydrocarbon reserves, the industry should set tasks targeted at the essential development of subsea technologies which will make a smooth and safe performance at depths over 3000 meters possible. To solve such a task with big depth, companies prefer to use both incremental and radical improvements of technology. The companies develop radical innovative solutions in the field of designing and installation of a subsea complex in deep waters, at a considerable distance from the coast, in the Arctic waters. Incremental innovations allow to avoid big spending on radical technologies by improvement of existing technologies. According to this, the potential functionality and service life of the technology can be increased. This fact is expressed in comparison between a sharp growth of R&D expenses on subsea and growth rates of all other expenses of oil and gas companies. According to the Norwegian oil and gas association (2015), the costs on R&D exceed more than 4 times higher comparing with other costs.

5.2 Implementation radical and incremental innovation

5.2.1 Uncertainties in technology improvement

Respondents state that uncertainties play an important role in decision making process for implementation of radical and incremental innovation. Companies face a lot of uncertainties before making decision concerning the improvement of technology. They define 3 types of such uncertainties. The first one is uncertainty of input information about the field. It involves the size of reservoir, the quantity of hydrocarbons in it, uncertainty and variability of production conditions. Declared license area may be tricky for produces. For instance, the reservoir may contain a huge amount of hydrocarbons but the level of recoverable oil or gas can be small. As was discussed above, some of the technologies are developed for special parameters of the field like a subsea complex. In this case, managers of the company should make decision concerning the improvement of technology to increased/enhanced oil production.

The second uncertainty is investment efficiency. This type of uncertainty involves final costs of technology modification, volatility of hydrocarbon prices and others. These both factors are interdependent. Market price on oil and gas strictly influence the final costs of technology improvement. In the situation when prices are low, the company is not interested in expensive modification of technology. If prices are high, the company invests a lot money in technologies to reach the maximum production level.

The third one is uncertainty of the external environment. There are three points that this uncertainty involves; ecological requirement, natural conditions and social factor. A government establishes the ecological requirements for oil and gas production. These requirements are strict rules that are necessary to follow. In some case, the government gives a licensee for production, provided that technologies, which company uses, strictly follow these requirements. Natural conditions also influence the decision-making process. For instance, the Gulf of Mexico is a more comfortable area than the Arctic shelf. Harsh conditions of the Arctic zone may require more reliable technologies made of other materials and this will increase the costs of technology creating. Qualification of staff determines the possibility to work with a certain technology. Due to this, social factor plays an important role.

Respondents also distinguish other uncertainties that strictly influence on decision-making process of the project:

- Economic uncertainty
- Technological uncertainty
- Organizational (and institutional) uncertainty
- Resource uncertainty
- Risk of events of jokers (difficult predicted events leading to radical changes)
- Standard and legal uncertainty

5.2.1.1 Economic uncertainties

According to third, fourth and fifth respondents, a price factor or the tendency of prices of oil has significant influence on technical and economic assessment of feasibility of the upstream project in general. Oil prices influence efficient investments into development of new technologies, especially in a short-term and medium-term period. Also, oil prices influence on the strategy of fields development. For example, many stranded projects have been frozen after drops in oil prices and strategic plans of the companies have been corrected. At the same time, considering a high project CAPEX and an insignificant percentage share of incremental innovations comparing with radical, the level of the oil prices isn't determining them. It is slightly more difficult with radical innovations. On the one hand, they can significantly reduce the cost of capital expenditures and transfer the project to a profitable level even in case of low oil prices. However, if these technologies are new and not approved yet, the companies are forced to pledge additional insurance sums for possible risks covering and to carry out a number of model and natural testing that can nullify all initial prize in capital costs. Anyway, expected level of oil prices at the moment of a project realization is used to assess project efficiency.

First and Second respondents argue that the implementation of new technologies or modification of the equipment is a natural process at any prices of oil to the level of the minimum profitability of production. Any innovation has to be assessed according to the level of potential economy and risks. Moreover, the technological progress itself moves forward. Scientists from government R&D and from other allied industries develop new technologies which also forward petroleum industry to develop. For instance, progress in seismic in mining industry is also applicable for petroleum upstream industry.

Another respondent under number five state that if prices decrease, a company's priorities will be forward to reduce expenses on development of fields. If the oil price forecast demonstrates an increase, a company's priorities will be displaced towards new technologies development and the developments of stranded fields.

The third opinion is referred to the respondent number 3. He estimates another strategy. He state that stable prices on the market force companies to develop incremental technologies that further will transfer in radical innovations. Market prices fluctuation force companies to search radical reliable technological solutions.

5.2.1.2 Technological uncertainties

From the literature was established that technology uncertainty is the product of knowledge insufficiency. Radical innovations as technology solutions for application in the Arctic waters, deep-water fields, harsh weather conditions are connected with a high degree of technological uncertainty and risk. Incremental innovations have lower level of technological uncertainty than radical. Nevertheless, this level is also high. Consequences and effects of development and use of new technologies are not defined and difficult to give in to forecasting. They can concern directly a technology application, for example, a safety break in extraction of hydrocarbons, and in adjacent spheres like transport, power supply, communication, etc.

All respondents estimated that technological uncertainties influence the development and implementation of radical and incremental innovation by:

- Increasing risks of innovative process. Such risks involve risks of project failure.
- Creating risk of implementation of the project in general. Problems of innovation can be met on the stage of implementation. Later the problems with performance may rise.
- Increasing possible fluctuations (risk of increase) of terms and project cost. Increase in CAPEX may make the project economically not viable. In this case, the company may lose huge financial sources. In case, when a company invests a huge amount of money in radical innovation the lost can be much higher than in incremental.
- Influencing through other risks like lack of knowledge in one node of technology. The delay or stop of one node development may lead to the bias in the term of the project. This delay can increase the cost of the project.

For each case of the development of innovative technology, it is necessary to build a matrix of technological risks and to make their quality and quantitative assessment. If this analysis shows that risks don't go beyond the admissiblly applied standards of industry and bring an economic benefit, it is possible to recommend these innovations for application Respondents define several factors that facilitate technology uncertainties.

1) Limited technological capabilities of oil and gas companies. This point involves lack of own R&D centers, weak technological development of company, lack or weak developed technological transfer, etc.

2) A limited knowledge base and shortage of data and operational information on behavior of systems and materials performance at high temperatures and pressure / in the deep-water environment / extreme weather conditions / at an ice covering. The lack the base where technologies can be tested increases the risk of this point.

3) Uncertainty of structural mistakes and violation of tightness (isolation) of a design. This point can result in a weak development of technological base such as R&D institutes or weak technological transfer.

4) Functional uncertainty on real indicators of production. This point can occur because of lack of technologies that will give correct data about well performing. Experts include the system of measurement and control in incremental type of innovation.

5) Change of requirements of standards. Due to a complex performance, the standards such as ecology safety can be changed. It will lead to the necessity of innovation implementation

6) Robotizing, transition to the unattended equipment. New technologies of robotizing may lead to technological uncertainties of servicing. Moreover, there is always the risk of new technology behavior.

First and second respondents especially highlights that decrease in technological uncertainty is possible to achieve by intensification of a technological transfer and use of scientific and technological reserves, including adaptation and use of the technologies which are successfully applied in other spheres of oil and gas sector and industries. Moreover, it is necessary to develop applied science.

Third and fifth experts argues that it is necessary to introduce the system risk management of innovative projects. This type of management should involve certain issues:

1) Risk analysis at a development stage of the project and at each stage of its realization. Studying of international industries experience (statistics), analysis of the previous assessment of risks, project documentation.
It is necessary to consider all types of the risks capable to influence technology solutions:
• Structural risk
• Operational risk
• Internal failures of control systems and control
• Degradation of materials
• The risk proceeding from the third parties
• Natural phenomena

2) Installation of systems of sensors (optical sensors), conducting checks and tests for monitoring of conditions of the environment and a condition of the systems and equipment, collecting and further analysis of data concerning the existing projects.
3) Creation of models and imitating analysis of behavior of subsea systems. It also may require an incremental improvement of a measurement system.
4) Testing of systems in various conditions. This can force a company to develop its own R&D hub with technology testing equipment.

All respondents agree that it is impossible to avoid technological uncertainties. However, to minimize such kind of uncertainties it is possible to implement changes basing on obtained experience and new data during the whole project. Fifth respondent state that technology uncertainty dispose companies to implement radical innovations because of lower risk.

5.2.1.3 Organizational uncertainties

Organizational uncertainties were considered from the point of view of a subsea complex project and technological development in general. Concerning the subsea technology all respondents state that there is a total absence of experts in the field of subsea technology in Russia. Fifth respondent add that the exception is a small number of the engineers working at foreign projects, at the Kirinsky project of Gazprom and in institutes/R&D centers, accompanying these projects. All respondents argue that it is possible to speak about the development of incremental innovations in subsea technology in Russia with a very big stretch. In most cases Russia does not even own the detailed production technology of the most responsible units. Moreover, there is a lack of knowledge how to use foreign production equipment of subsea construction. Radical innovations are theoretically possible on the basis of the available Russian technologies and practices in the field of shipbuilding. First and second respondents argue about big experience in the field of construction icebreaker fleet, submarines and nuclear power stations, control systems and communication in Russia. However, it will be necessary to create a special structure of highly qualified and well paid specialists from this and/or adjacent areas for the realization of a project of subsea improvement.

From general development of the project the all respondents define three major factors of organizational uncertainties:

1) Increase in terms of innovative projects implementation because of technological uncertainty
2) The volatility of the markets' influence on conditions change of innovative project implementation. It produces considerable fluctuations of project efficiency indicators. Moreover, new technology can penetrate the market during the project execution. This will lead to an urgent change in the project strategy and organization.
3) Internal strategy of companies. In the conditions of high market volatility and oil prices drop, companies prefer fast project strategy. According to this strategy, companies don't invest in development and implementation of new technology solutions but they use standard complexes and decisions from available projects. The advantage of this method is time saving and oil production acceleration.

Fifth respondent state that oil and gas industry develops in the conditions of the international cooperation because of universal status of current tasks in the industry. The international design bureaus, producers of the equipment, the international oil and gas companies participate in development of radical innovations (within the joint venture and consortia). Coordination of projects is connected with certain difficulties and uncertainty of geopolitical environment.

5.2.1.4 Resources uncertainties

Respondents define several resource uncertainties in the sphere of subsea development. All these uncertainties are common for incremental and radical innovation in Russia. The first one is the lack of standards of supply of materials, components, etc. Standardization of innovative process plays a key role in the field of material security and the security of technology performance. In addition, also the process of standardization of the organizations' projects in a company has a significant influence on technology implementation. The second resource uncertainty is connected with lack of scientific knowledge. Scientific knowledge is the basement for any technology development. This uncertainty has big influence on development radical and incremental innovation in upstream. Development of scientific knowledge takes a long-term period. The third uncertainty is the lack of financial sources. Technology development is very expensive. Just a few companies have such resources in Russia to develop incremental or radical innovations. Nevertheless, for them it is also risky to invest such a huge amount of money in technology creation. All respondents state that the government has to sponsor radical and incremental innovations. Just a government sponsorship can minimize the risk of technological failure. Moreover, both parties are interested in a successful creation and implementation of innovation in production process. The government benefits from the increased levied taxes. Companies benefit from increased profitability.

5.2.1.5 Field uncertainties

First and fifth respondents established field uncertainty. This uncertainty involves the behavior of reservoir during the production process. Seismic results can be rich with hydrocarbons inside the reservoir. However, during the process of drilling or production some problems concerning the recoverability of oil or gas can be found. Such problem can appear due-to the problems with reservoir porosity, disturbed soil and reservoir construction. All these factors can significantly increase the costs of field production. In some cases, they can make the development of the field not viable economically. In addition, offshore production is more complex than onshore. All problems with reservoir can force a company to drill additional wells. In offshore area, it increases the costs significantly.

5.2.2 Technological transfer

In the conditions of high uncertainty and technological complexity for the creation of radical and incremental innovations in the field of subsea technology and in the oil and gas industry in general, it is necessary to create a critical mass of research and developmental potential. It is possible only in the conditions of cooperation between private companies, government and universities and scientific centers. In the developed countries, oil and gas companies develop the cooperation model based on technological partnership with operators like oilfield services companies or big hydrocarbon producers, scientific research institutes, universities and producers of the equipment. It allows to achieve maximum effect that is represented in a final technological solution.

First, second, third and fourth experts states that state that development of a technological transfer also promotes maintenance of a balance between radical and incremental innovations by creating each type of innovation when it is necessary. Furthermore, it creates a continuous complex innovative process consisting of introduction of radically new technology solutions and their further improvement and modification like incremental innovations. The technological transfer allows to narrow the gap in a Paradigm shift S-curve of introduction of radical innovations connected with their distribution in the market and further optimization. Technologies and the equipment that have undergone skilled/practical approbation significantly reduce potential risks of technological failure. Technological transfer itself does not strictly influence decision making process between radical and incremental innovation development.

From the all respondents were found that technological transfer is developed weakly in Russia. Moreover, this poor development is one of the main barriers of the development and implementation of radical innovations. Incremental innovations can be dependent on technological transfer. However, they can also be developed by companies. International technological transfer of subsea technology is closed to zero point because of sanctions. Sanctions make it impossible to transfer any technologies from abroad. Just the projects with the usage of a subsea complex which were signed before the sanctions still perform.

The level of a technological transfer remains low. However, in oil and gas industry interaction between companies with scientific centers and universities is higher, than in other branches of economy. The largest oil and gas companies have own research centers (scientific research institute) in company structure, and also interact with industry universities and institutes. The main problem of technological transfer in Russia is the lack of unified state policy and commercial interests of companies.

5.2.3 Exploitation and exploration strategy

All respondents state that radical and incremental innovations strategies are interconnected between themselves. Furthermore, both exploitation and exploration strategies are also interconnected. Innovative process in the oil and gas company is complex and combines both radical, and incremental innovations. The purpose of the company is the strategy of evolutionary technological development. However, the exploration strategy involves radical innovation and incremental innovation is the part of the exploitation strategy.

Third, fourth and fifth experts state that exploration strategy is more expensive for the company than exploitation strategy. Projects based on development of radical technologies in the oil and gas sphere have high cost. According to the reason each project has unique characteristics. Besides the direct cost of development of technologies there are high costs for their adaptation. Risk level in the exploration strategy is always higher than in exploitation one. Moreover, this type of strategy requires long-term and practical technology approbation and change in technology, machinery suppliers, services and other financial schemes.

Exploitation strategy is less expensive and risky. This type of strategy is forward to improve the old technology with incremental innovations. Exploitation strategy is mainly implemented on existent fields to increase or enhanced oil and gas production. Such strategy is more spread in the companies than exploration.

First and second respondents argues that learning experience of technology exploitation plays an important role in the creation of new technologies. The accumulated experience and data on behavior of various materials and systems allow to reduce the level of technological uncertainty and reduce risks of the innovative process. Moreover, it leads to identification and judgment of bottlenecks in technology creation and performance process. The aspiration to improvement often leads to the creation of radical technologies. Oil and gas industry is international, and the methods of technologies usage are universal. It is necessary to study foreign experience, especially from developed countries like the USA and Norway.

According to all respondents, tendencies of subsea development assume the development of radical innovations. Due to the use of subsea in cardinally new conditions, companies face the main objectives to develop new functional and operational characteristics.

Respondents define several factors that influence on exploration and exploitation strategy choice.

- Uncertainty level. Combination of technological, resource, market and organizational uncertainties directly influence a strategy choice. Imbalance or existence of one of these uncertainties lead to exploitation strategy.
- The available (proved) reserves of hydrocarbons and technological tasks for their development. According to proved reserves, it is possible to calculate cash flow from the project and understand if this project is profitable or not. The level of project profitability influences decision making. Lower profitability leads to exploitation strategy. Huge resources and high level of profitability stimulates the implementation of exploration strategy.
- Costs of reserves development. Exploration strategy leads to the high production cost for development technology. However, after the implementation radical technology can strongly decrease production cost.
- Efficiency of technological innovations: general development (production), amount of investments into subsea technology, and etc.
- Terms of the project development and construction. In the conditions of a large number of projects with limited or unproven resources, the cost of new creation new technology decisions is a key factor, and also payback periods.
- Factors of the external environment including external infrastructure.

Radical innovations are possible only with a large-scale extensive growth of extraction of hydrocarbons. Just this will create the demand for radical innovations. Incremental innovations can be developed on existing production of hydrocarbons. Increased oil recovery stimulates the development and implementation of such type of innovation.

Also, all respondents state that exploration strategy is not spread in upstream industry in Russia. Due-to high risk level, technology is used for technology approbation on a just few fields. Exploitation strategy includes the risk of losing competitive advantage. However, such problem can be compensated by the increase in production volumes of oil. Nowadays, the strategy of radical innovation creation is difficult to become feasible. Companies in Russia prefer to follow exploitation strategy without any modifications and improvement of existent technologies. Since

Russia significantly lags behind in these developments and doesn't own the technologies of underwater production which are widely used abroad in the last 35-40 years. A subsea complex can be constructed under two conditions: a long-term period and the creation of joint ventures with foreign specialized companies in the field of subsea technology. Thus, it is more appropriate to follow evolutionary approach of technology creation.

5.2.4 Costs in upstream

All respondents define several types of cost for developing incremental and radical innovation: costs for development of technologies, their testing and administrative expenses. Because of specific features of all projects, introduction of innovative technology solutions demand additional expenses and temporary costs for adaptation of systems. The most expensive costs for creation radical and incremental innovation are model and natural tests costs of technologies and equipment development. However, two respondents state that the most expensive cost of radical and incremental innovation creation is the covering of losses. In Russia the situation is slightly different. In the upstream industry, the share of organizational and administrative expenses is approximately 30% for the project in Russia. These costs involve formation and content of organizational structure of the qualified and highly paid experts. They significantly raise the project costs.

5.2.5 Subsea in technological paradigm shift

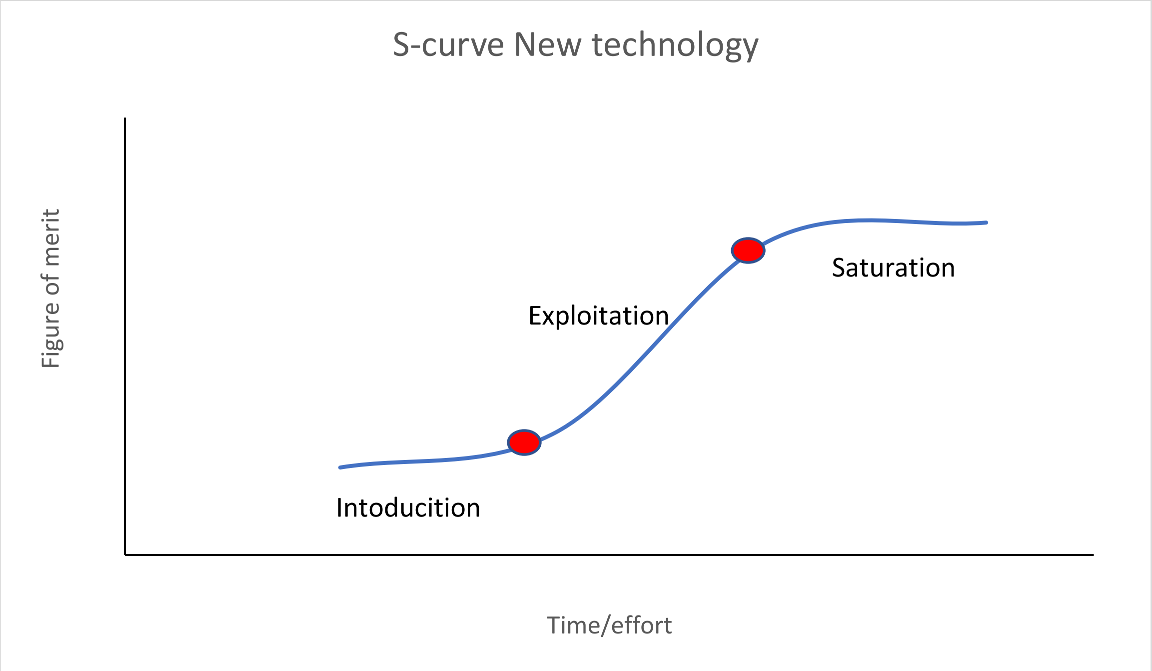

Table 4 S-curve New technology.

All respondents state that Subsea technology is located on the stage of "Introduction" in Russia. In developed countries and companies a subsea complex is located at the phase close to "Saturation" (see Table 4). Nowadays, this is the basic technology for oil and gas production in high-tech companies. Subsea development started in 2001 in Russia. The first company who raised the issue concerning the creation of subsea technology was "Baltsudoproyekt". All respondents state that a subsea complex in Russia will stay approximately for 5-6 years on the introduction stage. Western countries have been developing this technology since the 1970^{th}. Interviewee argue that subsea in this region will stay for 10-15 years before it reaches a saturation phase at the top.

Respondents state that subsea technology should be developed both incrementally and radically simultaneously. Implementation of radical innovation is necessary for use of expansion. Incremental innovation is necessary to reduce oil production costs. Nowadays, the main strategy of oil and gas companies is to cut the development expenditure and functional characteristics improvement. It can lead to falling interest in introduction of new technologies and radical innovations, but it promotes incremental innovations on costs reduction.

According to the literature that was studied, the extraction conditions of hydrocarbons production is worsening. It becomes more difficult and more expensive to extract hydrocarbons. This reason causes the necessity in decisions development for stranded reserves production of hydrocarbons. New technologies and competences will be demanded in the presence of an economic incentive for new fields development besides subsea cost, existence of coastal infrastructure, remoteness from the coast, the cost of hydrocarbons transportation.

Despite 35-40 years of experience, a subsea complex is being still actively developed. Moreover, subsea technology gradually forces out traditional schemes with the use of oil platforms and vessels. Russia is only in an initial stage of practical use of subsea technology.

5.2.6 Planning of innovations in the strategy of the companies

According to the third, fourth and fifth experts, planning of innovations depends on scale and the strategy of the company. According to financial opportunities, the large companies are more inclined to broader application of innovations. It is connected with quite a long term of their pay off period and in the absence of guarantees when the that technology becomes profitable. Companies with big financial resources can allow to wait for the technology is profitable.

Respondents define several factors that influence the strategy of innovation technology implementation:

• Forecast of the market. This factor involves the analysis of the production level and prices of hydrocarbons. Moreover, this factor provides the analysis of existing technologies with their parameters on the market and distinguish the trend of its development.

• Position of the company. This point involves the existence of licenses and a condition on licensed areas and advantage of production technologies like a subsea complex. All the factors that give competitive advantage will influence a company position

• Dynamics of costs of fields development with available technologies and at introduction of new technologies. This point distinguishes a company efficiency in upstream activity.

Interviews define the scheme in which innovation in technologies should be implemented. This scheme is based on two stages.

1. Development of radical innovations or separate nodes in a several options and their testing and practical usage in small scales
2. Determination of perspective (profitable) radical technologies and their transfer in the evolutionary category.

This scheme describes the variant of technology development where separate nodes firstly developed and after that they are all connected in one technology that has an evolutionary category for the market. Such scheme allows to reduce the risk of a total technology failure on the first stage of development. After an approbation of separate nodes, it is easier to forecast the behavior of the whole technology performance.

From the respondents' opinion, it is very challenging to highlight the most important factor that has the most significant influence on the process of decision making. Respondents argue that each company has its own priorities in innovation development and implementation. Moreover, each company has its own decision-making model or methodology. However, all respondents emphasize that oil price may have the dominant influence on the process of decision-making, which is quite understandable. Market oil price determines the profitability of company performance. Both types of innovations require big investment that can significantly reduce the profit of the company.

All respondents state that subsea technology is developed very weak in Russia. Moreover, all factors from the model have a strict influence on this weak development of the complex. They also underline that these factors are the problems for creating any technology in upstream industry. Furthermore, the factors also have direct influence on the Arctic region development. The lack of appropriate technologies makes it difficult to produce oil and gas in this area.

6. Analysis

The aim of this research was to find barriers and drivers for implementation of radical and incremental innovation in a subsea complex in the Russian context. Thus, to analyze the drivers and barriers of innovation implementation, I divided the analytical part in several parts. In the first part I present incremental and radical innovation from the Russian researchers and the major company representatives' point of view. The second part analyses the barriers and drivers of innovation implementation in subsea technology. Moreover, there is an assessment of technology management in Russia. Finally, I constructed the model where it is possible to see the problems of radical and incremental innovation implementation and the discussion how these problems can be minimized. Norwegian experience that was described earlier helps to compare the current situation in Russia and in Norway.

6.1 Subsea complex and innovations.

6.1.1 Subsea technology on the segmental stage of the development

From the analysis of subsea technology it was found that this technology can be modified in different ways. There are four main directions for the development of a subsea complex in a radical way Figure 8.

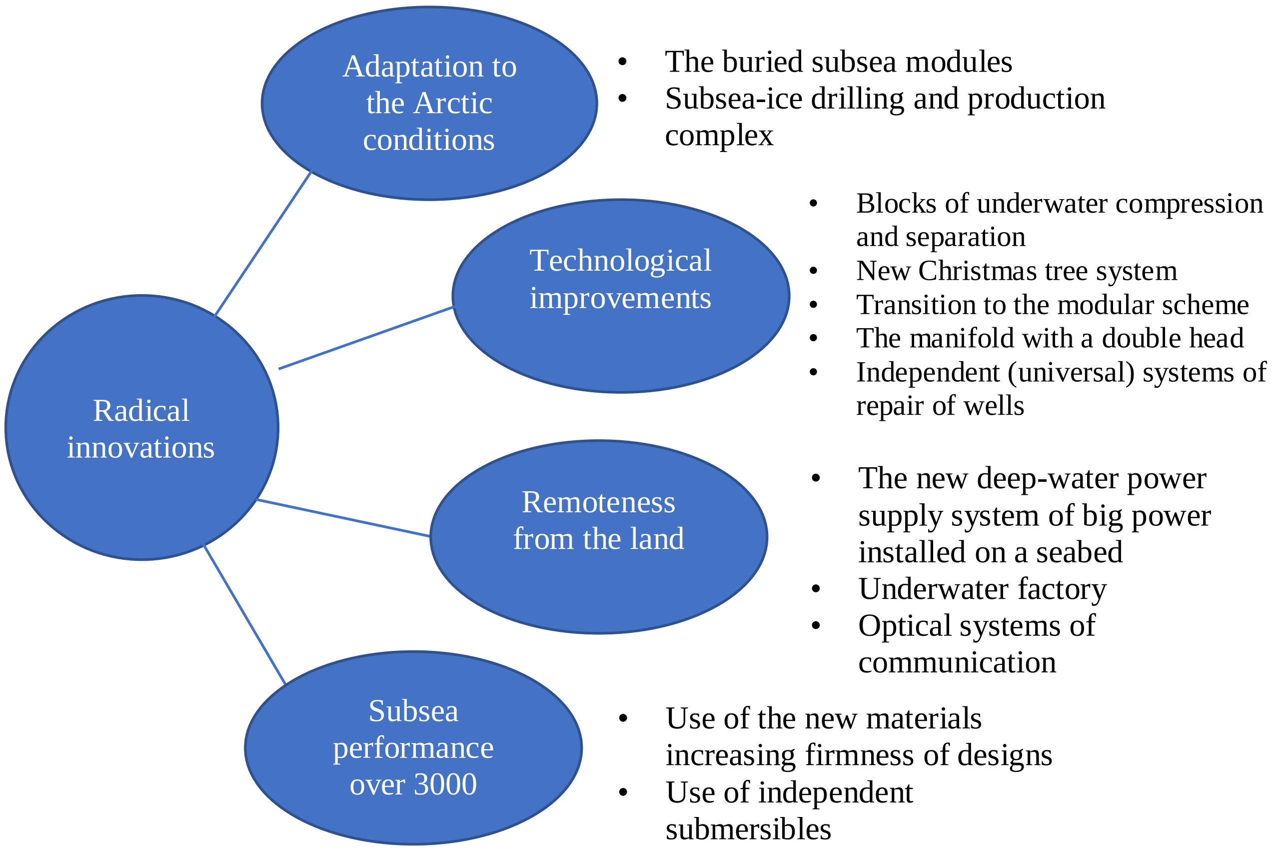

Figure 8 Radical innovations for subsea

A wide range of radical and incremental innovations can be implemented in a subsea complex. All main nodes of the complex can be modified radically or incrementally. From the experts was established that it is necessary to adapt subsea to the Arctic conditions where the requirements for the performance differ from the performance in other regions that are free from ice and icebergs. According to this fact, it is possible to implement this technology on Segmental Stage of the Utterback and Abernathy (1975) model. A dominant design of subsea technology was developed and now the main trend of a subsea construction is independent from the onshore facilities. Moreover, the adaptation of subsea technology to other regions with other performance conditions such as Arctic offshore. In Russia, the main performance zone of a subsea complex is the Arctic area with sever performance conditions. In radical innovations, it is possible to highlight several main radical improvements in subsea technology:

- Adaptation of a subsea complex to the Arctic harsh conditions
- Improvement of underwater blocks of compression and separation
- Technology of new Christmas tree
- Independence in power supply from onshore
- New system of automatic control for performance of a subsea complex

- Development of new materials increasing reliability of subsea construction
- New construction of the separate nodes like valves.

It can be clearly seen that there are a lot of directions of a radical subsea technology modification. From the literature analysis was found just a small number of radical improvements of subsea complex. Experts' answers give wide variations of radical innovations that can significantly improve the performance of the subsea complex. All these improvements allow to reduce the cost of performance and make the process of production and servicing automatical. Adaptation of a subsea complex to new severe conditions of the Arctic increases the number of subsea technology implementation. The main problem of performance in the Arctic region is icebergs that can destroy subsea technology. Moving by the wind power they can demolish the complex with all facilities protected from oil spill. Engineers and scientist offer to bury the subsea. However, in some cases an iceberg can be so big that this measure will not prevent subsea complex from being destroyed.

Improvement of underwater block of separation allows to extract cleaner oil and gas from reservoir. It can significantly reduce the cost of further separation. Compression block will allow to produce more hydrocarbons from a well and enhance oil or gas production.

The main function of Christmas tree technology is oil and gas flow performance and control. This technology exercises all inflows and outflows from and to the well. This system functions under great pressure and temperatures that can destroy Christmas tree by rapid fluctuations. The improvement of such systems will make the node more reliable. Radical innovation is the implementation of totally new material or new construction of this technology which also leads to the reliability. Christmas tree is also responsible for a safe performance through downhole safety valve. In an extreme situation, Christmas tree can automatically block the flow of hydrocarbons through this valve. Radical innovations can make this node safer in performance. The Arctic zone is very sensitive to any changes in the environment and it is very important to avoid any damages and spill in this region.

Power supply is one of the main questions in a subsea development in the Arctic zone. Remoteness from the onshore facilities forces companies to develop complexes with their own systems of power supply without cable connection to the onshore. Implementation of radical innovation in this node will allow to reduce dependence on the onshore and open new fields remoted from the shore.

With remoteness of subsea complexes and their spread, it becomes necessary to automatically control the performance of subsea technology. In the Arctic zone, a reliable automatic control is of great significant. In case of an emergent situation an automatic performance and remote control of the complex will prevent the accident. The automatization of a subsea complex will also reduce the costs of its performance.

The Arctic waters increase the level of metal corrosion. Radical solution to this problem is the creation of new materials that will prolong the life time of the complex and separate nodes. Thus, it will not be necessary to change separate nodes or the whole subsea complex. The development of new materials is important not just for the Arctic region. New materials will prolong the life time of a subsea complex in every performance zone of technology.

Subsea technology is a complex that consists of different parts or nodes. Radical improvement of nodes construction will increase the performance of the complex and make it easier in servicing. In the Arctic sever conditions of performance this radical improvement should be also forward to increase the reliability of the complex. Moreover, remoteness from the land and low temperatures make it difficult in servicing. Maintenance operations require divers or submersibles intervention depending on the working depth or the type of a subsea structure. Modern construction of separate nodes like valves will allow to service it with submersibles. This will significantly reduce the costs.

The main advantage of radical innovations is a significant cost reduction and competitive advantage. Radical technologies allow to solve difficult problems of oil and gas production and make a breakthrough on the market. However, it is still a controversial topic concerning a strict determination of radical innovations. Each company determines radical innovations in its own way accounting for its own level of technological development. In the case of this research, radical innovations coincide. Petrobraz company highlights the remote-control transportation of oil and gas. My respondents also state that automatic control of subsea performance refers to the radical improvement. The main disadvantage of radical innovations is high level of risk. However, the success from implementation of such technology can cover all spending for R&D. For the Arctic development, radical innovation is a necessary tool. Just radical solutions will allow to produce oil and gas in this area.

6.1.2 Incremental modification of subsea

Incremental innovations are more spread in a subsea complex than radical. The main advantage of this innovation is that it is cheaper and less risky for development and implementation. It allows to maintain competitive advantage on the market by cost reduction. From the experts' opinion was established that the main disadvantage of incremental innovation is the lack of a breakthrough on the market. Such innovations don't give big competitive advantage or big profits comparing with radical one. For the development of the Arctic zone it is necessary to develop radical innovation rather than incremental. Russian companies don't have such technology. Moreover, the challenges of the Arctic conditions require implementation of radical solutions. In this case, the experts state that it is necessary to create subsea technology with radical improvements to solve the Arctic problems. Incremental innovations can be more useful for such a field that is not located in such a sever condition like the Arctic. There are three main directions of incremental technology development. (see Figure 9).

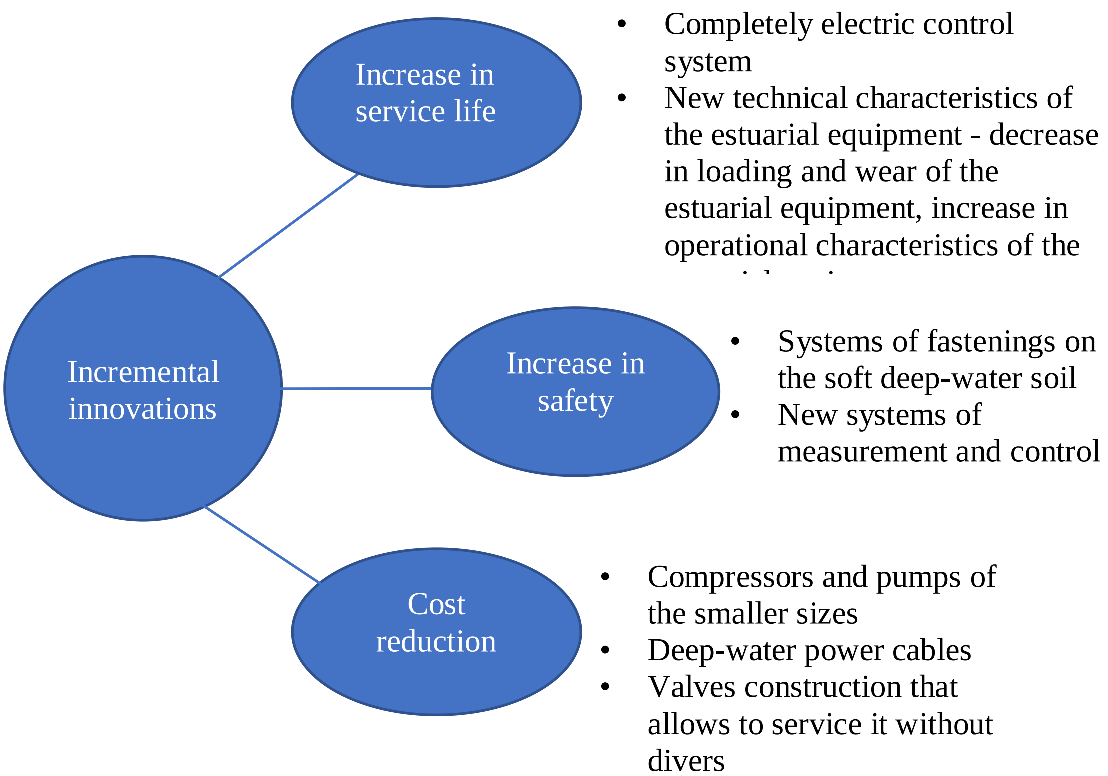

Figure 9 Incremental innovations for subsea

An increase in service life and servicing improvement are the main functions of incremental innovations. Completely electric control system is incremental innovation. This system can replace hydraulics mechanisms. Completely electric control allows to avoid corrosion of hydraulics mechanisms. This significantly reduces the servicing cost and increases the service life time. Incremental innovations in the estuarial equipment decrease in loading and wear of the estuarial equipment. A decrease in loading and increase in admissible temperatures and pressure will allow to increase the flow of hydrocarbons. This significantly increases the production of oil and gas.

Safety performance plays a vital role in production of oil and gas. Systems of fastenings on the soft deep-water soil will allow to install a subsea complex on the deep seabed. This will give an access to stranded fields and sustainable performance of the complex. Moreover, incremental innovation in fastening of a subsea complex to the seabed will increase the safe performance. Incremental innovations in measurement and control are also important. Subsea performance supervision will allow to minimize the risk of accident and improve the current performance of the complex.

Cost reduction of technology usage can influence the viability of the project. Incremental innovations which are aimed at the reduction of the production costs can make project profitable in a situation with low oil prices. Compressors and pumps reduced in a size are an incremental innovation. Such a reduction will allow to be more energy efficient. Energy efficiency is useful everywhere including the fields located in the Arctic zone. Experts state that deep-water power cables are incremental innovation. Replacement of hydraulic tubes will reduce the level of corrosion. Moreover, this technology will increase power supply for a subsea complex. Thus, a subsea complex will increase profitability. This incremental innovation will increase the level of production and decrease the level of corrosion. Accordingly, it will significantly reduce the costs of power supply and servicing. Incremental innovation in such separate nodes like valves will make servicing of these nodes easier. In order to maintain the complex, it will be possible to use submersible except divers and this will reduce the costs. Furthermore, this incremental innovation will allow to service the complex on the deep waters. Stranded fields on the deep waters become more accessible for production and stable performance.

Incremental innovations play a significant role in technology performance. In the research, it was established that such type of innovation for a subsea complex involves three directions. These directions allow to maintain competitive advantage on the market by reducing costs, prolong lifetime of technology and increase in performance safety. In addition, incremental technologies will transfer into radical innovations. For the Arctic zone, such innovations can be less useful than radical. However, some technologies can be applicable to this sever area. All the information that was found during the research about incremental and radical innovation in subsea is unique due-to the lack information in literature about subsea modifications. Moreover, were also estimated factors that are influence on decision making process concerning complex improvement.

6.2 Factors that influence on implementation of radical and incremental innovation.

From the analysis of the literature review and the opinion of the experts, it is challenging to identified the drivers for implementation of radical and incremental technology. However, all the factors that influence on process of decision making can be referred to the barriers and just some of them can be referred to the drivers. Due-to this fact, it is possible to construct the table below (see Table 5). All uncertainties and costs are referred to the barriers. Technological transfer, Exploration and Exploitation strategies and Technological paradigm shift can be referred to both as a driver and as barrier for radical and incremental technology development and implementation.

Barriers for innovation implementation	Barriers/ Drivers for innovation implementation
Uncertainties of the first stage: • Input information about the field • Investment efficiency uncertainty • External environment • Economic uncertainty • Technological uncertainty • Organizational (and institutional) uncertainty • Resource uncertainty • Risk of events of jokers • Standard and legal uncertainty	Technological transfer
	Exploration versus Exploitation
	Technological paradigm shift

Table 5 Factors distribution

6.3 Barriers

6.3.1 Influence of uncertainties

The following four types of uncertainties were defined by literature review presented in this thesis: economic, technological, organizational and resource uncertainty. The conducted interviews made it possible to add the following uncertainties: input information about the field, investment, external environment, risk of events jokers and standard and legal uncertainty. This addition from the experts makes my model wider in analysis. The first three uncertainties from the Table 5 are the uncertainties that a company meets on the first stage of technology analysis. Analysis of input information about the field helps to minimize the risk of incorrect date about reserves and reservoir construction. The analysis of investment efficiency helps to estimate the profitability of the project after innovation implementation. The analysis of external environment observes three separate points: ecological requirements, natural conditions and social factor. All these three types of uncertainties allow to overview the possibility to create or implement technology at the first stage. For the Arctic region, this analysis is significant. Sever conditions of the Arctic and big depth make this reservoir stranded and seismic can be not correct.

Economic uncertainty

During the study were found additional 6 types of uncertainties. . Economic uncertainty is defined by the low oil prices on the market. This type of uncertainty was proved by the opinion of the experts. This uncertainty can significantly influence the project profitability. This type of uncertainty is very difficult to forecast. However, considering all the risks connected with such uncertainty allow to prepare to high price fluctuation in a short-term and medium term period. From the analysis of respondents' opinions and literature review, different consequences from price fluctuation were estimated. The first opinion refers to the statement that radical innovations are profitable for implementation and development because of significant cost reduction even in the situation with low oil prices. The second opinion refers to the statement that implementation and modification of technologies is a natural process at any price level on the market. The third opinion refers to the statement that with an increase of oil prices on the market, companies' priorities change in development and implementation of innovative technologies. When oil prices decline, companies change the strategies towards the new technology development.

The differences in these opinions are determined by the companies' strategies. Each company estimates its own strategy by its own vision of performance. However, the development of new technology is a long-term process and price rise or decline can happen rapidly. According to this, it is possible to invest in new technologies and after that meet the fall on the market. This situation is suitable for the second opinion. For the Arctic development, economic uncertainty is significant. All the projects and technologies that are used in this area require a lot of investment. Each project has unique equipment and technology that significantly increase the cost of the project.

Technological uncertainty

Experts' opinions allow to look wider on this uncertainty. Technological uncertainty can be exposed in two stages development technology and technology implementation. There are several risks that are involved in these stages. First of all, technological uncertainty increases the risk of innovative process. Secondly, this type of uncertainty creates the risk of implementation new technology in the project. Any technological problems can lead to the problems in technology testing and performance. Thirdly, technological uncertainty can lead to the rise of the project costs. High capital expenditure costs including new technology development and implementation can make the project unprofitable. Other risks may contain such challenges like lack of knowledge in node of technology, and this may lead to the project delay. Technology uncertainty contains all these risks.

For analysis of these risks, it is necessary to use technological risks matrix. This tool allows to assess the risk and make the decision concerning development and implementation of technology. Risk analysis should be provided before decision making about technology development. The next measure of the risk management that helps to reduce the risk of technological uncertainty is the system of sensor for control and test the performance of a subsea complex. Data collection from the tests and sensors and further analysis help to improve technology and avoid breakages. Imitating analysis of subsea behavior is also the tool that helps to decrease the risk of technology failure. Such analysis allows to prepare to various situation that can happen during the exploitation of the complex. Testing of the a subsea complex in various conditions significantly reduce the risk of technological uncertainty. The analysis of the behavior from the testing allows to prepare for accidents and environmental influence on the complex performance.

The Arctic usage of a subsea complex is closely connected with technological uncertainties. Sever environmental conditions like low temperatures and high level of water corrosion make the process of development and implementation of the complex more difficult. Incremental innovation is less risky than radical innovation in the sphere of technology uncertainty.

Incremental innovation is based on previous technologies that were used and it is possible to analyze the behavior of these technologies in different conditions. Radical innovations are totally new technologies and their behavior in sever conditions of the Arctic may be unknown or difficult to forecast. Nevertheless, both types of innovations have high level of technological uncertainty. It is impossible to avoid technological uncertainties. However, it is possible to reduce the level risks in this uncertainty by analyzing them and collecting experience during exploitation and development of the technology.

Organizational uncertainty

Organizational uncertainty involves project risks of subsea development and implementation in general. Literature review gives just common understanding of this uncertainty. Experts gave deeper understanding of this challenge. Furthermore, organizational uncertainty may refer to the managerial conflict between incremental or radical innovation implementation. The issue concerning the subsea technology development and implementation is very weakly developed in Russia. A subsea complex was installed just on one field by a foreign service company and they provide all services connected with technology performance. Just few organizations who interact with the project Kirinsky oil field know about the subsea technology. However, the level of development of this complex is low. Due-to this fact, it is difficult to talk about incremental modification in subsea in Russia. Nevertheless, this lack of knowledge allows to penetrate into the market with radical improvement of subsea. Nowadays, the government and big oil and gas producing companies started to develop this technology under the program of the Arctic development. Russian previous experience in shipbuilding construction may be helpful for subsea development. The reason that stimulates the development technologies in the Arctic is huge oil and gas fields which are located in this region like Shtokman field with reserves 3.9 trillion cubic meters. For creation of a radically improved subsea complex, it is necessary to create the structure of well qualified and paid specialists from the sphere of creation of subsea technology or adjacent areas. The lack of such specialists creates organizational uncertainty.

Organizational uncertainty is closely connected with other uncertainties. Technological uncertainty strictly influences the organizational uncertainty through the terms of technology implementation. An increase of technological uncertainty may delay the implementation of a subsea complex and this creates organizational uncertainty. Economic uncertainty influences organizational uncertainty through oil prices fluctuation. A change in oil prices influences the terms of the project realization. Such fluctuations can decrease the indicators of the project effectiveness and this will lead to the organizational uncertainty. A company internal strategy also influences organizational uncertainty. Low oil prices stimulate the company to avoid new long-term projects. In this case, companies switch their attention to the existing solutions or the technologies for the available projects.

Nowadays technologies are developed in the system of global cooperation with the usage of technology transfer. In this situation, difficulties of the technology transfer that can rise connected with organizational uncertainty.

Resources uncertainties

This uncertainty also was mentioned in the literature review. However, answer from respondents allow to investigate this challenge deeper. There are three factors that create resources uncertainties in upstream industry in Russia: lack of standards of the supply of materials, lack of scientific knowledge of the technology and lack of financial sources. All these three factors are significant for the subsea technology development, especially in the Arctic region. Standardization of materials play a significant role in insurance of materials quality and safety. The Arctic is a fragile region with its own ecosystem. It is necessary to establish high safety standards of oil and gas production. Nowadays, standardization is a new way of competition. Companies raise the standards of their materials quality and apply them to organizations like API and ISO. The government prefers to give a license for hydrocarbon production to companies which have the highest standards proved by these organizations (API and ISO). Standardization is important for both radical and incremental technology. Russian companies are implementing API and ISO standards in the production process. Moreover, they are trying to create their own standards based on American Petroleum Institute and International Standards Organization.

A lack of scientific knowledge is a multifarious problem of my model. Technological and organizational uncertainties, technological paradigm shift may contain this problem. There are two solutions for this scientific gap. The first one is technological transfer. The second one is the development of one's own scientific base and scientists. This factor is significant for radical and incremental innovation development and implementation. Moreover, a lack of scientific knowledge is significant to any technology in upstream industry in any region.

Both radical and incremental innovations require a huge amount of investment. The Arctic region requires huge investment because of its unique severe conditions that force companies to create totally unique projects. Radical innovations require more financial sources than incremental. For companies, investments in such projects as incremental and radical innovation creation are a big risk of project failure. The government can minimize such a risk by giving inceptives or sponsorships to petroleum companies.

Field uncertainty

This type of uncertainty was added by the experts as significant factor that influence on decision-making process. During the drilling and production process engineers can meet the problems with reservoir. Incorrect data about quantity of hydrocarbons and structure of reservoir may lead to huge financial losses. Offshore production and seismic in the Arctic are more difficult than in other regions. Radical or incremental innovations in 3D seismic will improve information accuracy. Furthermore, it will help to get prepared to a difficult structure of the reservoir.

Costs for innovation development

Another barrier for incremental and radical technology development and implementation are costs in upstream industry. The opinion of the experts and literature description of this factor is similar. However, experts add some specialties of this factor. For instance, the highest costs from the process of innovation development and implementation is the development of technology. Incremental and radical innovations have different level of costs on development technologies. Radical technologies require more investment because of involvement of more organizations for development. Incremental technologies require less investment comparing with radical innovations. In the structure of costs the technology test captures the major part. The proof that the technology is reliable is very important for the companies. The share of administrative/organizational expenses is 30% from the total project costs in Russia. Such a big share was formed by the necessity to employ expensive foreign experts for such difficult projects. As was previously mentioned any upstream Arctic project requires huge investment that leads to the costs increase. To reduce costs, it is necessary to improve innovation management in a company.

6.4 Barriers/Drivers

6.4.1 Technological transfer in Russia

Technological transfer is a driver for radical and incremental innovation development and implementation. That was described in literature review and proved by experts. This approach maintains the balance between incremental and radical innovations. Moreover, technological transfer provides the whole supply of new technology creation and further improvement. However, in the situation where a company doesn’t have its own research and development hub or a scientific center, technology development will be difficult without an interaction with an external scientific organization. In this case, the lack of technology transfer will be the barrier for innovation development.

The Arctic region or subsea technology itself require high level of knowledge to improve or created the complex. The lack of mass development and research potential forces companies to interact with external scientific centers. However, government scientific centers have a low level of competence in the field of subsea construction and implementation. The opportunity to interact with foreign centers from abroad was inhibited due to the sanctions. Nowadays, government scientific centers try to increase their competence in the field of subsea construction. Government stimulates both companies and R&D centers by financing and other support. Nevertheless, without a unified state policy in the sphere of control government R&D institutes, technological transfer will be low. Companies are also remained at a low level of technological transfer. They are more interested in fast projects without any new technology implementation which safer for the company. Before the sanctions foreign service companies provided all stages of production for Russian companies. This made the scheme of technological transfer weak. Radical innovations suffer mainly from the lack of technological transfer. Incremental innovations can be made by the companies themselves basing on the previous experience of technology exploitation. For Russian companies, such a tool as technological transfer will be as an accelerator for technology development. Moreover, in some cases technology transfer is vital. Interaction between three organization is one way for technology development. Weak performance of just one dimension of this triangle may lead to the failure of technological development. The absence of technological transfer is a barrier for creation and improvement of a subsea complex in Russia.

6.4.2 The necessity for exploration strategy for subsea development in Russia

From the empirical data, it was found that companies are aimed at the strategy with evolutionary technological development. Exploration strategy forward to develop and implement radical technological solutions. This strategy is the driver for innovation development and implementation. Transfer from old to new technologies allow to get competitive advantage. Radical innovation is connected with a high risk and high capital expenditure costs. Exploration strategy is a long-term strategy. Moreover, development of radical innovation in upstream industry is possible just through the extensive production of oil and gas. Demand for new technologies stimulates the creation of innovations. Incremental innovations are usually used in exploitation strategy when it is necessary to increase or enhance oil or gas production. Smaller risks and costs on exploitation strategy allow to maintain or gain permanent competitive advantage. Moreover, this strategy allows to gain the knowledge during exploitation of technology and this is an advantage. Furthermore, this experience can be a transfer into radical innovation. Exploitation is a short-term or medium term strategy comparing with exploration.

The strategy choice between exploitation and exploration depends on several factors such as uncertainty level (the sum of all uncertainties mentioned above); proved reserves of hydrocarbons and technological tasks; costs of reserves development; technological innovation efficiency; terms of project development and implementation; external environment influence like infrastructure. Nowadays Russian companies use exploitation strategy. They use existing technologies.

The Arctic conditions require the strategy of exploration. It was further discussed that it is necessary to penetrate into the market with a radically improved subsea complex for stable performance in the Arctic conditions. Exploitation strategy is difficult to execute because of lack of Russian own technology in upstream industry and lag behind in science. Exploration strategy is the only way for subsea development. There are two factors that are necessary for creation of a subsea complex: long-term period and technology transfer. The lack of exploration strategy with all its challenges will be the barrier for a subsea complex development.

6.4.3 Technological paradigm shift in upstream in Russia

The main challenge for a subsea complex in Russia is that the level of its development is on the project stage. Concerning the theory of technological paradigm shift a subsea complex is located on the stage of “Introduction”. Subsea technology in developed countries is located on the exploitation stage closer to the saturation phase. It is possible to implement both incremental and radical innovation in a subsea complex when it is located in this point. This technology is still being developed actively approximately during 35-40 years. However, for Russia, as was previously mentioned, it is necessary to penetrate into the market with radical solution for a subsea complex to achieve or overtake the position of developed countries.

“Introduction” stage of the Russian subsea complex is the driver for radical innovation implementation and a barrier for incremental innovation implementation. Development of incremental innovation in subsea will not give any competitive advantage on the market for the

Russian companies. Moreover, companies may lose tenders for production hydrocarbons at home and abroad to companies from developed countries. Technological possibilities of Russian companies will be lower comparing with developed companies. The stranded oil and gas fields stimulate the implementation of radical innovations in the Arctic regions

This approach was not described in literature. Due-to that respondents' answers is unique in this field.

6.5 Strategic development of innovation

A company strategy in the sphere of technology planning is closely connected with the analysis of factors that were mentioned above. The amount of financial sources that a company spends on R&D is the dominant factor for technology development. It allows to provide policy of both exploration and exploitation strategy to achieve a maximum effect from development, implementation and further modification of technology. Besides, a financial factor allows to accept certain risks. In the situation of limited financial resources such usage of both strategies is impossible. Moreover, the lack of investment in R&D forces a company to assess the risk more accurately. Big financial resources give the possibility to wait for the result from R&D. Companies with small amount of investments in innovations wait for fast result from R&D. Factors that impact on determination of technological strategy can be seen in Figure 12

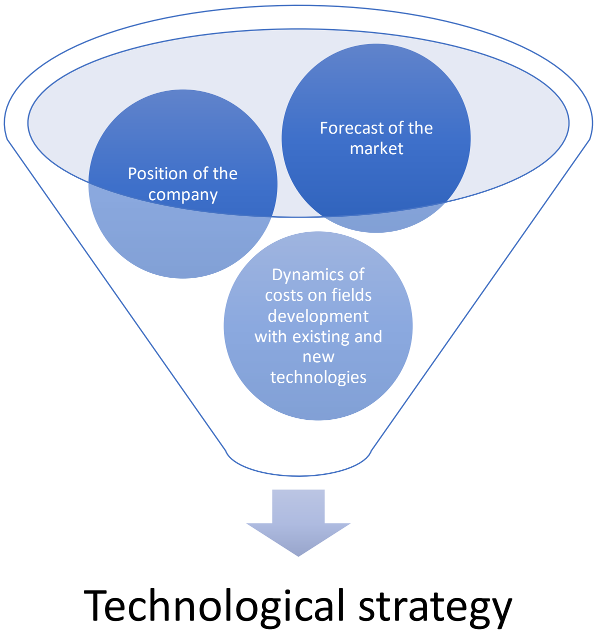

Figure 10 Factor that influence on technological strategy

From the analysis of the literature and experts' opinions similarities in the factor that influence on the process of decision making were found. Furthermore, the experts add additional uncertainties. They allow to look wider on the factors. Academic literature coincides with the experience of the companies from developed countries. Oil prices is the factor that has greater influence on decision making for Russian companies and companies from developed countries. Russian development of subsea technology biases from the experience of developed countries. In the research, it was found that to compete on the market and to achieve efficiency, it is necessary to create subsea technology with radical innovations in Russia. According to this it is necessary to consider a radically improved subsea complex.

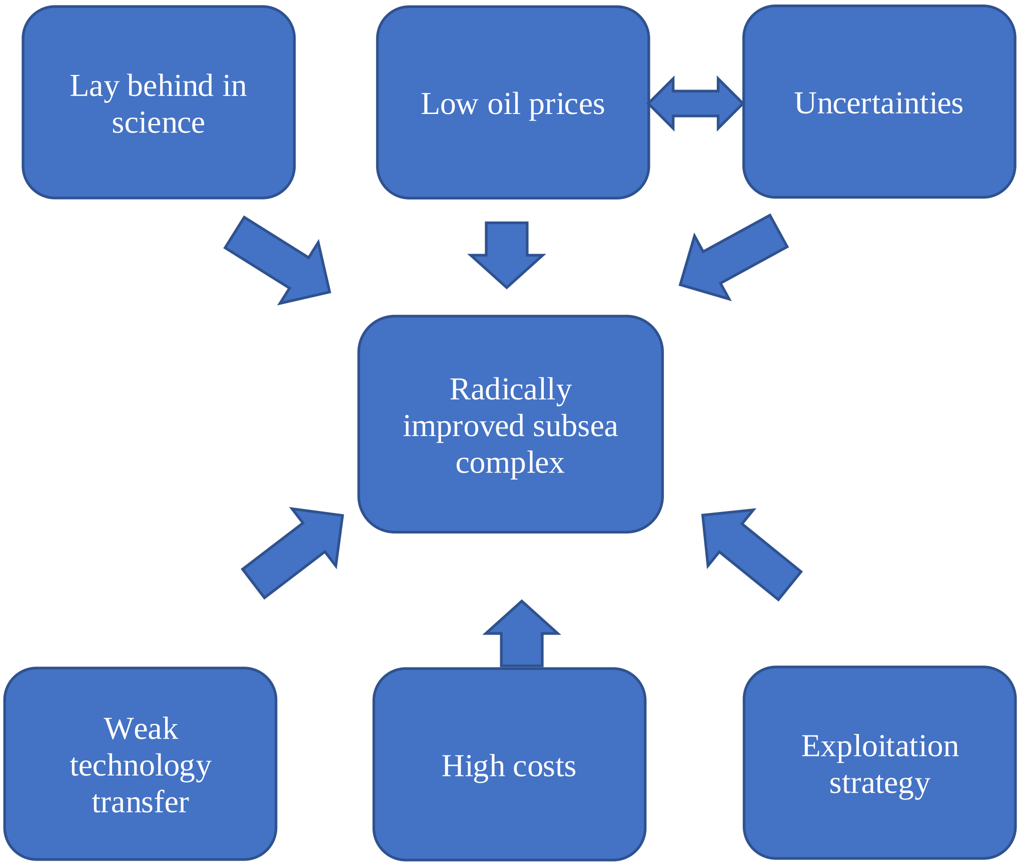

Figure 11Barriers for subsea development

Figure 11. demonstrates the barriers for the Arctic radical subsea development in Russia. The factor of low oil prices was distinguished specially for demonstration that oil prices have a significant influence on the innovation development.

7. Conclusion

The upstream industry is highly dependent on technologies (Inken and Moffet, 2011). The main purposes of innovations in that sphere are cost reduction and getting an access to the stranded fields. Depletion of existing fields force companies to open new stranded reservoirs with the help of innovations like subsea. Subsea complex opens the perspective of the Arctic development for Russia. Moreover, this technology significantly reduces the costs of production. Subsea complex is a cutting-edge solution for offshore oil and gas production that spread around the world. Innovation management in technology creation plays a vital role.

Norway has a strong position in innovation management in upstream. It has big experience in development and modification of upstream technologies and subsea complexes. Russian experience in development technologies in upstream is very weak. From the analysis, it can be said that technological gap between Norway and Russia is big. Especially in the field of subsea complex development. The incorrect performance of such systems concerning funding technological development and transfer supply for industry with the latest technologies forms challenges for technology creation. The implementation and adaptation of Norwegian experience in Russia could be useful to overcome technological gap between Russian companies and companies from developed countries. For this purpose, it is necessary to improve performance of governmental and private R&D hubs, the system of technological funding and government system of stimulating R&D activity.

Moreover, the existence of big fields with huge reserves of hydrocarbons and sanctions stimulates the technology development in Russia. The government program of the Arctic development gives additional incentives for the subsea complex creation and modification. Such fields as Shtokman attract technology development for upstream performance by its huge reserves of approximately 3.9 trillion cubic meters. The Arctic region is an attractive zone for oil and gas producers. Offshore production becomes the alternative for depleted onshore activity. However, stranded oil and gas fields located in harsh condition and on the big depth require radical and incremental solutions for getting access for these fields and effective performance from engineers. That is why the question was raised in this research:

What are the factors that influence on radical and incremental innovation implementation in subsea complex in Russian oil and gas sector?

Experts gave significantly valuable opinions that helped create the answer on my research question. During the research, it was found out that Russian companies don't have subsea technology. Scientific centers and R&D hubs just started develop this technology. After the sanctions imposed on Russian oil and gas producers have to produce their own technologies instead of foreign import. The foreign market of subsea technologies has a high level of technological development. According to this fact, it was estimated that for Russian companies it is necessary to penetrate into the upstream market with radically improved subsea complex.

The analysis of the factors that influence radical and incremental innovation implementation and development of a subsea complex in Russia from my model (See the Figure 3.3.1) demonstrates the existence of barriers and a lack of approaches. The barriers for development of radical and incremental innovations in subsea are high level of uncertainties and big project costs. The lack or weak developed technological transfer and exploration strategy. Technological paradigm shift theory demonstrates the necessity for high level of scientific development to create subsea and radical innovations. The factor of oil prices that isinvolved in economic uncertainty can be distinguished separately. During the study, it was found that oil prices have great influence on decision making concerning decision making of innovation development. Big companies with big budgets can feel this risk less important than small oil and gas producer. However, for both types of companies this factor is important.

To minimize the barriers of technology and innovation creation, it is necessary to assess the risk through risk matrix to decrease the level of uncertainties. Reducing the costs of development and implementation is also necessary to increase the profitability from technology usage. A weak level of technological transfer is the barrier for technology development. Governmental stimulation of scientific institutes and interaction with oil and gas producers will increase the level of technological transfer. The lack of exploration strategy makes the company less risky in innovations projects. The type of company strategy mainly depends on financial sources which a company owns. Government subsidies can help company to be more innovative. Technological paradigm shift demonstrates a subsea complex development in companies from developed countries and in Russian companies. The gap between these two types of companies is big. Due to this, it is necessary to create a radically improved subsea complex. Also, it was estimated that companies from developed countries suffered less from uncertainties and costs. Furthermore, they are flexible in a strategy choice. The mechanism of technological transfer is also developed in these companies. From the technological paradigm shift a subsea complex is close to a saturation point. However, companies continue developing incremental innovations in subsea.

For Russian companies, there are two tasks in the frames of subsea. The first one is to develop and implement a subsea complex from a zero point. The second task is to develop subsea with radical innovations. These two tasks are difficult to execute because of existing barriers. However, the improvement of these factors will allow to develop not only a subsea system but all upstream technologies. The analysis of Norwegian experience in innovation management can be useful for the improvement of the existing situation in Russia. The implementation of a new mechanism of innovation management can improve situation.

8. Contribution, limitations and further research

8.1 Practical contribution

In this thesis, I have dealt with a topic that is interesting for innovation managers in Russian oil and gas companies. The model that was developed allows to analyze the main risks and factors that influence on decision making process of technology development and implementation in upstream industry. Nowadays, innovation management in Russian companies on the stage of development. Furthermore, this management has special features that was formed by technology import policy, weak scientific development and low level of government support. According this fact, oil and gas producing companies have very low level of innovation management. My model help to analyze drivers and barriers for radical and incremental technology development and implementation for the innovations. The case of subsea development adds the value for this topic because of governmental program of Arctic development. This program and huge reserves on the shelf attract oil and gas producers. However, the sanctions are the border for technology import. In this case, my model can be a useful tool to evaluate and make decision in which way company should develop their own technologies to become competitive on the market. Moreover, the model allows to estimate what niche it is possible to take to be gainful on the market. Considering how important oil and gas industry for Russian economy, it would be interesting for the companies to understand how they contribute to the further technological development. Moreover, by the understanding what are the main factors that influence on the decision for technology implementation it would be possible for other industries with connection to the oil and gas industry to adapt to this. Additionally, I would emphasize the importance of interaction between government, scientific research centers and producing companies. The dysfunction of one element will lead to the low technology development.

8.2 Limitations

This thesis is only focuses on general description of factors that are influence on the decision-making process of technology development and implementation. By interviewing different respondents from scientific centers and oil and gas producing companies, I have managed to give a common understanding of which factors act as a barriers and driver. Moreover, may approach of interview gave me narrow answers. The aim of this thesis was to describe and analyze estimate what factors influence on decision making process in Russia. This thesis only deals with subsea technology. The overlook of the Arctic region is also limitation of the study.

Due to the time limit, I have only interviewed 5 experts but they don’t cover all industry. Moreover, I didn’t interview respondents from the Norway. Norwegian experts’ experience in determination of the factors that influence on innovation management will be useful to compare it with Russian companies’ situation. The result of this is that this thesis based upon limited information. Nevertheless, the interviews performed has given me a good impression of what is typical for this industry. All my respondents are people with high ranking position who responsible for technology planning and development. However, if I also had interviewed representative from the other oil and gas producing countries, it could have given me an even better understanding of how management deals with innovation management of technology development and implementation.

8.3 Further research

For further research, it would have been relevant to conduct comparative study and to interview the experts from Norwegian companies. Moreover, it would have been useful make new interview guide with deeper question concerning the factors that influence on the process of decision making.

it would have been also interesting in study the mechanisms for reducing the risks of barriers for technology development and implementation. In the research was found that several conditions influence on the process of decision making. In further research, it will be interesting to develop scenarios of company technological development including oil prices as the dominant factor for decision making, and defining what type of innovation should be implemented.

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10. Appendix

Appendix 1: Interview guide

Request for participation in research project "Drivers and Barriers for implementation radical and incremental innovation in subsea complex in Russia "

Background and Purpose

The main aim of the study is to estimate the barriers and drivers for decision making process for implementation radical and incremental innovation in subsea complexes. This master thesis is developed with support from Nordland University of Bodø, Norway.

The sample has been selected due-to the experience in decision making process of innovation implementation in upstream offshore projects. All the experts are highly qualified in the sphere of management innovations in oil and gas industry.

What does participation in the project imply?

Data collection for the research will be made by remote interview. All experts will receive semi-structured questionnaire with open ended questions through email. Each expert will asked to fill questionnaire and send it back. After that all answers will be collected and analyzed.

What will happen to the information about you?

All personal data will be treated confidentially. Just author of this thesis will have an access to the personal data. All answers and personal data will be stored in the author’s personal computer and it will be protected with password.

Participants will be not recognizable in the publication.
The project is scheduled for completion by 19th of May. At that point all data will be collected and analyzed.

Voluntary participation

It is voluntary to participate in the project, and you can at any time choose to withdraw your consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous.

Questionnaire

1. How do you understand “an introduction of radical innovation” in subsea complexes?
2. What examples of radical innovation in subsea complexes can you give?
3. How do you understand by “an introduction of incremental innovation” in subsea complexes?
4. What examples of incremental innovation in subsea complexes can you give?
5. Which of the two types of innovation, radical or incremental, in your opinion, are used more often in oil and gas industry and why?
6. What kinds of uncertainties do oil and gas companies face when they take a decision to modify technologies (a subsea complex or any other)?
7. What types of uncertainties influence a decision-making and why?
8. How do oil prices, in your view, influence the decision to introduce radical or incremental innovation and why?
9. How can oil prices have an impact on the introduction of a certain type of innovation?
10. What types of additional modifications in technology, in your opinion, can be introduced at different oil prices?
11. What do you understand by the term “technological uncertainty”? What role can technological uncertainties play in the process of a subsea modification or other technologies employed in oil and gas industry?
12. What role do technological uncertainties play at the creation and introduction of radical and incremental innovation in a subsea complex and why?
13. What promotes technological uncertainties?
14. What should be undertaken to avoid technological uncertainties?
15. What factors connected with an organizational structure at the creation of radical and incremental innovation in a subsea complex or other technologies in oil and gas sector are important and why?
16. What uncertainties of resources in the process of creation of radical and incremental innovation for a subsea complex or other oil and gas technologies are of consequence and why?

17. Can you describe the level of technological development of a transfer in the Russian Federation?

18. How is the level of technological transfer developed between state scientific centers and private companies in Russia?

19. Why does technological transfer influence decision making on the introduction of radical and incremental innovation?

20. In technological management there exist two strategies: the strategy of creation of new (radical) technology and the strategy of exploiting and modifying of an already existing technology. How does an oil and gas company decide which of the two strategies to choose?

21. Which innovation must be exploited under these strategies and why?

22. What degree of risk do these strategies present and why?

23. Please describe what factor/factors are determinative to make a choice between these two strategies? Can oil prices be such a factor?

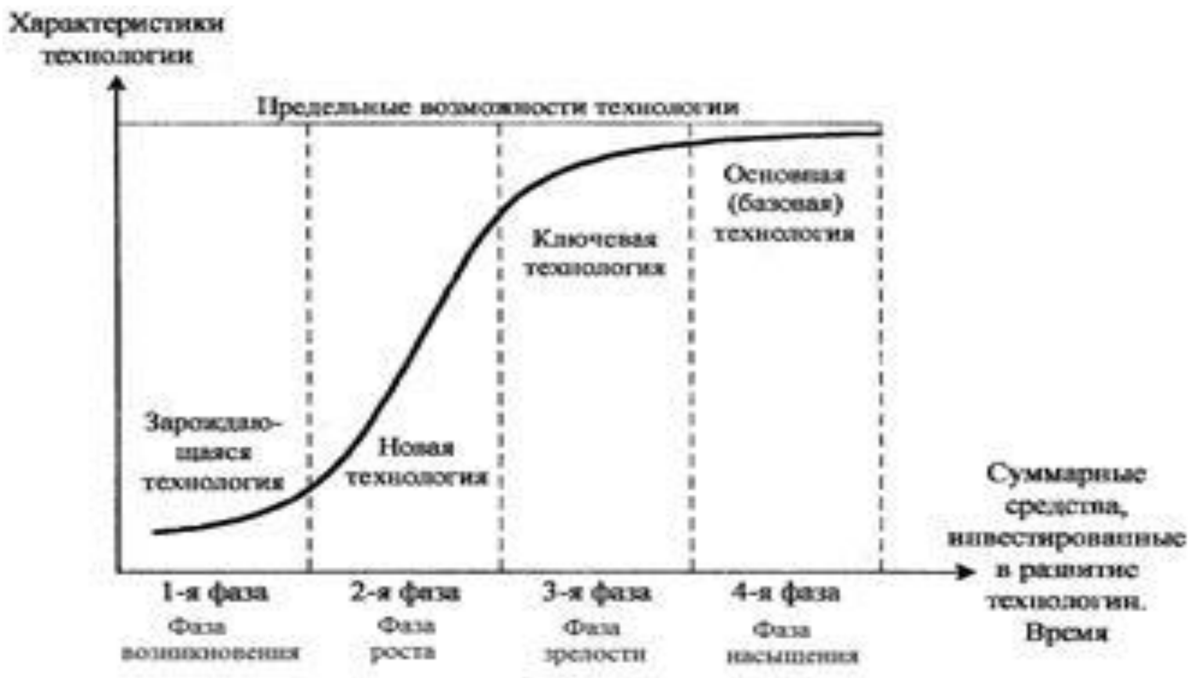
24. Why, in your view, is the strategy of creation of a new (radical) technology costly to an oil and gas company?

25. Which strategy is more admissible nowadays from the view point of technological development (a subsea complex) and why?

26. What role does the accumulation of experience while using current technology play for the creation of new technologies and why?

27. What costs are there in the process of creation of radical and incremental innovation?

28. What costs are the highest in such innovation and why?



29. In what stage of S-curve is a subsea complex now, in your opinion, and why?

30. To proceed from the place of a subsea complex on S-curve now, which type of innovation must be introduced, radical or incremental, and why?

31. In your opinion, how long will a subsea complex in S-curve position indicated by you remain and why?

32. In your opinion, how should companies make decisions on using innovation in technologies and why?