Master's degree thesis

LOG950 Logistics

Title: LOGISTICS CHALLENGES INVOLVED IN CONSTRUCTING OF OPERATING FACILITIES IN MEGA - PROJECTS
(A Case study of Cost Overrun in Snøhvit LNG Project)

Author(s):Beltus N. Onyia and Olawande Osuma

Number of pages including this page: 95

Molde, 25th May 2010

Molde University College

Publication agreement

Title: LOGISTICS CHALLENGES INVOLVED IN CONSTRUCTING OF OPERATING FACILITIES IN MEGA - PROJECTS (A Case study of Cost Overrun in Snøhvit LNG Project)

Author(s): BELTUS N ONYIA and OLAWANDE OSUMA

Subject code: LOG 950

ECTS credits: 30

Year: 2010

Supervisor: Prof. Arild Hervik

Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).
All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).
Theses with a confidentiality agreement will not be published.

I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication: ☒**yes** ☐**no**

Is there an agreement of confidentiality? ☐**yes** ☒**no**
(A supplementary confidentiality agreement must be filled in)
- If yes: **Can the thesis be online published when the period of confidentiality is expired?** ☐**yes** ☐**no**

Date: 25th May 2010

PREFACE

This project work was taken due to the extremely important role of oil and gas sector in today's economy. At first we wanted to take on a comparative study of two separate gas projects – Snøhvit and Ormen-Lange. This was necessitated by the fact that Ormen-Lange was constructed without significant cost overrun and within schedule while Snøhvit was riddled with much cost and time overrun. We believed that finding out why Ormen-Lange was within budget would throw more light on what went wrong in Snøhvit but we were dissuaded by our external examiner who argued that both projects adopted different technologies and as such there is no solid base for such cost comparison. As a result, we scaled it down to this present scope where we conducted an in-depth analysis of causes of cost overrun in Snøhvit. Nevertheless chapter 8 of this work was more on Ormen-Lange, particularizing on its scope, technology and contacting method and comparing them to that adopted in Snøhvit. This was aimed at understanding how the logistics challenges faced during construction of Ormen-Lange were solved.
Our believe was that such findings will help reduce the extent to which projects overran their budget especially in Nigeria – a country with numerous on-going oil and natural gas projects.

Our thanks go to our supervisor Prof. Arild Hervik for providing the necessary data and link to those we interviewed and for guiding us through the project. We equally appreciate the efforts of Egil Gjesterland - the then acting chief executive of Statoil, and Henrik Carlsen - member of the investment committee **(INVESTERINGSURVALGET) 1998** set up by the Norwegian Ministry of Petroleum and Energy to analyze the trend in investment on the Norwegian continental shelf, for assisting us with the project by agreeing to be interviewed.

SUMMARY

Snøhvit was a pioneer LNG project in which an entirely new engineering concept was adopted. It was an enormously gigantic project, with work having to take place all year round in quite a tight schedule. During its construction, the project was riddled with logistical challenges that resulted in budget and time overrun. The project exceeded its original cost estimate by more than 50%. Regular gas deliveries started on 1 December 2007. This is eight months later than the originally estimated date of 1 June 2007. Our task therefore, was to identify the logistic challenges that led to these overruns with the aim of limiting its effect in future LNG mega-project undertakings.

Our analysis of the scope, technology, management, time schedules and cost estimations adopted during the construction of Snøhvit revealed, apart from others, three very important logistic shortcomings that eventually resulted in cost and time overrun. They are:

1. IMMATURITY OF THE PROJECT WHEN IT'S PDO WAS APPROVED. The project was not sufficiently mature upfront when its PDO was approved. This resulted to changes in the scope and construction technique as the construction progresses. Changes were made to the original designs and the modules modified to be at par with these new designs. The outcome was extra costs and time that were not accounted for at the time the original cost and schedule estimates were made.

2. CONTRACTUAL FLAWS. Conventionally, no contact is complete in itself and Snøhvit wasn't an exception. Due to the contract system adopted, there was the problem of asymmetric information between principal (Statoil) and agent (Linde). The consequence of that was an opportunistic behavior on the part of the agent, at least during the projects concept defining and selection stage. The agent presented an appealing engineering concept which unfortunately was not comprehensively researched on – a fact that was hidden from the client. As the project progressed, it became evident that they do not have an exhaustive control of the task and was quite incapable of handling such a gigantic, huge project. This resulted in faulty engineering

and re-workings which had to be corrected thus leading to delays and cost escalations.

3. DELAYS IN SUPPLY OF MATERIALS ALONG THE SUPPLY CHAIN. Snøhvit recorded, to a significant degree, uncertainty and disruption along its construction supply chain. These were in form of delays in supply of some strategic materials. The fact that Snøhvits supply chain was already complex and highly interdependent escalated the impact. The consequence was that a delay in one area led to delays and increased cost on other areas. It was hard to solve unforeseen problems in one phase without this having consequences for the next phase. Therefore, there costs which were not parts of the original budget.

Key words: cost overrun, logistic challenges, cost estimates.

TABLE OF CONTENTS

Appendix

A. LIST OF TABLES

B. LIST OF FIGURES

CHAPTER 3. INTRODUCTION AND RESEARCH PURPOSE

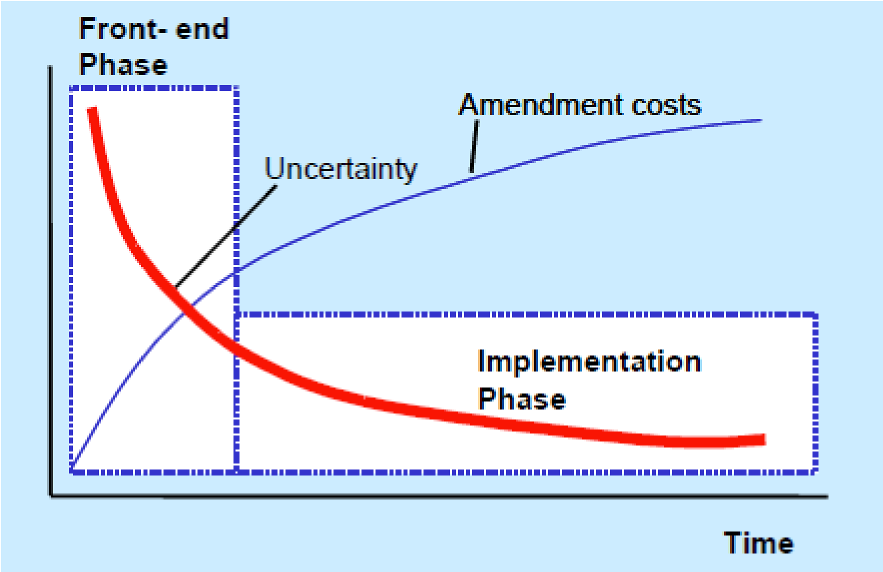
3.1 INTRODUCTION

According to Jackson (2002),"*the construction industry has a reputation of delivering projects over budget, making national headlines for being financial disasters".* He cited Barricks' (1995) survey of construction industry clients in the United Kingdom, which found that *"nearly one third (of clients) complained that their projects generally overran budget".*

In Norway, Olsson et all (2003) reported that analysis conducted by a Norwegian Parliamentary committee (Kaasen 1999) revealed a *"total budget overrun of 13% or 3,470 million Euros for the total set of projects between 1994 and 1998".*
The Norwegian government report (NOU 1999:11) showed that even though the total amount spent on development and construction of projects along the country's continental shelf has gone down over the last ten years, the extent of reduction was not as much as expected. The report gave total cost overrun of 25 billion NOK for all projects that were approved by the government within 1994 to 1998.

Normally, most construction projects comprise of two distinct phases; the pre-construction and the construction stages. Y. Frimpong, J. Oluwoye and L. Crawford (2003) noted that *"delay and cost overruns occur in both phases however, major causes of project overruns usually take place in the construction phase".*

Figure 1. THE IMPLEMENTATION PHASE IS CHARACTERIZED BY HIGH AMENDMENT COST.



Source: Olsson et all (2003)

The oil and gas sector are also not immune to this phenomenon. Almost all such projects - starting from their conceptual and developmental stages to construction and commissioning stages - are always huge technological, engineering and construction undertakings anywhere in the world. Flyvberg (2007) listed the characteristics of mega-projects to include:

* *They are inherently risky due to long planning horizons and complex interfaces between the project and its context, and between different parts of the project.*

* *Decision making, policy, and planning are often multi-actor processes with conflicting interests.*

* *Often the project scope or ambition level change significantly over time.*

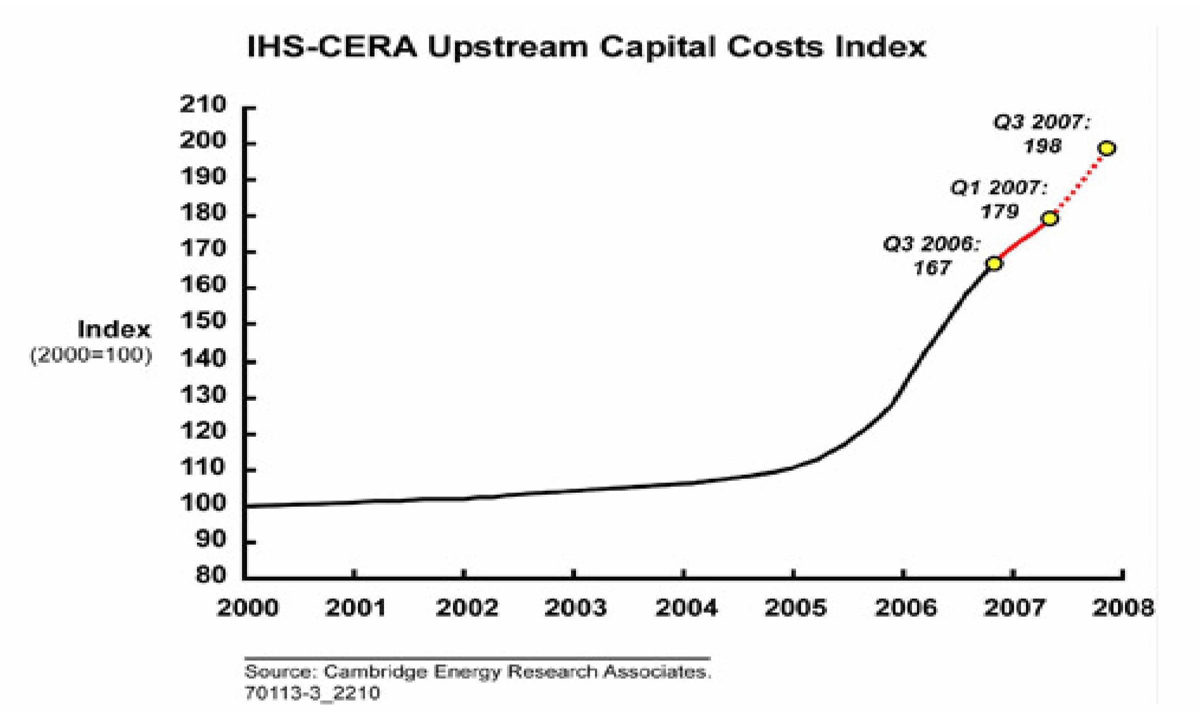
* *Statistical evidence shows that such unplanned events are often unaccounted for, leaving budget and other contingencies sorely inadequate.*

* *As a consequence, misinformation about costs, benefits, and risks is the norm.*

* *The result is cost overruns and/or benefit shortfalls with a majority of projects."*

Certainly, there is no shortage of examples of oil and gas projects with cost overrun. A typical example is Shell's Sakhalin II project. It is a huge and complex oil and gas production project at Sakhalin Island, off the east coast of Siberia in Russia. Construction of the project was approved in 2003 at an estimated cost of $10 billion. This figure is bigger than Shell's net income for the prior year but after two years of construction work, Shell announced that the cost had doubled to $20 billion.

Figure 2: INCREASE OF UPSTREAM OIL & GAS CAPITAL COSTS OVER TIME



In Nigeria, the Gas–to-liquid Escravos plant, which will convert natural gas into liquid petroleum products, has seen its initial cost estimate reviewed to $5.9 billion. This amount is more than three times its originally estimated cost. The project is designed to produce 34,000 barrels of fuel per day using flared gas. According to Senate report the project was signed in 1998 at a cost of $1.294 billion. This was increased to $2.721 billion in 2001 and is currently fixed at $5.9 billion. But the Oryx GTL in Qatar, which has the same volume and specification, began construction in 2003 and was commissioned and put to use in 2006 at the cost $900 million, ahead of Nigeria's plant whose contract was signed 1998. The Senate report states that, *"the Nigeria's GTL* *plant at Escravos which was due to be commissioned in 2009, has faced repeated upward review of job cost and that completion time is now fixed at December 2010".*

Nonetheless, there are reported and documented cases of oil and gas mega-projects that have been completed within cost and time. A report in the Economist by Mary Evans (2005) stated that, *"the Saudi-Aramco Harady gas pipelines with original budget of $2 billion and three years was completed within six months ahead of schedule and 27% under budget".*

Also here in Norway is the Ormen-Lange Liquefied Gas project. The field was discovered in 1997 off the coast of North West of Kristiansund at a depth of about 850 to 1100 meters below sea level. Just like Snøhvit, the Ormen-Lange was drilled in an area with extreme weather conditions and sub-zero water temperatures at seabed. The gas processing plant is also located onshore at Myanma and processed gas exported via pipeline to Easington-UK, 1200km away.

The construction period was riddled with many challenges including steep and uneven seabed, harsh weather, subzero temperatures and many other issues but these did not prevent the teams from completing the project within the agreed budget and on time of 66billion NOK and 3 years (2004 – 2007) respectively.

3.2 RESEARCH PURPOSE

So many efforts has been made within the Norwegian oil and gas sector at reducing cost and time of projects within the sector. Early 1990, a task force named NORSK was formed solely to tackle this problem. They carried out a number of organizational and contractual changes with particular attention paid at reducing the construction lead time. Such changes saw the emergence, within Norway, of entities capable of handling complete projects from concept development, installations and start-up.

They also revised the way risks were shared by stakeholders. Initially, risk were borne by oil companies but now, an even split of cost overruns and savings between the oil companies and contractors, relative to a target amount was introduced.

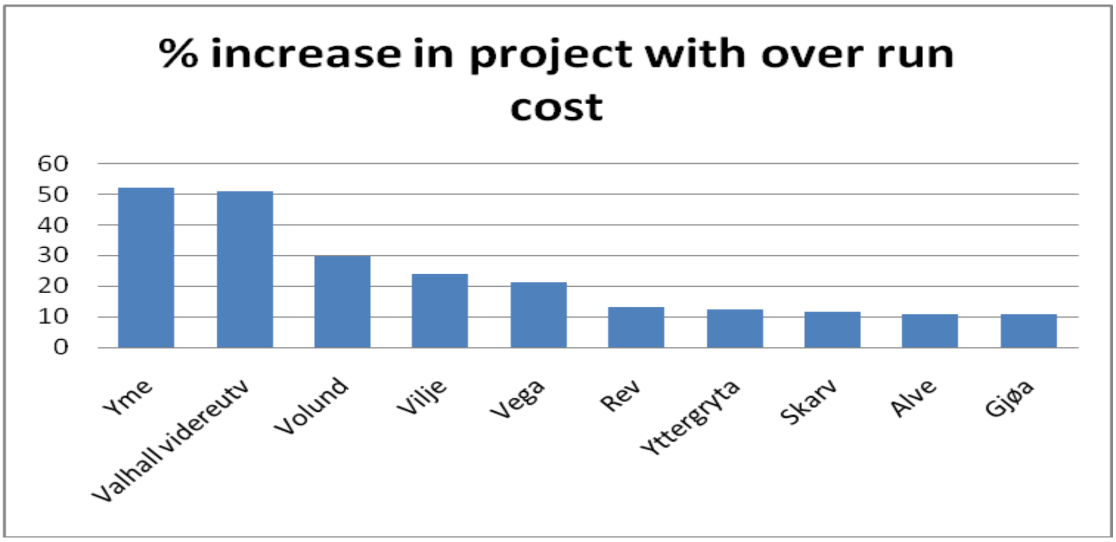
Regardless of all the efforts, figures obtained from the government study of 1999 for oil and gas projects carried out after the plan implementation in 1994 show an average of about 13.8 percent increase from what it was originally budgeted. The table below shows the analysis of budget overruns on some projects they conducted.

Table 1. ANALYSIS OF BUDGET OVERRUNS IN SOME OIL/GAS PROJECTS

PROJECT	BUDGET ESTIMATE (MILLION NOK)	PRESENT COST (MILLION NOK)
Yme	4572	6940
Valhall videreutv	23.225	35.051
Volund	2982	3865
Vilje	2216	2743
Vega	6363	7718
Rev	2852	3224
Yttergryta	1302	1461
Skarv	33.643	37.490
Alve	2583	2865
Gjøa	29.635	32.854

Source: Norwegian Oil and Energy Department (2009)

Figure 3. INCREASE IN PROJECTS WITH COST OVERRUN



Source: Norwegian Oil and Energy Department (2009)

Analysis of the figures indicates that the entire projects under consideration has cost overrun of between 10.9 and 51.8 percent. This (in real figures) is a huge amount as most of these projects run into hundreds of billions of dollars.

These unbudgeted amounts pose serious financial risks to the stake holders; therefore there is the need to identify the **"logistic challenges, reasons and decisions"** that contribute to these increases. Unfortunately, the extents of these challenges, which undoubtedly led to time and cost overruns, have remained under-studied. **Therefore the objective of our project is to find out what logistic challenges face a typical mega project in order to throw more light on why projects overrun using Snøhvit project as a case study**. This will serve as platform at limiting the extent to which future undertakings are affected by cost and schedule overruns.

3.3 SCOPE OF THE RESEARCH

In an attempt to understand the logistic challenges involved in constructing and operating facilities in mega projects, our research was carried out as an analytical case study of a mega gas project constructed here in Norway. It was a mega-project constructed with many delays and associated high cost over-runs.

The Statoil Snøhvit project operates within the oil/gas industry and was designed and constructed from scratch. Feasibility studies, financial and contractual implications for the project were carried out by seasoned professionals but at the end of the first construction phase, Snøhvit was late with considerable budget over-runs. According to, Krauss et all (2005), "*overruns have put the price of Snøhvit at $8.8 billion, almost 50 percent above its original estimate".*

The study was based on documented project cost data obtained during the construction of the project's first phase. By carrying out a research in form a study of the projects operational pattern, sequence and time period allocated during construction, this paper will aim to identify and examine the logistics challenges and decisions (if any) that resulted in delays and cost overruns in Snøhvit LNG project despite its huge financial and professional abilities.

3.4 DATA SOURCES

Relevance and importance of any research project depends on quality and reliability of information and data used. In this regards we made use of published data from these reliable sources:

(i) The Norwegian petroleum and energy department.

(ii) The Norwegian Oil and Energy department.

(iii) Annual reports of Statoil (2001 to 2008) and other publications from Statoil News journal.

(iv) Report of the Investment committee **(INVESTERINGSURVALGET 1999)** set up by the Ministry of Petroleum and Energy to analyze the trend in investments on the Norwegian continental shelf.

(v) Interview with Egil Reinhard Gjesterland, the then acting chief executive of Statoil.

(vi) PhD thesis report by Trond Nilsen titled “Regional Interest in Snøhvit and Ormen-Lange projects” of University of Tromso. (2008)

We equally gathered primary information through interviews of other individuals some of whom were part of the decision makers during the construction period of Snøhvit while others are panel members in various oil and gas review committees. Questions used in the interviews were not really structured in nature but all were directed towards challenges faced during Snøhvits’ construction. Therefore not exactly the same questions were asked every one interviewed.

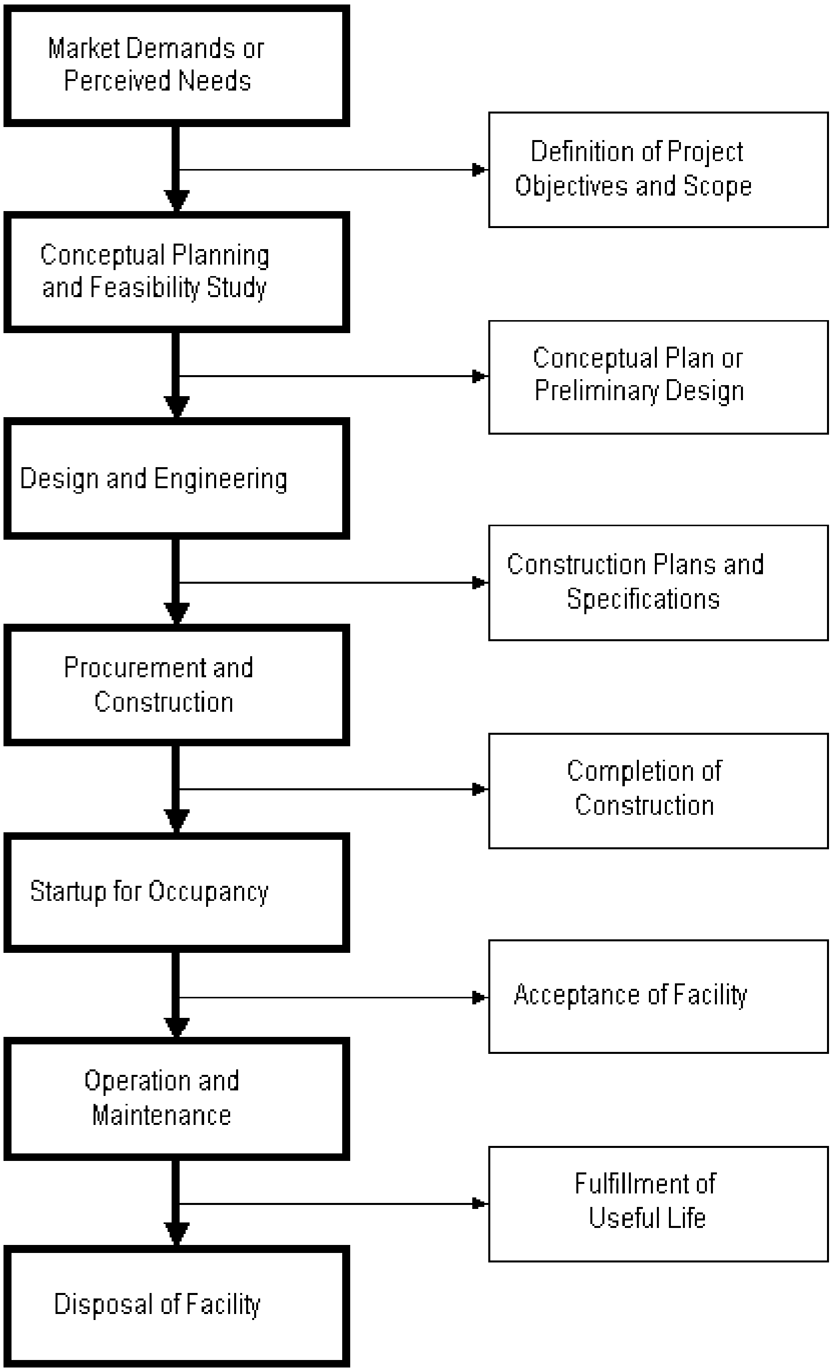
We also gathered quite a large number of information from validated scientific journals/publications relating to oil and gas sector.

3.5 RESEARCH METHODOLOGY

Our work was mainly qualitative and required careful analysis of so many published works and literatures as regards the Snøhvit LNG project. The data sources are listed in section 3.5. Issues and topics related to cost and time overrun in Snøhvit were carefully sieved out from these literatures and publications and detailed analyses conducted in order to identify what logistic and other problems they faced that could have resulted in the cost and time overrun recorded.

We also consulted and interviewed some persons some of whom were part of the management of Snøhvit project during its construction period. Some others were economists and others part of the committee set up by the government to identify problems and its causes as regards construction projects within the Norwegian oil and gas sector. The interviews were somehow personal and as such were not structured in nature, This means that not exactly the same questions were asked every person but all question were directed towards identifying what could have led to the cost and time escalation in Snøhvit. At the end, our findings were pooled together and analyzed and results obtained.

Figure 4: TYPICAL LIFE CYCLE OF A CONSTRUCTED PROJECT.



© C. Hendrikson 1998

Analysis of the above figure shows that a completed project is made up of so many interdependent phases. Each of the phases contain hundreds of sub-phases. Delays and cost overruns occur in all these phases however, major causes of project overruns usually take place in the construction phase but the mistakes that led to these overrun were actually done during the planning and design stages. This paper attempted to locate the challenges faced during the approved time limit of Snøhvit regardless of phase's demarcations.

3.6 LIMITATIONS OF THE RESEARCH

A limitation of the research is that we studied only one case of a completed oil and gas mega-project riddled with cost and time overrun. This project (Snøhvit) was constructed in Norway – a developed, rich and highly civilized country. As such, findings from just Snøhvit might not be used as a trusted yard stick for measuring challenges or why costs overrun in other developed but poor countries nor in less developed parts of the world. This is because of the existence of different challenges and situations within countries. All the same, it is our belief that our findings will undoubtedly throw more light as to why there are cost overruns in oil and gas mega-projects.

CHAPTER 4. THE SNØHVIT LNG PROJECT

4.1 AREA HISTORY

The Snøhvit LNG Development Project, operated by Statoil, represents a pioneer project in the history of LNG. It is the first LNG full-scale liquefaction facility ever built in Europe and is located in one of the most fragile marine areas in the world.

Figure 5: GEOGRAPHICAL LOCATION OF HAMMERFEST

© Tractebel Gas Engineering

The gas reserves in the Barents Sea off the coast of Northern Norway were discovered in the early 1980s. The Snøhvit area is located at the Norwegian Continental Shelf at 71° North in the Tromsøflaket West province of the Barents Sea. Snøhvit - the worlds' northernmost Liquefied Natural Gas plant – is a project comprising of production of gas and condensate from three fields in the Snøhvit-area namely Snøhvit, Albatross and Askeladd. The distance from the fields to shore is about 140 -160 kilometers and in 300 to 350 meters water depth. The total reserves are in excess of 300 billion standard cubic meters of gas and 20 million cubic meters of condensate. (Heiersted and Lillesund 2004)

4.2 PROJECT DEVELOPMENT.

The first oil and gas exploration activity in the Norwegian continental shelf of the Barents Sea began back in 1980, with quite a substantial amount of gas-condensate discoveries made in the central part of the sea in the Snøhvit area. The major gas reserves were found contained in Middle-Lower Jurassic sandstone structures in 300-340 m depth of water.

Oil, on the other hand, was not found in large commercial quantities though Snøhvit field has about 500 million bbl of oil within a thin zone at the base of the reservoir. An attempt at drilling the oil was frustrated by rapid breakthrough of gas and water during the production test thus recovery was deemed noncommercial.

In1994, drilling was completely stopped because of technology limitations prompting the Norwegian government in 1996 to revise existing licensing laws to encourage continued exploration activities. They cancelled drilling commitments for some awards, enabled group license applications, increased the equity shares and expanded oil blocks.

In September 2001, the formal plan for development and operation was submitted by Statoil to the Norwegian Parliament. It was approved in March 2002. The plan showed that the whole process will be constructed in phases. It contained a field development made up a subsea production system with the well stream transported to the onshore processing plant in a multiphase transportation pipeline.

4.3 GAS FIELDS

The location of the processing plant is on the Island of Melkøya near Hammerfest. According to Norwegian Oil and Energy Department, the fields consist of the following licenses:

* PL097, PL099 and PL110, which accounts for Snøhvit.

* PL064 and PL077, which accounts for Askeladd field.

* PL078, part of PL097 and PL100, which accounts for Albatross field.

Figure 6: LOCATION OF SNØHVIT GAS FIELDS IN RELATION TO THE PLANT SITE

© Tractebel Gas Engineering

Interests of licensees in the Snøhvit project are indicated in the Table below.

Table 2: LICENSES AND ALLOCATION OF INTERESTS

COMPANY	OWNERSHIP INTERESTS
Statoil ASA (operator)	22.29%
Petro AS	30.00%
Total Norge AS	18.40%
Gaz de France Norge AS	12.00%
Norsk Hydro Producksjon AS	10.00%
Amerada Hess Norge AS	3.26%
RWE-DEA Norge AS	2.81%
Svenska Pet. Exploration AS	1.24%

Source: Norwegian oil and energy department

The fields are scheduled for development in different phases which are shown in the table below.

Table 3: TIME ESTIMATIONS FOR COMPLETION OF THE PHASES

PHASES	ACTIVITY	PRODUCTION SCHEDULE
1	The Snøhvit field, pipeline to land and plant facilities at Melkøya.	2005
2	Askelaad	2011
3	Albatross	2018
4	Compression platform	2021
	End of plateau period	2032
	Field life	2035

Source: The Norwegian oil and energy department

4.4 CONTRACTORS AND TECHNOLOGY

In 1997, three contractors Kellogg, Bechtel and Linde were requested by Statoil to carry out conceptual designs for the Snøhvit LNG plant located at Melkøya Island near Hammerfest.

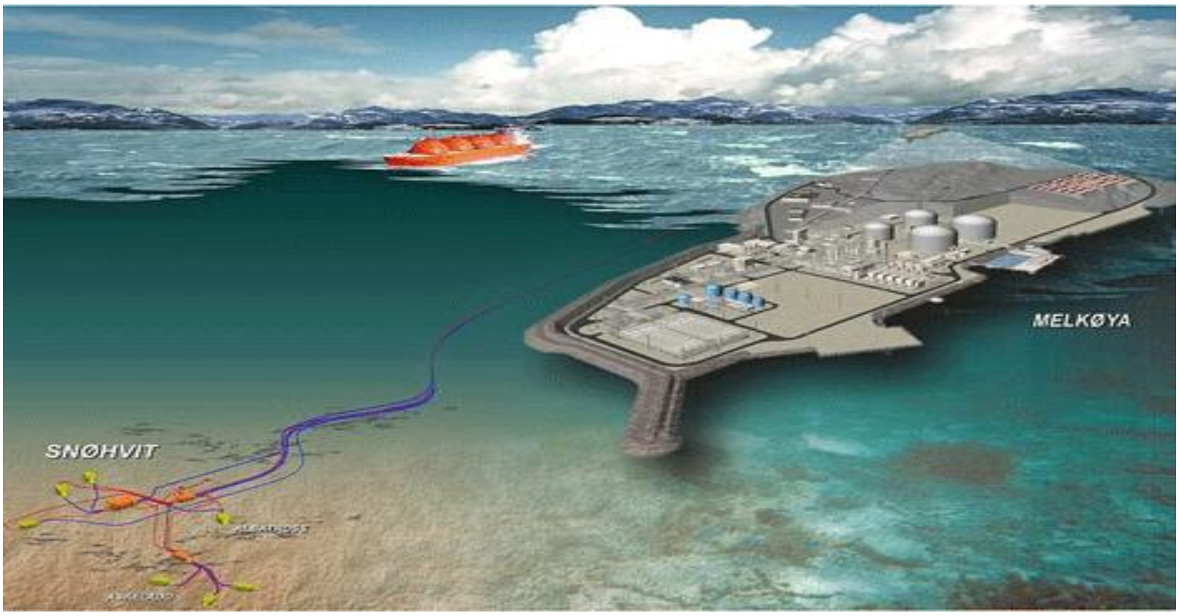
The conceptual designs submitted showed that Kellogg adopted the APCI propane pre-cooled process, C3/MCR Liquefaction Process, in their design (Heiersted and Lillesund 2004). According to them, the process is *"the far most utilized process for base load liquefied natural gas plants, and has been utilized in virtually all base load liquefied natural gas plants installed (in) the last 20 years, with some few exceptions".*

Figure 7: THE PLANT SITE IN MELKØYA NEAR HAMMERFEST.

© Linde Technology

They also noted that Bechtel applied the “Optimized Cascade Liquefaction Process” which is based on Phillips technology while Linde based their conceptual design on a *“dual flow liquefaction process but proposed to change their design in eventual*

Figure 8: A SIMULATED DRAWING OF THE PLANT AND THE FIELDS

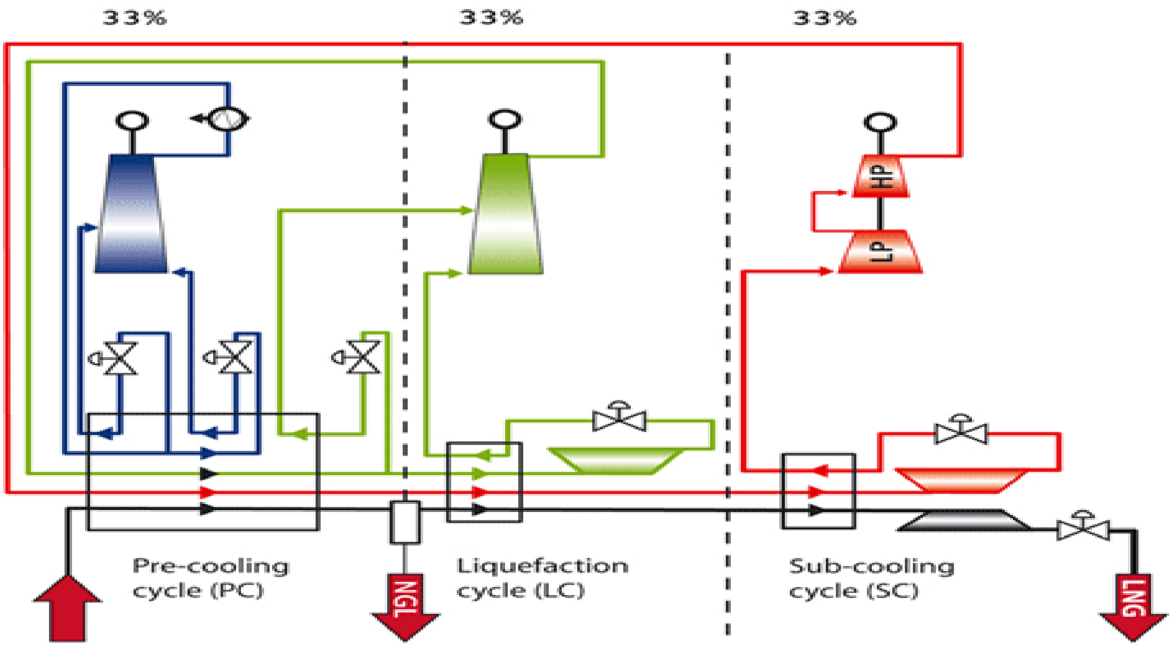


© Tractebel Gas Engineering

further stages of the project to a newly developed, proprietary Mixed Fluid Cascade Process, the MFC process". (ibid).

At the end of the three conceptual designs evaluations, Statoil decided to award what it called an "Extended Conceptual Engineering contract to Kellogg and Linde". The technology suggested by the third contractor, Bechel was not accepted but directed for further studies, due to the fact that *"its overall energy efficiency was too low compared to the MFC process and the C3/MCR process, which virtually have the same efficiency."*(ibid)

FIGURE 9 : FLOW CHART OF THE LOAD-BALANCED MFC®S3 PROCESS.



© Statoil

4.5 MAGNITUDE AND COMPOSITION OF THE PROJECT

Snøhvit is an extremely complex installation. The process is extensive, encompassing subsea control processing, complex LNG processes, storage and loading of the final products.

The whole operation is made up of the followings:

4.5.1 PIPELINES: These will act as the transportation system of all liquid streams to and from the offshore field structures. The pipelines are designed to go in closed loops thus ensuring a zero discharge situation during normal operations.

The pipelines are further divided into three:

i) The main pipeline which will carry unprocessed well stream from the fields to the gas plant on Melkøya Island. This is about 143 km and 29 inches in diameter. The pipe is made of steel with an outer coating of reinforced concrete. Each pipe section weighs between eight and 10 tonnes, with a total of 11,000 sections making up the main line. The actual pipe laying operation began from Melkøya on 18 April 2005, with 12-metre lengths of line pipe welded together in a continuous process on the lay barge and the task was completed June 4 2005 in what is to become the longest multiphase-flow pipeline in the world.

ii) The umbilical's – this took shape in the form of a NOK 550 million contract awarded to Technip Offshore Norge and involved laying and connecting flow lines and umbilical's on the Barents Sea field, as well as the umbilical and chemical lines between Snøhvit and Melkøya.

iii) The carbon dioxide pipeline. This is to transport recycled CO_2 separated from the crude gas back into a separate formation on the Barents Sea field. It is a 9 inch pipeline with a 5 inch chemical line (mono-ethylene) laid onto the seabed in a method which provides a laying speed of 10-20 kilometers per day. According to Jorunn Klovning, manager of health, safety and the environment for the Tromsø Patch/Snøhvit, *"this will become the first offshore injection of carbon dioxide from a land-based plant,"*

4.5.2 SUBSEA OPERATIONS OF THE PRODUCTION: The offshore fields were developed with subsea templates and the production managed from the onshore operation center at Melkøya. The subsea templates are four in number, each with four well slots. In addition is a control distribution system, which allocates power, control signals and chemicals, and a pipeline end manifold. (Statoil June 2004)

The pipeline end manifold will provide the connection point between flow lines from the templates and the main pipeline to the land-based plant at Melkøya outside Hammerfest. All the offshore systems are located on the sea bed and controlled from land via a 143 – kilometer pipeline. Drilling of the production wells will be performed using a semi-submersible rig.

4.5.3 ONSHORE LNG PLANT: This is a 33,000-tonne unit processing plant which forms the heart of the entire project. It consists of a barge-mounted production plant shipped to Norway from the fabrication yard in Cadiz, southern Spain. The process plant was constructed as one integrated unit on top of a barge with a deck size of 154 by 54 meters – considerably larger than an international football pitch (Statoil 2007). It was assembled at the Dragados Offshore yard in Cádiz - Spain, before being sailed to Hammerfest in a voyage estimation period of just under 11 days.

Figure 10: THE SNØHVIT LNG PLANT ON THE BARGE "BLUE MARLIN".

© statoil

According to Heiersted and Lillesund, *"The LNG plant construction strategy is based on maximum prefabrication. The basic concept is to install a base load LNG process train and most of its utilities on a purpose built barge and ship it to site. Compared to* *other LNG plant executions, the Snøhvit project has changed the philosophy from on-site, stick-built solutions to yard prefabrication, placing focus on maximum work executed in fabrication yards."*

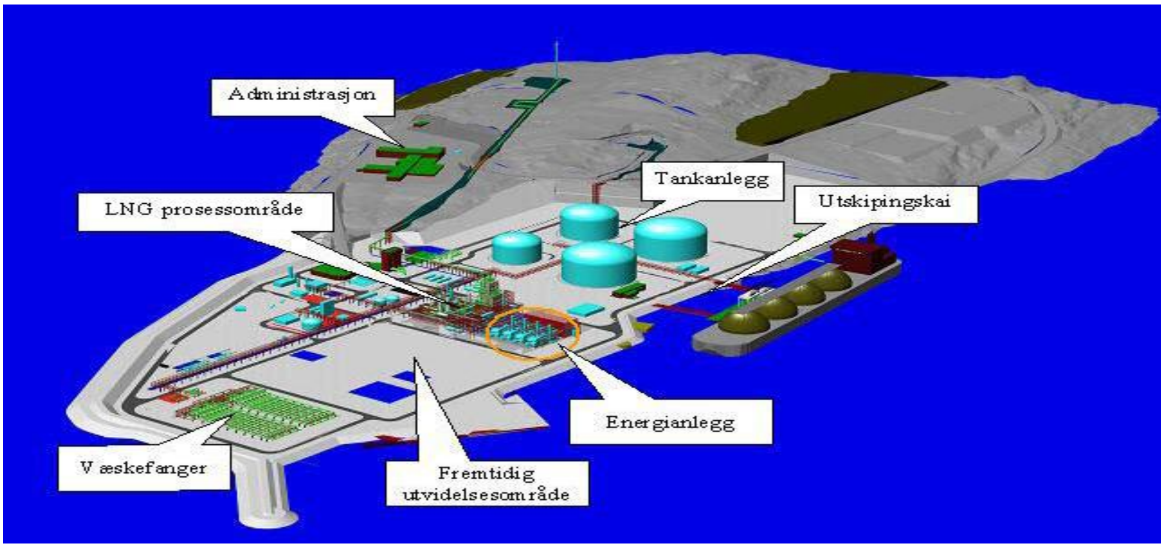
4.5.4 SHIPMENT OF PRODUCTS.

The Snøhvit LNG carriers are specifically built for operation in the toughest LNG trade so far and are the highest specified gas carriers in the world.

Figure 11: THE ARTIC PRINCESS: LNG CARRIER FOR SNØHVIT

© Statoil

Figure 12: SITE ARRANGEMENT OF SNØHVIT GAS PROCESSING PLANT.



© Tractebel Gas Engineering

4.6 THE LNG PROCESSING PLANT

The actual Project Plan was delivered to Norwegian authorities in September 2001 and since the project was controlled by the Norwegian government, (in part through its majority ownership of the energy company Statoil), it is imperative that Snøhvit should be a success.

The process to make liquefied natural gas requires energy. The LNG plant is a large refrigeration system, with three different cooling circuits, each powered by a compressor. Total power consumption for the three cold compressors is 152 MW. The compressors are powered by electric motors. In addition, the process has a heating requirement of 116 MW. Heating demand is covered from the gas heat. The power demand is covered by the 4 gas turbines (5 in a later phase of project). Gas turbines are connected to generators which supply power to the electrically driven compressors.

Apart from Liquefied Natural Gas and condensates, the Snøhvit project is also expected to produce wet gases (LPG) which is separated out during the cooling of natural gas. LPG is a product which is also stored in liquid form at atmospheric pressure before shipment. Products are shipped to the markets using specifically constructed ships.

4.7 ASSEMBLY PUZZLE:

The various components of the liquefaction plant were not manufactured in a single workshop but had to be outsourced to different location and countries. These components were pre-assembled at eight major sites in Europe before final assembly and installation in Cadiz, Spain. Linde technology (2006) listed the locations and details of jobs done as shown below:

A. MELKØYA, NORWAY: Blasting, site preparation, excavation of process barge dock, construction of tanks, coolant tunnel, operations building and underwater access tunnel.

B. BREMEN, GERMANY: Fabrication of cold box modules

C. ANTWERP, BELGIUM: Final assembly and shipping of cold box.

D. ZWIJNDRECHT, NETHERLANDS: Fabrication of slug catcher.

E. HOBOKEN, BELGIUM: Fabrication of miscellaneous components and pipe bridges.

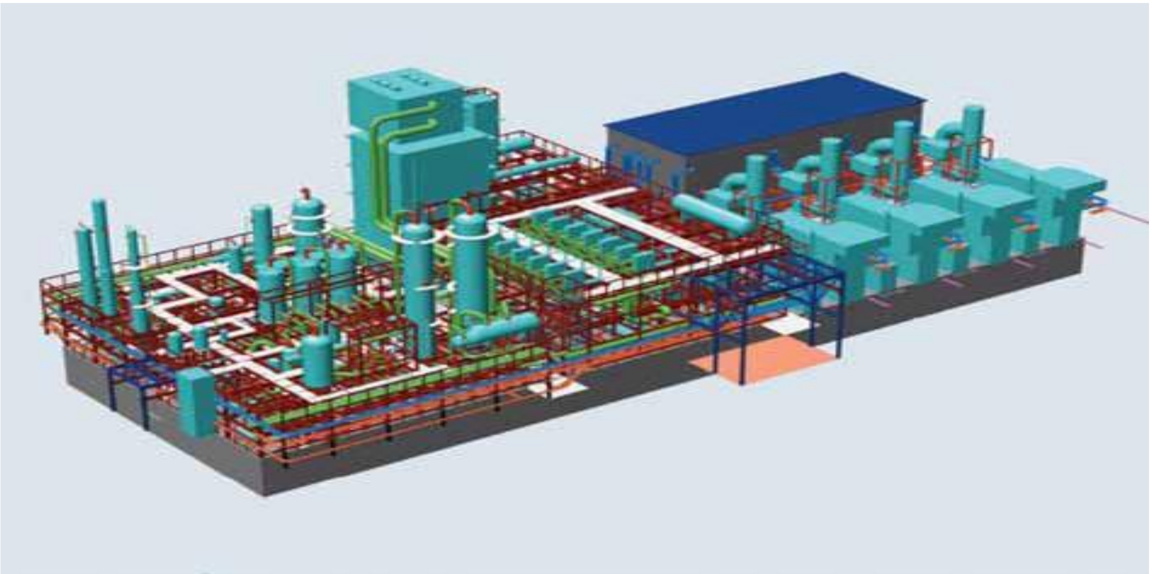
F. SCHALCHEN, GERMANY: Fabrication of cryogenic heat exchangers.

G. MASSA AND FLORENCE, ITALY: Fabrication of gas turbines and compressors.

H. FERROL, SPAIN: Assembly of barge (steel hull).

I. CÁDIZ, SPAIN: Installation of process plant on barge

Figure 13: THE PREFABRICATED PROCESS WHICH WAS SHIPPED FROM A YARD IN SPAIN



© LNG technical review

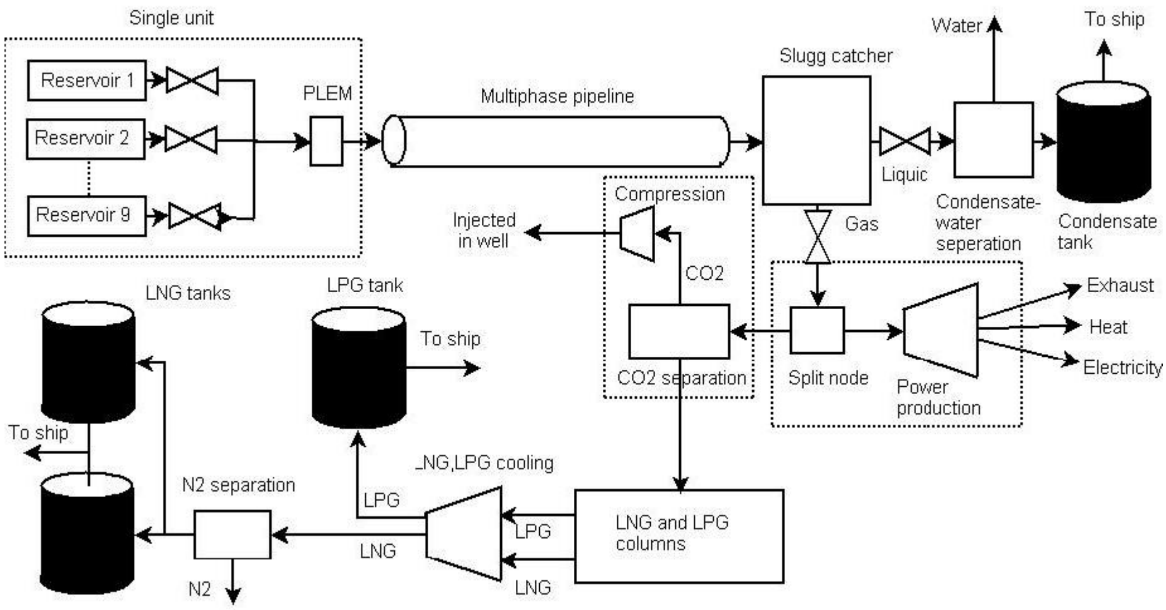
4.8 OPERATIONAL MECHANISM

Snøhvits' uniqueness is in its combination of offshore production, (a distinct operation from shore), with an onshore processing using up-to-date technology. It also makes use of recycled gas for its operations. It is a method where CO_2, separated from the produced gas onshore, are sent back offshore via pipeline for re-injection to a suitable reservoir. According to Engsbretsen et all, (2002), this is *“the first offshore development ever where CO_2 is separated onshore and re-injected”.*

The actual operation of the plant started at the end of 2007. It involves the sucking of gas stream through a 143km-long, 28 inch-wide steel pipe from the Snøhvit gas field out in the Barents Sea. It will then be cooled to -163 degrees Celsius before loading into specially constructed fleet of four tankers expectedly to sail 70 times a year to the US, France and Spain.

According to the EU Observer (June 26 2006), the capacity of these tankers are such that on each trip, *“each tanker will carry enough gas to power a city the size of Amsterdam for six months”.*

Figure 14: FLOW CHART OF SNØHVIT LNG PLANT



© Dahl 2007

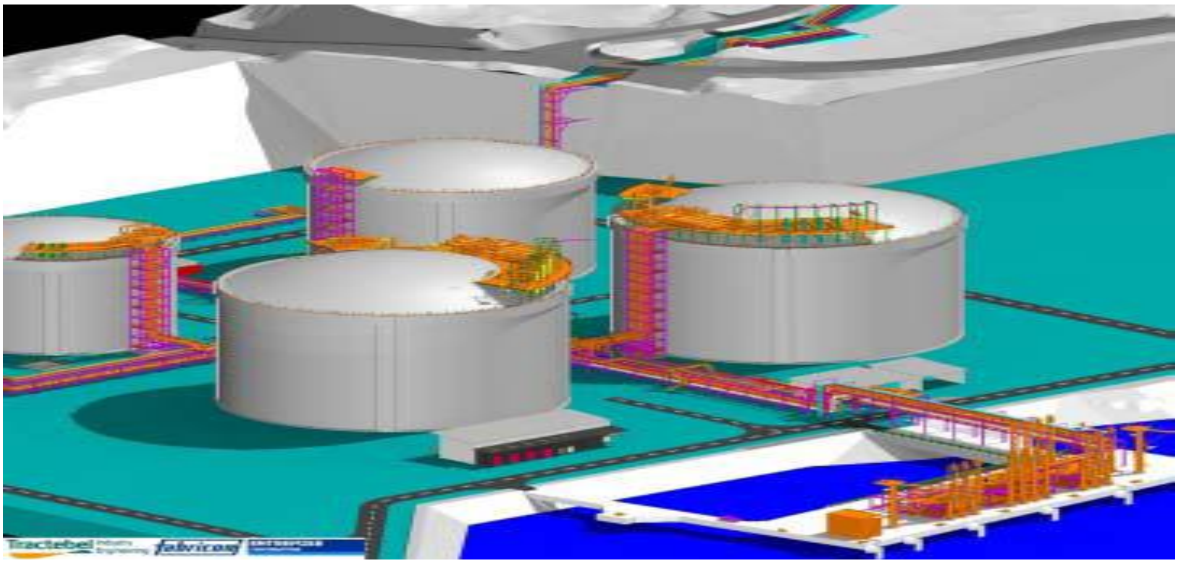
4.9 OTHER INSTALLATIONS ON MELKØYA ISLAND

Besides the processing plant and the pipelines, there were other installations in Melkøya upon whose success are equally vital to the success of the entire project. The science and technology report (2003) listed these other installations as:

- Pig receiver and slug catcher.
- Tank farm with 2 LNG tanks, 1 LPG tank and a condensate tank.
- Metering stations for the LPG and condensate.
- Transfer station for LNG, LPG and condensate.
- Construction jetty for site supply.
- Construction jetty for construction activities.
- Utility service station for offshore/subsea production.
- Ethane and propane refrigerant drum.
- Hot oil drain drum.
- MEG (methyethylene glycol) tanks.
- Fresh and de-mineralized water tanks.
- High and low pressure flares with separators.
- Cooling water intake and pump-pit, sump, outlet and weigh box (or equivalent pipe design).
- Fire extinguishing water system.
- Effluent treatment plant.
- Electrical power network, sub-stations for tank storage and harbor.
- Buildings for the central control room, offices, canteen, first aid, bathroom, maintenance facilities, warehouse, fire station, garage parking lots, guard houses/check point at tunnel entrance as well as on island (including fence between two areas), harbor offices, chemical storage, storage for gas bottles, laboratory, harbor facilities for tug and mooring boats.
- Permanent camp.

- Temporary camp.
- Subsea tunnel, roads, helicopter landing area.
- Rock protection walls.
- Service harbor.

FIGURE 15: 3-DIMENSIONAL MODEL OF THE LNG STORAGE TANKS



©Tractebel Gas Engineering

CHAPTER 5 THEORITICAL REVIEWS

To fully understand the underlying logistics implications inherent in projects with cost overruns, we tried to analyze cost overruns from the perspective of those logistics and supply chain theories that are related to it. These theories abound in most supply chain and logistics literatures and publications and some are analyzed below:

5.1 COST ESTIMATION AND ITS EFFECT ON COST OVERRUN

According to Business dictionary (2010), cost estimation is defined as the *"approximation of the probable total cost of a product, program, or project, computed on the basis of available information".* It is seen here that the objective of cost estimate is its function as the yard stick upon which the cost of the project at different stages of development is measured. Almost all cost estimation technique use either one or more of the approaches below. They are fully explained in the book, "Project Management for Construction" by Chris Hendrickson (1998).

5.1.1 Production function: Hendrickson (1998) describes the production function as *"relationship between the output of a process and the necessary resources (input)."* He also stated that production function can be expressed in construction terms by the relationship between the volume of construction and a factor of production such as labor or capital. This function shows the relationship between the amount (and volume) of output to the different inputs of labor, material and equipment.

Mathematically, the size of the output (Q) is a function of the different input factors of X_1, X_2, ……......, X_n. Thus, at any output level, it is possible to find the corresponding set input values in order to minimize the production cost.

5.1.2 Empirical cost inference: Empirical estimation of cost functions makes use of statistical applications by relating the cost of a project to some important characteristics of the system (Hendrickson 1998). This approach employs regression analysis to estimates the best parameter values (constants) in an assumed cost function.

5.1.3 Unit costs method of estimation: In this cost estimation approach, the entire project is decomposed into elements at various levels of details. There after quantities representing these tasks are assessed and a unit cost assigned to each of these tasks. The total cost is represented by summation of the costs incurred in each task. This concept of estimation apply to both design estimates and bid estimates, although varying elements may be selected in the decomposition.

Consider a situation where a project is decomposed into n number of elements. Q_i is the quantity of the i^{th} element and u_i be the corresponding unit cost. Then the projects total cost is expressed mathematically as

$$y = \sum_{i=1}^{n} u_i Q_i$$

By adjusting either one or all of the characteristics of the construction site, type of technology adopted, or even changing the management of the construction process, the estimated unit cost, u_i for each element may be adjusted.

5.1.4 Allocation of joint costs: Allocation of joint costs approach requires the development of a cost function through assigning each expenditure item to specific characteristics of the project. According to Hendrikson (1998), *"the allocation of joint costs should be causally related to the category of basic costs in an allocation process".*

An example of allocation of joint costs in construction projects, is classifying the accounts for basic costs in terms of (i) labor, (ii) material, (iii) construction equipment, (iv) construction supervision, and (v) general office overhead.
These basic costs are then allocated accordingly and proportionally to various tasks which are subdivisions of a project.

Summarily, all the above cost estimation approaches unfortunately, are only error proof in ideal situations. In reality, errors occur when costs of projects are estimated or when the capital expenditure costs are reported. These errors are due to the fact that a significant portion of the cost estimates are based on “forecasts”. A projects total capital expenditure is therefore obtained from this error-prone estimated cost and this amount can be significantly inaccurate depending on the cost estimation technique adopted. An example below, (though in transportation sector) analyses the extent of inaccurate cost estimation on cost overruns.

TABLE 4. INACCURACY OF TRANSPORTATION PROJECT COST ESTIMATES BY TYPE OF PROJECT (FIXED PRICES).

Project type	No of cases	Average cost escalation (%)	Standard deviation	Level of significance
Rail	58	44.7	38.4	<0.001
Fixed-link	33	33.8	62.4	<0.004
Road	167	20.4	29.9	<0.001
All projects	258	27.6	38.7	<0.001

Source: Bent Flyvbjerg et al (2002)

General analysis of the above table shows that there exists inaccurate cost estimation of 31.6 % (on average), in all transport projects. Flyvbjerg et al (2002) went on to explain that, *“the phenomena of cost underestimation and escalation appear to be* *characteristic not only of transportation projects but of other types of infrastructure projects as well".* They suggested that the **incorrect cost estimation** results from, *"forecasting errors" in technical terms, such as imperfect techniques, inadequate data, honest mistakes, inherent problems in predicting the future, lack of experience on the part of forecasters"*

The Norwegian Government report (NOU 1999:11) also showed that there was *"a cost overrun of 25Billion NOK (3Billion USD) for projects within 1994 to 1998".* This reported amount were attributed to "**incorrect cost estimation"** due to the large uncertainty in the construction industry and also due to the fact that most of the projects were being done for the very first time and as such does not give room for much learning process.

5.2. CONTRACTING AND ITS EFFECT ON COST OVERRUN

Construction industry, especially oil and gas projects, is made up of complex network of participants - employers, professionals, contractors and subcontractors. According to van Deventer and Lloyd, (1993), these participants are, *"all involved in highly technical processes, often with considerable financial investments at stake".*

In construction terms, contracts is defined by business dictionary (2010) as, *"a written agreement between the owner of a project (client) and a firm of professionals (called construction manager) for planning, design, construction, and commissioning of a construction project."* Depending on the type of project and contract type that best suits the project, contracts can be divided into:

5.2.1 Fixed-Price Contract

A fixed price contract is described by Wiley (2004) as when *"the price paid by the customer for the project is agreed and fixed at the out-set. When the product or* *service is delivered then the customer pays this agreed price".* This type of contract has two variables:

i) The Fixed-Price with Economic Price Adjustment: This variation of fixed price contract according to Wiley (2004), ensures the protection of the customer and the contractor from unforeseen economic fluctuations in material and labour costs

ii) The Fixed-Price Redetermination: This type of fixed-price contract ensures the shifting of unpredictable risks from the contractor to the client after the initial price has been negotiated. This is normally used when there is difficulty in cost estimation as a result of incomplete or unsure product requirements but there can be room for cost adjustment based on agreed terms enshrined in the contract.

The fixed-price contract favors the customer by allowing them to put the project out for tendering. They can also receive bids and decide on the best offer but there is the danger of over estimation or underestimation by the contractor either which is detrimental to them. Nicholas (2001) stated that, *"over- estimation can result in the contractor losing out to a competitor while under-estimation can lead to little or no profit after completion".*

5.2.2 Cost-Plus/Cost Reimbursable Contracts

There are variations of this type and they include.

i) The cost sharing contract: Here, the client and the contractor agree on how costs will be shares. It is normally used for situation of joint project developments.

ii) The cost plus fixed fee contract: This variation according to Nicholas (2001) ensures that *"the contractor's allowable costs are reimbursed and also a fixed fee is paid by the customer".* This type is normally employed in research and development where the costs are difficult to predict and there is a desire to share risk.

iii) The cost plus award fee contract: This contract type is based on some performance criteria like product quality or noise reduction. Here, payments are made to the contractor if he performs to the desired quality. Such payments to the contractor are irrespective of the agreed basic fee for the project.

Summarily, even though details in contracting systems are beyond the scope of this study, its effect on cost overrun is very visible. According to Robert (2003), *“Projects routinely exceed their estimated value, almost costing three or four times as much. Both contractors and procurement officials knew about this but deliberately downplayed the likely increases in order to launch their projects”.* A typical example of this is on the construction of The Oslo opera house. According to Olsson et all, (2003) the contractors applied *“a commonly used technique in major public projects, termed "strategic budgeting", i.e. to initiate the project using a budget that only visualizes parts of the total cost in order to "get the ball rolling" before the project concept is settled, including the project's objectives and strategy. Once the planning had gained momentum, the possibilities for reversing or terminating the project were limited.”*

Also Flyvberg et all (2002) shows that *“costs are underestimated in almost 9 out of 10 projects. For a randomly selected project, the likelihood of actual costs being larger than estimated costs is 86%. The likelihood of actual costs being lower than or equal to estimate costs are 14%. Actual costs are on average 28% higher than estimated costs (SD=39). Costs are not only underestimated much more often than they are overestimated or correct, costs that have been underestimated are also wrong by a substantially larger margin than costs that have been overestimated”.*

5.3 PRINCIPAL – AGENT THEORY

The problems that occur when tasks are delegated to agents with private information led to the emergence of incentives theory. Private information here can be of three types:

i) A situation where the agent can take action unobserved by the Principal, often referred to as the case of “moral hazard or hidden action”.

ii) A situation in which the agent possesses some private knowledge about his cost or valuation and which is ignored by the principal. This is referred to as the case of "adverse selection or hidden knowledge".

iii) A situation in which the principal and the agent share the same information but no third party and especially, no court of law, has access nor can observe this information. This is referred to as the case of "non verifiability".

Incentive theory therefore is a means of considering when this private information are problems to the principal and offers solutions by suggesting the optimal way for the principal to deal with it. The question then is "to what extent can these information types be a problem during contracting?

5.3.1 PRINCIPAL – AGENT MODELS

Model 1. This is a case where the principal delegates a duty to one agent through the "take-it-or-leave-it" type of contract.

In this model, it is assumed that;

i) There are no bargaining problems.

ii) There are control mechanisms (court of law) that makes sure none of the parties deviates from the terms of the contract.

In this model, three types of information sharing problems exist:

(a) Adverse selection problems.

(b) Moral hazard problems.

(c) Non-verifiability problems.

All three can lead to additional costs to the project.

Model 2. This type is a case where the principal delegates a duty to more than one agent through the "take-it-or-leave-it" type of contract. Due to asymmetric information, each agent might adopt an individualistic behavior thus affecting interaction amongst fellow agents. It may also lead to collusion amongst agents with the principal being worse off.

Summarily, the problems that arose as a result of how information are shared amongst parties during the execution of any project can very well result to non achievement of the projects set objectives. According to Laffont and Martimort (2002), *"the mere existence of informational constraints may generally prevent the Principal from achieving (cost) allocation efficiency"*. Simply put, these strategic behaviors by either or all parties certainly incur additional costs that were unbudgeted in the initial cost estimation resulting in cost overruns.

5.4. GOVERNANCE AND RELATIONSHIP MECHANISMS

Contracts can never include completely detailed agreements covering all possible future contingencies. (Robert 2003) stated that such incompleteness can be due to two facts:

(i) "parties are incapable of efficiently contracting over measures of performance that cannot be verified".

(ii) "at times, it can be deliberate in the sense that the parties had other reasons for leaving the terms in question unspecified".

Mega projects, by their very nature, present major governance problems. They most often last for several years, with the amount involved running into billions. Perritt, Jr. (1996) noted that *"fragmentation in the institutional structure of employee relations in the construction industry frequently made it difficult to establish and maintain a coherent set of relationships and work rules, while (at the same time) protecting a project from disruptions arising from incompleteness of (written down) contracts. As a result, governance mechanisms are put in place for such projects".*

Governance is therefore concerned with accountability and responsibilities; it describes how the day to day running of an organization is directed and controlled (OGC journal 2010). The journal further stated that governance is concerned with:

• organization - the organizational units and structures, groupings, and co-coordinating mechanisms established within the organization and in partnership with external bodies, for the management of change.

• management - the roles and responsibilities established to manage business change and operational services, and the scope of the power and authority which they exercise.

• policies - the frameworks and boundaries established for making decisions about investment in business change, and the context and constraints within which decisions are taken".

5.4.1 FORMS OF GOVERNANCE

Williamson (1975) identified three fundamental forms of transaction governance:

MARKET: Autonomous parties' exchanges are governed by prices in supply-demand equilibrium

HIERARCHY: Transactions among parties occur under a unified owner, who settles disputes by administrative fiat

HYBRID: "Long-term contractual relations that preserve (parties') autonomy, but at the same time providing added transaction-specific safeguards as compared with the market."

Summarily, delivering a project on time and within budget depends on how well the activities of the departments and the individuals concerned are coordinated. According to Ram Singh (2009), *"activities of the contractor are governed by market contracts. On the other hand, efforts of government officials are determined by the hierarchical relations among and within the government organizations. Each mode of governance is subject to failure. Such failures, among other factors, can cause delays and cost overruns".*

5.5 INCENTIVES AND MOTIVATIONAL MECHANISMS.

Most project organizations these days, has enough managerial experience to tackle any type of project, nonetheless, this alone do not guarantee the successful completion of the project as originally planned. This is due to the fact that when stake holders in any given project have diverging interests, there always are the possibilities of cost and time overrun. To guard against possible cost overrun, the idea of incentives was introduced in contracts.

5.5.1 INCENTIVES MECHANISM TYPES

i) **Profit sharing incentives:** Rose and Manley (2005) while quoting Bower et all (2002), stated that the primary aim of financial incentives mechanism is to *"simply take advantage of the contractor's general objective to maximize his profits by giving him the opportunity to earn a greater profit if he performs the contract efficiently"*

A cost under – or overrun from the actual construction cost is shared between the principal and the contractors in a predetermined ratio. Therefore, both the principal and the contractor works together to reduce the actual costs. The contractors' motivation is maximizing his profit margin above his specified fee by taking a share of the benefits from a reduced project cost while the principal's motivation lies in his reduction of the total amount paid out.

ii) **Bonus/Penalty Performance incentive:** this incentive mechanism is based on the achievement of set performance target. It acts as an extra motivation to contractors aside that already set aside for meeting or exceeding the least acceptable performance level. The amount paid out here as incentive is determined from evaluations carried out during or after the project.

Bonus financial incentives act on other areas of the project aside from cost. It can be either schedule or technical incentives and include – operation, non-disturbance, design integrity, safety and quality.

In schedule incentives, the expected motivation lies in the bonus offered to the contractor for completing the project earlier than target.

In technical incentives, bonus is given to the contractor as regards – efficient operation, non-disturbances to clients and third parties, minimization of risks and accidents, achieving the desired and predetermined level of quality and maintaining design integrity by adhering to the original design intentions.

Summarily, Incentives, when strategically applied in consideration of a project context, leads to motivation (Rose and Manley, 2005). The process of incentives requires the sharing of financial risk and control between the owner and the contractor, according to a ratio established in the project design stage. This helps suppress the negative effects of diverging interests. For large scale and mega-projects which involves hundreds of billions of money, incentives can be a method in which millions, which would otherwise have been lost in overruns are saved through the much lower cost of incentives.

CHAPTER 6. LITERATURE REVIEWS ON CAUSES OF COST OVERRUN

There are much published literatures and reports which indicate that cost overruns in infrastructure projects are a global phenomenon. But reasons as to why theses overruns occur are not quite as much documented. Below are some published literatures on the issue of causes of cost overrun.

Work conducted by Nils Olsson, Kjell Austeng, Knut Samset and Ola Lædre looked into **"CHALLENGES IN FRONT-END MANAGEMENT OF PROJECTS*".*** Their research work conducted regarding the construction of some mega projects within Norway show that *"uncertainty affecting projects is commonly considered to be at its highest at the outset and gradually decreases as the project is planned and implemented (and this is) partly because of increased access to relevant information".*

They took a look into the offshore oil and gas development projects where available analysis conducted by a Norwegian Parliamentary committee (Kaasen, 1999) showed that there is "*a total budget overrun of 13% or 3 470 million Euro for the total set of projects between 1994 and 1998".*

The major reason the group gave for such budget overrun was that *"different stakeholders in a project at times have entirely different interests in a project with different project concepts. This means that there might not be a uniform desire to get a neutral analysis of all available alternatives".*

Ram Singh in his work **"COST AND TIME OVERRUNS IN INFRASTRUCTURE PROJECTS: EXTENT, CAUSES AND REMEDIES"** investigated various issues related to delays and cost overruns in publically funded infrastructure projects. The study was based on, a large data-set of 850 projects across seventeen infrastructure sectors in India. At the end of the study, he found and divided the causes of project cost overruns into four subgroups which include:

A.* TECHNICAL AND NATURAL FACTORS:* He stated that the "*estimation of project time and cost for infrastructure projects is a characteristically complex exercise. Though* *the estimation techniques have become better and sophisticated in recent times, still they are imperfect. As work on a project starts, its future unfolds and the authorities along with the contractor become better informed about the specific technological and material requirements of the project.*" Such new information may *"necessitate changes that may require extra time as well as funds".*

B.**THE CONTRACTUAL FAILURES***:* Ram Singh also stated that "*in principle, contracts known as complete-contingent-contracts should ensure that project is completed on time and within budget………but in reality, however, the initial contract cannot fully describe every possible scenario that may unfold during the construction phase. Therefore, some of the cost overruns are caused by what we have called the contractual incompleteness which increases with the project size."*

C. **ORGANIZATIONAL OR INSTITUTIONAL FAILURES***:* The third reason cited by Ram Singh as reason for cost overrun was organizational or institutional failure. He noted that *"real world hierarchy based organizations, especially the government organizations, are inherently weak in inducing the desired efforts from the people involved".* He also said that *"incentives created by government organizations are particularly weak thus at every stage of hierarchy there is a conflict between the individual and the social objectives.* The resulting effect of such is that, "*infrastructure projects have to face the consequences of many sources of failures within the sponsoring organization".*

D. **ECONOMIC FACTORS:** He finally noted that *"economic aspects of the place where a project is located can also affect the project time and costs"*. He was of the opinion that *"projects located in developed regions have lower cost and time overrun than those within less and developing countries".* This is because the up to date infrastructure will help in execution of projects.

"POLICY AND PLANNING FOR LARGE INFRASTRUCTURE PROJECTS: PROBLEMS, CAUSES, CURES" by Bent Flyvbjerg contain research work on budget overruns in the transport sector. He found out that *"9 out of 10 projects have cost overrun among the*

20 nations and 5 continents covered by the study". He observed that *"overrun is constant for the 70-year period covered by the study and that estimates have not improved over time".*

He offered some explanations on the causes of budget overruns and these he grouped into three headings.

A. TECHNICAL EXPLANATIONS*: in terms of imperfect forecasting techniques, inadequate data, honest mistakes, inherent problems in predicting the future, lack of experience on the part of forecasters, etc.*

B. PSYCHOLOGICAL EXPLANATIONS: *decisions based on delusional optimism rather than on a rational weighting of gains, losses, and probabilities. Planners overestimate benefits and underestimate costs. They involuntarily spin scenarios of success and overlook the potential for mistakes and miscalculations. As a result, planners and promoters pursue initiatives that are unlikely to come in on budget or on time, or to ever deliver the expected returns.*

C. POLITICAL-ECONOMIC EXPLANATIONS: *Political-economic explanations see planners and promoters as deliberately and strategically overestimating benefits and underestimating costs when forecasting the outcomes of projects. They do this in order to increase the likelihood that it is their projects, and not the competition's, that gain approval and funding."*

"WHY PROJECTS OVERRUN AND WHAT TO DO ABOUT IT" by Richard E. Westney noted that *"in spite of the excitement of $100/bbl oil, the majority of energy industry executives are dissatisfied with project performance (40% of capital projects overrun); this level of dissatisfaction is the highest ever."*

He went further to note that *"everyone in the industry is aware of the major cost overruns and schedule delays associated with major projects but they often overlooked the fact that these overruns are often announced when projects are well into construction—long past sanction and at a time when traditional project risks have (or should have) been mitigated"*

He quoted causes of cost overruns to include *“changes that are required to make the facility work but are not included in the basis of design.”* He listed them *“as changes in legislation, infrastructure capacity, or local conditions.”* Other reasons stated as causes of overrun are:

A. MARKET CONDITIONS – includes both general worldwide economic conditions as well as specific trends, such as worldwide contractor backlog for critical capabilities associated with the project’s requirements and location.

B. LOCATION FACTORS – includes geo-political risks, taxes and regulations, extraordinary environmental conditions, etc.

Commercial or partner requirements and behaviors – includes misalignment of business goals, host country laws and regulations, financing issues, etc.

C. ORGANIZATION (INTERNAL) RISKS – Includes risks typically associated with an asymmetry between size, complexity, location, and risks of a project and the organization’s ability to deliver. These risks can be assessed by looking at such variables as:

- Resource requirements and availability, skills, and ability to be effective.
- Work processes, methods, systems, and effectiveness for the project’s size and complexity”.

In summary, the author is of the opinion that *“projects overrun because most owners and contractor organizations lack a practical and disciplined approach to Strategic Risk Management – as a result, strategic risks and volatility are seldom understood or mitigated effectively”.*

Perhaps the work that captures closest the causes of cost overrun in oil and gas projects was the report of the research conducted by the **INVESTMENT COMMITTEE (INVESTERINGSURVALGET) 1998** set up by the Norwegian Ministry of Petroleum and Energy to analyze the trend in investment on the Norwegian continental shelf. The main task of the group was to find the **reasons why investments have increased compared to the original plans** for all oil and gas projects approved from 1994 to

1998. In their evaluations, the group summarized their findings by grouping them into the following headlines:

A. DECISION-MAKING BASIS, BUDGET, AND RISK COMPREHENSION: The report stated that the majority of the PDO estimates have been unrealistic due to:

* *exaggerated optimism based on positive trends (at the period in question).*

* *unison unrealistic ambitions regarding substantial, further improvements and little comprehension of the uncertainty resulting from thin project maturing and introducing of new elements.*

B. DRILLING AND COMPLETION: The committee found out that production and injection wells accounted for 33% of the total cost overrun. The report stated that the operators did not "*to a sufficiently detailed extent plan their drilling operations in connection with the preparation of the PDO".* As a result the operators complained of *"reservoir complexity and technologically advanced wells"* they had to deal with.

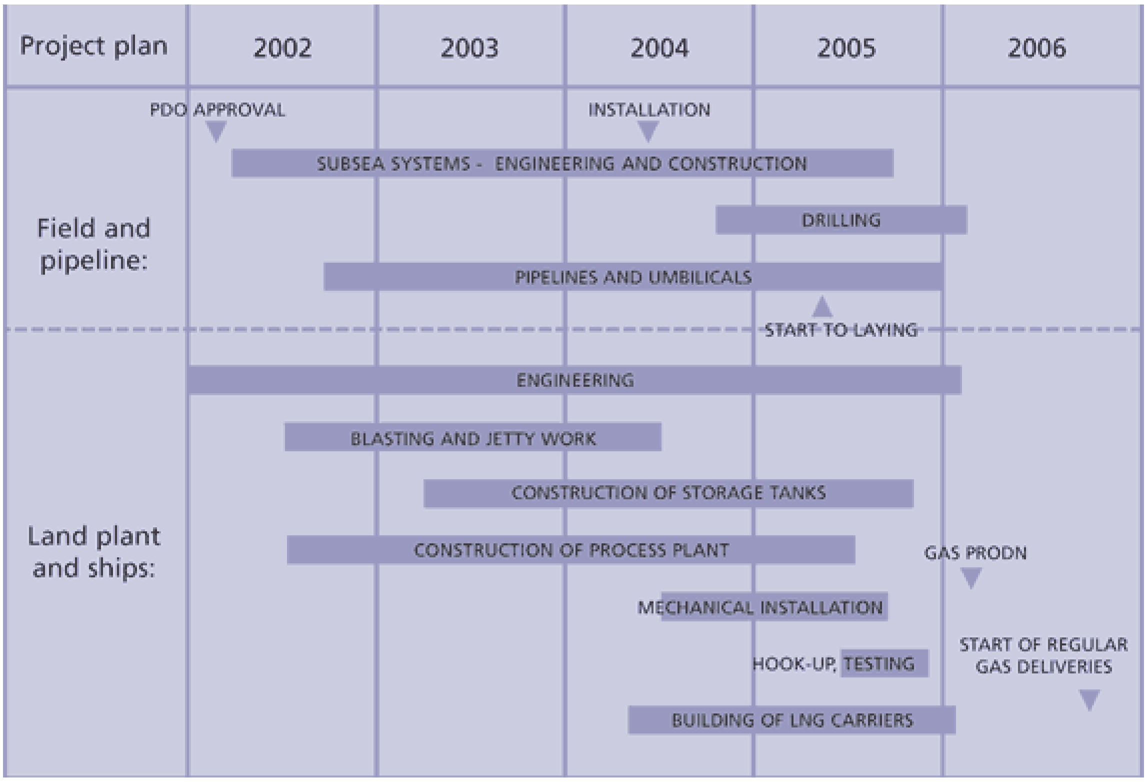
C.TECHNOLOGY: The introduction of new technology different from the old but tested and trusted method was found to have resulted in cost overrun. The report stated that *"the implementation of new technology has introduced major factors of uncertainty which have not been paid sufficient attention in budgeting and implementation of the projects".*

D. PROJECT IMPLEMENTATION: It was also the opinion of the committee that the time periods allocated for projects implementation were too short and as such contributed to cost overrun. They stated that *"the amount of time in the phase prior to initiation of the project and the time of the actual project has been reduced*" as such there was *"limited possibility to solve unforeseen problems in one phase without having consequences for the next phase".*

CHAPTER 7. DATA ANALYSIS

7.1 ESTIMATED SNØHVIT PROJECT TIME SCHEDULE

Figure 16: ESTIMATED OVERALL TIME SCHEDULE



© Tractebel Gas Engineering

The above figure shows the estimated time schedule for the entire Snøhvit project constructions. The entire project time was estimated at 5 years with the start up in early 2002 and finishing time of early 2006. It was expected that the first supply of gas will take place mid 2006. Detailed analyses shows that the entire phase 1 was divided into two separate projects parts each with separate but inter-lapping time frames.

PART 1: FIELD AND PIPELINE

This is subdivided into three parts.

(i) Subsea systems / engineering and construction - The time frame for construction was from the time of PDO approval of early march 2002 and continues till last quarter of 2005.

(ii) Drilling – late 2004 to early 2006.

(iii) Pipelines and Umbilical's - late 2002 to end of 2005

PART 2: LAND PLANT AND SHIPS

This is also subdivided into seven parts

(i) Engineering – projected to run throughout the time period of 2002 to early 2006

(ii) Blasting and Jetty work – mid 2002 to mid 2004 (two years)

(iii) Construction of storage tanks - March 2003 to October 2005

(iv) Construction of process plant – mid 2002 to mid 2005

(v) Mechanical installation – mid 2004 to mid 2005 (1 year)

(vi) Hook up Testing – June 2005 to Nov. 2005

(vii) Building of LNG carriers – April 2004 to Jan. 2006

7.2 STORAGE AND LOADING FACILITY SCHEDULE

TABLE 5: STORAGE AND LOADING FACILITY CONSTRUCTION SCHEDULE.

s/no	**Date**	**Activity**
1	July 16th, 2002.	Contract was awarded to TGE
2	01 October 2002.	Blasting plans issued
3	01 April 2003.	Site mobilization
4	03 August 2005.	LNG tank 1 ready for commissioning
5	17 August 2005	LNG tank 1 ready for operation
6	31 October 2005	Plant fully ready for operation

© Tractebel Gas Engineering

The storage tanks project as awarded to Tractebel Gas Engineering Company in July 16th 2002 show the major items of the contract as:

a. 2 x 125.000 m3 full containment LNG Tank.

b. 75 000 m3 condensate Tank.

c. 45 000 m3 LPG Tank.

d. Jetty with 3 Loading Systems (1/product).

e. Metering Systems.

f. LNG HP – Send Out to Liquefaction Plant.

g. LNG BOG Blower.

h. External Flare and Incinerator.

i. All interconnecting piping, electrical and instrumentation works.

(source: Tractebel Gas Engineering)

7.3 REAL-TIME SNOHVIT TIME STRUCTURE

The tables below show (in real terms) the important dates in the construction history of Snøhvit. Some of the activities gave marked deviation from what was originally given in the estimate.

TABLE 6: ACTUAL MANAGEMENT AND ENGINEERING TIME FRAME.

S/No	DATE	ACTIVITY
1.	1981	Gas fields discovered in the Barents sea.
2.	1991-1997	An attempt was made to establish a basis for developing the area. The plan was for an offshore field development and gas liquefaction plant on Sørøya near Hammerfest that would sell LNG to the Italian market. Statoil halted the planning process, citing cost and market factors. A

		new solution for developing the field was proposed, with a facility on Melkøya island outside Hammerfest and subsea production installations remotely operated from land.
3.	1991-1993	Protests against various oil companies' exploration operations in the Barents. Bellona filed suit against Statoil to halt drilling activities.
4.	1996	Statoil and Linde form LNG technology alliance to develop the mixed fluid cascade (MFC) liquefaction process.
5.	1998	New proposal submitted to the ministry in the following year. This included both new impact assessments and upgrading of preparatory work done in the previous development process. Carbon capture and storage now included in the plan.
6.	1998-2001	Negotiations and seminars with experts and authorities in Finnmark, information meetings with locals in Hammerfest.
7.	December 2000	Pre-engineering phase begins. The plant design takes concrete form.
8.	April 2001	New Environmental Impact Statement (EIS) published.
9.	July 2001	Snøhvit's partners put the project on hold because of lack of clarity over government taxation terms.
10.	Sept. 2001	Special tax benefits approved by ESA. Contract with partners signed. Statoil submitted a plan for development and operation (POD) of the field.

11.	Oct. 2001	Long-term sales contracts signed with El Paso LNG, Iberdrola, Gaz de France and Total.
12.	Dec. 2001	Due to poor economic situation of the project, Finance Minister announced that ways to support the project would be investigated.
13.	Jan. 2002	POD presented to Parliament Environmentalists organize intensive protests.
14.	March 2002	POD for LNG plant approved by Norway's Parliament in March 2002. Statoil announces that tax position is unclear due to the involvement of the ESA.
15.	April 2002 till present.	In the engineering phase, construction gets underway. First site work is blasting, which turns Melkøya from a barren island into a made-to-order construction platform. Rock removed amount to 2.3 million cubic meters (including road tunnel to mainland), enough to fill Great Pyramid to the tip. Volume of concrete eventually placed is 60,000 cubic meters.
16.	May 2002	May 2002 Pollution Control Authority allows Statoil to start construction work (preparation of the site and filling of land).
17.	July 2002	Resolution of the tax position by the ESA.
18.	August 2002	Construction phase begins as plant components are built at Melkøya and elsewhere in Europe.
19.	August 2002	Statoil announces that delays caused by the ESA tax investigation have increased costs by € 130 million.
20.	Oct./Dec.2002	Following a detailed project review, CEO says that the project's management and organization need to be strengthened to ensure cost control and progress: costs

		have risen by € 740 million, to 5.75 billion.
21.	June 2003	EFTA court rules against Bellona's action against the ESA20 Case 24 ECN-E--07-058.
22.	July 2003	At La Coruna, Spain, the process barge is launched on July 11th. Pumps, heat exchangers, compressors and the power plant with its five gas turbines will later be installed on this huge "floating island".
23.	2003	Installation work on the barge begins at Cadiz.
24.	June 2004	The "slug catcher" is finished at Zwijndrecht, Netherlands. This system of large branched pipes separates entrained moisture and sledges from gas delivered via the pipeline.
25.	June-Oct2004	Following an 'extraordinary review', Statoil's board is notified that costs could rise by a further € 510-760 million. Risk of delay by 6-12 months. Measures implemented to deal with failures by contractors and equipment suppliers. Statoil's cost overruns discussed in the Oil and Energy Ministry and Parliament.
26.	August 2004	Monoethylene glycol tanks are finished in Sicily and soon afterwards shipped to Hammerfest. A pipeline carries monoethylene glycol from the island to the well, where it is added to the mixture of gas, water and condensate. Its function is to prevent the formation of solid hydrates at the wellhead and during transport to land.
27.	April 2005	The cold box, the liquefier proper, is finished at Antwerp. The heart of the LNG plant, this unit was pre-fabricated at Lindes Schalchen works (in Bavaria) and at Bremen;

		final assembly took place In Belgium. The 62 meter tall tower is next carried to Hammerfest by a heavy-lift vessel (HLV).
28.	June 2005	Workers at the Cadiz yard finish the topside, the superstructure on the process barge. In the Gulf of Cadiz, the barge now weighing 25,000 tonnes is loaded piggyback-fashion on the HLV Blue Marlin.
29.	June 2005	Partners launch studies to assess doubling the plant's capacity.
30.	30th June 2005	The barge secured on board Blue Marlin departs Gulf of Cadiz, bound for Hammerfest. The voyage lasted eleven days with a voyage distance of 2,700 nautical miles.
31.	July 2005	Hammerfest Energy submits EIS for 100 MW power plant to Pollution Control Authority, and complains in public that Statoil has refused to contribute to its project.
32.	Sept. 2005	New review reveals that cost estimates have risen and further delays are expected. Cost estimate rises to €7.42 billion. Deliveries scheduled to begin in December 2007. Statoil starts to secure alternative supplies to US and Spanish customers.
33.	Nov.2005	Remote control system and power relay tested and remote monitoring system in operation.
34.	21st Aug2007	The valves were opened of Snøhvit wells in Barents Sea and gas flowed through 143–kilometer pipeline to land and in the plant at Melkøya, where the well flow is separated into natural gas and condensate.
35.	13th Sep2007	Statoil commenced production of LNG at the Hammerfest LNG plant

36.	2007, 1st Dec	The gas is accepted for commercial production and delivery commences.

Sources: Norway online 2006; Kårsta 2002; Natur og Ungdom 2002; Bellona 2006; Petroleum Economist 2006 and Linde Technology 2006.

The important observation from the table above is the time it finally took for gas production and delivery to commence. Gas production began in 1 June 2007 and regular gas deliveries started on 1 December 2007. **This is eight months later than originally estimated**.

7.4 SNØHVIT COST ESTIMATE

The final plan for "Development and Operation" (PDO) of Snøhvit field was approved on the 7th day of March 2002, by the Norwegian parliament. Also approved on the same day was the "Plan for Installation and Operation" (PIO) of the gas liquefaction plant at Melkøya Island near Hammerfest including a subsea development linked through pipeline to the receiving terminal and liquefaction plant at Melkøya. The processed LNG will be exported using specially made ships to terminals in the USA and southern Europe.

The project was estimated at NOK39.5 billion, excluding the LNG carriers with plans to start production in 2006 and lasting until about 2030. It was expected that jobs at Melkøya in the construction phase will total up to 1,200 work-years while land based operation facilities will need about 180 permanent employees drawn from the local area.

Phase 1 has an investment budget of 23.2 billion in 2001-kroner. Phase 1 includes the LNG plant at Melkøya, pipeline to shore and the development of the Snøhvit field. Costs for shipping of LNG will be added based on a new construction program, and is estimated to approx. 5.4 billion. The project's total investments as approved in 2001 (excluding ships) and even up till 2021 are shown in the table below.

TABLE 7: TOTAL INVESTMENT COST AS APPROVED IN 2001

Cost item	Cost (million 2001 – NOK)
Concept design for PDO / PIO	262
Project management	247
Snøhvit field	7 257
Hammerfest LNG plant	14 917
Operations Preparation	524
Total Phase 1	**23 207**
Askeladd field and compression country (Phase 2)	4 555
Albatross field (phase 3)	2 147
Compression and future offshore installations (phase 4),	4 340
Total	34 249

Source: oil and energy department

7.5 COSTS OVERRUN

Within the total period of construction of the project, a review of the construction cost was formally made a total number of four times. In 2008 another review was made when it became glaring that the last cost estimate was less than realistic. Table below is the summary of the reviews.

TABLE 8: SUMMARY OF COST REVIEWS FOR SNØHVIT

S/NO	DATE	PARTICULARS OF REVIEWS
1	7th March 2002	Plan for development and operation approved for Snøhvit. The project cost estimated at NOK39.5 billion.
2	13th Dec. 2002	Upward review of the cost from NOK39.5 billion to NOK45.3 billion. This is an additional NOK5.8 billion.

3	11th June 2005	Upward cost review showed cost rise between NOK4 – 6 billion. New cost estimate now between NOK49.3 – 51.3 billion.
4	21st Aug. 2005	Another upward review to NOK58.3 billion. This is an increase of NOK7 billion from the last estimate.
5	15th Oct. 2008	An upward review to Euro 8 billion. This is an increase of Euro 2 billion from the last budget of 2005

Sources: oil and energy department, Statoil Observer and Barents observer.

7.6 COST OVERRUN ANALYSIS

7.6.1 THE FIRST REVIEW: This was the first cost review after the plan for development and operation (PDO) was approved. The review was on the 13th of December 2002. The analysis showed an upward review of NOK5.8 billion. This gives a 14.7% increase from what was estimated initially.

REASON CITED FOR THE INCREASE: According to Egil Gjesteland, the project director for Snøhvit, the reason for the cost increase was that *"the plant's capacity was increased by 30% at an early stage. At the same time, the consequences of such an expansion in a large gas liquefaction facility were under-estimated"*. He also stated that *"costs rose because the start of the construction work was delayed by discussions with the EFTA Surveillance Authority (ESA) over the tax regime for the project".*

7.6.2 THE SECOND REVIEW: This was carried out in the middle of 2005. The new cost estimate showed an increase by NOK4 – 6 billion to give a new cost of between NOK49.3 – 51.3 billion. This means an increase of 24.8% to 29.8% from the first original estimate of NOK39.5 billion.

REASON CITED FOR THE INCREASE: The acting chief executive of Statoil Egil Øverland said that *"Snøhvit is one of the most extensive and technically complex projects we've ever launched".* He also noted that they *"have under-estimated its complexity and we acknowledge that the project was not sufficiently matured when the decision to develop was taken in 2001"*. He went further to give details of why there was a cost increase and they were stated below.

- *The project insufficient maturity at the time when the decision to develop was taken.*
- *Lacking and delayed deliveries of drawing and materials from the main contractor.*
- *Late mobilization and poor productivity at the main yard.*
- *Tests carried out in May 2004 show that the key refrigeration compressors have to be modified to meet the specifications.*

7.6.3 THE THIRD REVIEW: This was carried out in August of 2005. Breakdown of the figures indicated an upward cost estimation to NOK58.3 billion which is an increase of NOK7 billion from the last estimate. This amounts to a 47.5% increase from the original estimate of NOK39.5 billion.

REASON CITED FOR THE INCREASE: The chief executive of Statoil, Helge Lund stated after the review that "*the Snøhvit project has struggled with problems from the onset, mainly because the project was not sufficiently mature when it was sanctioned in 2001. The new review of costs and progress has revealed that control of the project has been insufficient and we have not managed to correct the imbalances in the project quickly"*. He therefore gave the reasons for the cost increase as:

- *Delayed engineering.*
- *Quality flaws and delays to modules from continental Europe which in turn led to transfer of work to Melkøya.*
- *Underestimation of the scope of work, particularly within the electrification discipline.*

- *Extra work at Melkøya which prolongs project execution and raises cost at initial stage.*

7.6.4 THE FOURTH REVIEW: As part of the authorities' annual updating of projects under development, Statoil management on 15th of October 2008 submitted a revised cost of developing the Snøhvit LNG project. The latest estimates show that the project will be NOK13 to 16 billion more expensive than what was assumed three years ago in 2005. This puts the new estimate to between NOK71.3 and 74.3 billion.

A breakdown of the new cost estimate shows that NOK3 billion will be needed for the final construction of phase 1 which gives a final cost of NOK48.1 billion in nominal terms compared to what was estimated in September 2005.

The reason cited by Statoil management for this cost increase was the problems they had with the completion of the onshore plant.

NOK 2.5 to 5.5 billion was needed to solve the problems associated with regularity and capacity. They will have to bring the plant to the planned capacity in order to ensure stable and safe operations.

Also needed is an additional NOK7.5 billion related to the future development of Snøhvit for the period 2015 to 2032. The total estimated investment in Phase 2- 4 is 20.8 billion, which is 7.5 billion more than projected in September 2005.

REASON CITED FOR THE INCREASE: This increase was for the cost of future drilling rigs and other equipment. As yet, no contracts have been signed for this work and Statoil has not made a final concept for the future compression solution on the field. There is therefore considerable uncertainty about this estimate.

CHAPTER 8. COMPARATIVE STUDY OF ORMEN-LANGE LNG PROJECT

8.1 INTRODUCTION

In order to appreciate fully the findings of this research work, an attempt is hereby made to compare two liquefied natural gas projects constructed within Norway – the Snøhvit and Ormen-Lange. Ormen-Lange was noted to have been completed without much cost and within schedule; Snøhvit on the other hand was riddled with cost escalations and time overrun. Both projects are similar in nature and were carried out within Norway and as such, one would have thought that Snøhvit should have been completed with little or no case of cost overrun.

Earlier chapters concentrated on Snøhvit LNG project, thus this chapter delved more on Ormen-Lange LNG project. The aim was to identify what procedure they took that resulted in the project sticking to budget and schedule.

8.2 OVERVIEW OF THE ORMEN-LANGE LNG PROJECT

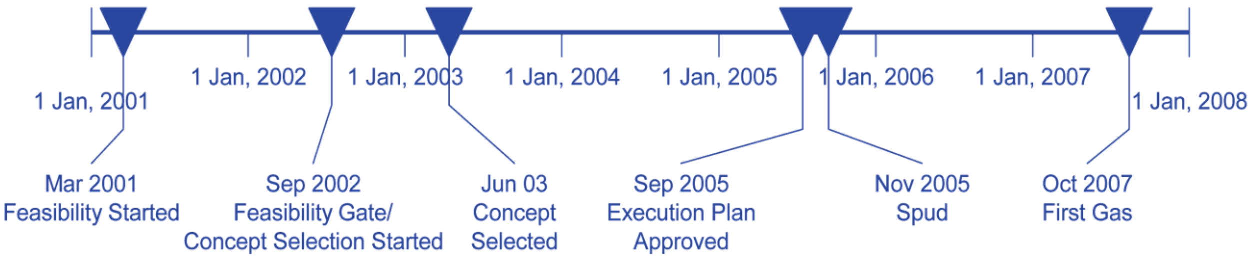
Ormen Lange was discovered in 1997 and is the first true deepwater (850 – 1100 meters) project in Norway. The gas fields are located in the North Sea at a distance of about 120kilometers from North West of Kristiansund with the gas reservoir lying 3000 meters below the sea surface and cover an area about 40 kilometers long and 8 to 10 kilometers wide. The field is embedded at the centre of a depression left behind from the Storegga mudslide. The ocean floor is highly rugged – with 30-60 meter peaks protruding from the seabed due to the slide. The wells exist in an area with ambient weather conditions coupled with sub-zero water temperatures at seabed. The gas stream is sent via pipeline to an onshore processing plant at Nyhamna.

On arrival at Nyhamna, the untreated well stream is first sent to its first stop - the slug catcher. This removes slugs – or fluid plugs – which have the capacity of filling and damaging the process systems. After that, the gas, condensate, water and antifreeze are all separated using different processes. The gas is dewatered and desiccated, before undergoing compression for export, 1200 km to Easington-UK, in what is to be known as the world's longest offshore gas pipeline, Langeled .The condensate (light oil) is stabilized and stockpiled in a 150,000 cubic meter rock cavern, and exported by tankers. The antifreeze is separated and recycled. Any produced water is thoroughly cleansed, and then released into the sea. At its plateau production, Ormen Lange will process some 20 billion standard cubic meters of gas per annum. This is equivalent to Norway's entire energy consumption thus making Norway, the world's second largest exporter of natural gas. Ormen Lange production wells are known as "big bore" gas wells and are the largest in the world, with 9 5/8-inch pipe dimensions. (www.hydro.com)

8.3 THE ORMEN-LANGE PROJECT DEVELOPMENT

The plan for development and operation for Ormen Lange was submitted to the Ministry of Petroleum and Energy on Thursday 4th December 2003 at an estimated cost NOK 66 billion. Phase 1 of the development, involving the Langeled gas pipeline, the land-based process plant at Nyhamna and offshore installations on the Ormen Lange gas field itself, was completed within the total budget of NOK 50 billion in 2003 NOK (statoil). Constructed was started in 2004 and despite being one of the largest and most demanding industry projects ever carried out in Norway or indeed globally, the field started production almost two weeks ahead of the 1 October plan on 13 September and will continue for up to 40 years.

FIGURE 17: ORMEN-LANGE TIME LINE



(www.hydro.com)

8.3.1 GAS PROCESSING COMPLEX

The processing plant is sited at Nyhamna in Aukra commune in Møre and Romsdal, Norway. On arrival at the plant, the crude well stream is first sent to a reception facility (slug catcher) where liquid condensate slugs are removed. This prevents damage to some areas of the processing facility. The task of the slug catcher is to separate the crude stream into gas, liquid condensate, water and antifreeze.

The processed gas then pass on to a gas dew pointing unit where it is compressed for export. The water is cleaned and discharged to the sea. The condensate on the other hand is stabilized and stored underground in a storage facility awaiting export. The antifreeze is recycled and sent back to the wellhead.

FIGURE 18: THE ORMEN–LANGE LNG PLANT AT NYHAMNA

(HYDRO)

8.3.2 LANGLED PIPELINE

This is the exportation mechanism for the processed gas. It is a pipeline stretching 1,200km from Nyhamna via Sleipner in the North Sea to Easington in the UK. It was expected that at the height of production the Ormen-Lange gas processing complex will handle 20 billion m^3 per year and all these will be transported through this underwater pipeline which is the world's longest subsea export pipeline, The northern section, from Nyhamna to Sleipner, is made of 42in-diameter steel pipeline, while the southern section to Easington is a 44in-diameter steel pipeline. The two sections are connected at a junction called Sleipner which serves as a distribution and quality control point. It will also serve as distribution point for future branches to mainland Europe.

At Easington in United Kingdom, the gas will then be distributed to fulfill supply contracts with industrial (power generation) and domestic distributors.

8.4 ORMEN-LANGE CONTRACTS

A notable strategy in Ormen-Lange was the manner in which the contracts were awarded. The jobs were divided into modules and awarded separately to individual contractors. By this method, each client is responsible for proper and timely execution of modules assigned to them. All the contracts were divided into two viz: Onshore and Offshore contracts.

8.4.1 OFFSHORE CONTRACTS

The table below lists all the offshore contracts and companies to which they were awarded to.

TABLE 9: OFFSHORE CONTRACTS AND CONTRACTORS

S/NO	COMPANY	CONTRACT DESCRIPTION
1	Reinertsen Engineering AS	Engineering for the import pipeline to Nyhamna.

2	Snamprogetti	The export pipeline engineering.
3	ABB Offshore Systems	The Sleipner tie-in.
4	Bredero Shaw Norway	Pipeline coating.
5	Europipe GMBH and Mitsui & Co Norway	Provision of the line pipe.
6	Stolt Offshore AS and Allseas Marine Contractors SA	Shallow water marine installations.
7	FMC Kongsberg Subsea AS	the subsea production systems
8	Van Oord ACZ AS	subsea rock installation
9	Tenaris Global Services	Service pipelines
10	Stolt Offshore.	The monoethyleneglycol (MEG) installation and pipelines
11	Saipem	Installation and tie in deep water
12	Provided by Nexans and installed by Subsea 7.	Umbilicals
13	Heetema	Heavy liftings
14	Nexans	Subsea dredging
15	Geoconsult	Marine surveying
16	NorSea Group, Olympic Shipping, District Offshore, Solstad Shipping and Havila Shipping.	Line pipe transportation

(Source: www.hydro.com)

8.4.2 ONSHORE CONTRACTS

TABLE 10: ONSHORE CONTRACTS AND CONTRACTORS

S/NO	COMPANY	CONTRACT DESCRIPTION
1	Aker Kaeverner	Engineering, procurement, management, construction and architecture (EPMCA) for the gas complex (receiving and

		export). Other onshore infrastructure including the flare tower, slug catcher and emergency shutdown systems.
2	Multiconsult and Skanska	Civil engineering for the gas complex
3	Aker Kaeverner	Construction of gas reception and export area.
4	Vetco Aibel AS	Engineering, procurement and construction (EPC) of jetty.
5	Aker Stord	Design and install all process systems and utility systems, including civil engineering, steel structure, pipe work, HVAC, mechanical engineering, electrical installation, instrumentation installation, insulation and surface protection
6	Midsund Bruk	Process equipment for the separation of condensate, gas and water will be constructed

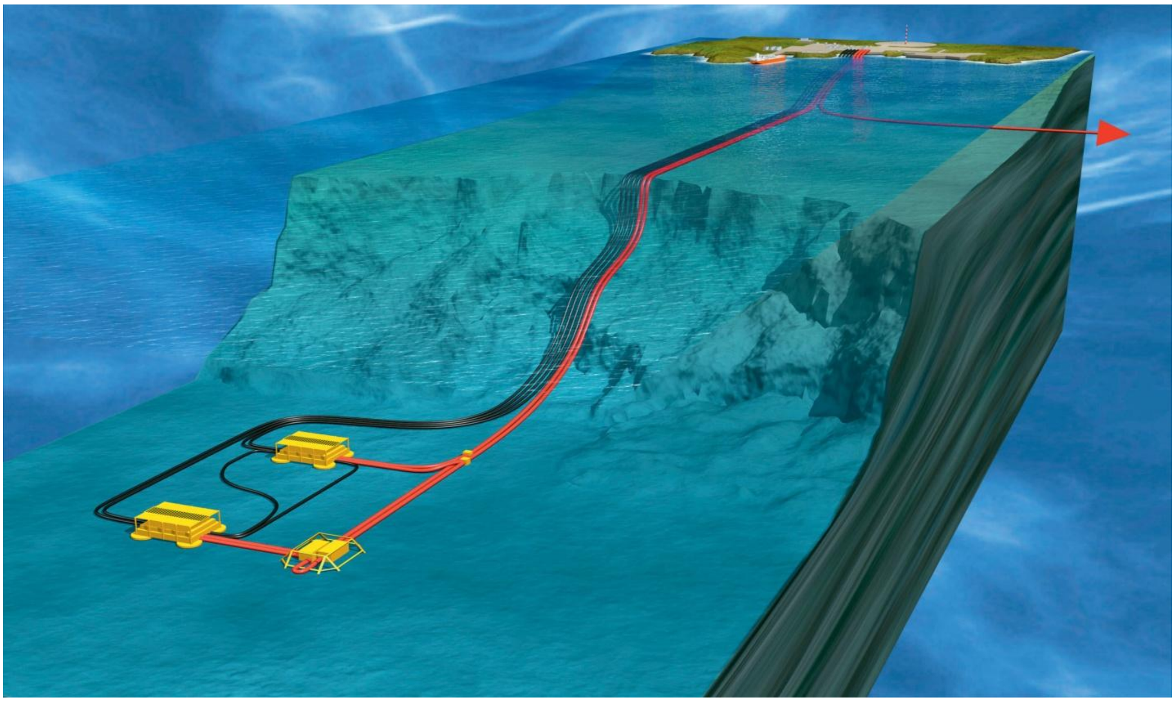
(Source: www.hydro.com)

8.5 MAJOR SIMILARITIES BETWEEN SNØHVIT AND ORMEN-LANGE LNG PROJECTS

Snøhvit and Ormen-Lange are both mega natural gas projects and shares some identical physical characteristics which include:

1. Complete subsea production facilities in combination with onshore
2. Pipelines and umbilical's to and fro shore for liquid streams.
3. Onshore processing plant for liquid streams.
4. Harsh and ambient weather conditions.
5. Construction and production within the same economic time period.

FIGURE 19: SUBSEA PROCESSES OF ORMEN-LANGE



(www.hydro.com)

8.6 OTHER INSTALLATIONS IN NYHAMNA

a. Landfall for pipelines, shut-off valves and pig traps.

b. Slug catchers for removal of liquid plugs.

c. Process systems for separation and treatment of condensate

d. Facilities for drying and compressing gas for export

e. Condensate treatment facilities

f. Glycol recycling plant

g. Flare tower

h. Unit for fiscal metering of gas

i. Rock cavern for condensate storage

j. Loading jetty for condensate

k. Utilities including air-, water-, and heating unit, etc.

l. Transformers.

m. Offices and control room

8.6.1 ORMEN-LANGE PHASE 1 SCOPE OF WORK

Phase 1 of Ormen-Lange development involved the Langeled gas pipeline, the land-based process plant at Nyhamna and other offshore installations. Below lists all the developments that are part of phase 1.

a. Eight (8) enhanced horizontal 7" 10,000 psi subsea trees.

b. Separate installable-retrievable choke modules.

c. Nine (9) UWD-15 subsea wellhead systems.

d. Two (2) 8-slot foundation bottom structures and manifold systems with 20" headers including 30" pig-loop system.

e. One (1) PLET (pipeline end termination) module.

f. KS-200 control systems with fiber optic as primary communication system.

g. Electro-hydraulic Work-Over Control Systems (WOCS) with XT, LS and HSW umbilical systems.

h. Open sea Lower Riser Package (LRP) and Emergency.

i. Disconnect Package (EDP).

j. Drill pipe landing string system.

k. Choke module running tool, Module Running Tool (MRT) and ROV tooling system.

l. Large-bore tie-in system for 20"/30" clamp connectors.

m. Small-bore tie-in system for less than 14" collect connectors.

n. System Integration testing, installation assistance, service and maintenance.

(Hydro.com)

8.7 MAJOR DIFFERENCES BETWEEN BOTH PROJECTS

8.7.1 ADOPTED TECHNOLOGIES

This probably is one of the main reasons for cost budget differences between the two projects. It had been shown earlier that Snøhvit adopted a completely new technology – the mixed fluid cascade – which makes use of recycled gas for its operations. It is a method where CO_2, separated from the produced gas onshore, are sent back offshore via pipeline for re-injection to a suitable reservoir. This is an entirely new engineering concept which has never been tried before.

Ormen-Lange on its part adopted a tested and trusted conventional technology – natural separation – of which the contractors has complete control of and as such did not present much technical problems.

8.7.2 CONTRACT METHODS

The major contract of Snøhvit was more like a single packaged contract in which the entire job of building the gas plant was contracted to one company, Linde technology.

In Ormen-Lange, the operators split the project into individual modules and awarded separate contracts for them. Around a third of these contracts were awarded to Norwegian contractors, who duly won them amidst stiff competition with players from other countries.

8.8 EXECUTION STRATEGY FOR ORMEN-LANGE

The first notable execution strategy by the operators of Ormen-Lange was the foresight shown by modifying and extending the time frame postponing the submission of the plan for development and production (PDO) to the Norwegian authorities until fall 2003. This move was necessitated by studies and tests which reveal there was a need to use more time mapping and doing essential preliminary work to determine the best concept and to optimize well placement. Even though the extension resulted in a new production start-up date in fall 2007, it undoubtedly secure more time for finalizing details which would have been bottle necks during construction thereby causing cost escalations.

The second strategy employed was the move to award some contracts prior to PDO approval. This was done in order to maintain the time schedule of the project. The operators showed an early commitment as regards key suppliers and contractors, by awarding contracts for services like line pipe material, pipeline installation, large-diameter and high-pressure pipeline valves, pipeline coating and anodes, tie-in and testing before the PDO was approved. The gain from such move was in securing capacity and process level for services needed for the project. Though this method involves some extent of risk if for any reason the project was not sanctioned as anticipated, it nevertheless ensures that capacity was secured before market prices escalated in 2003/2004. By acting in this manner, Statoil had frame agreements established with the most important contractors and services. This was clearly beneficial for the project as its cost estimate was not really affected by market price escalation in 2003.

Another strategy employed by Hydro during the projects execution was the splitting the project - the pipeline fabrication and construction works into separate units and contracts awarded separately for each one. This ensures good enough balance of risk between the principal and clients. By splitting and awarding individual contacts, the operators was able to control the whole project by ensuring that contractors take on jobs (and risks) that they have experience to take and can control.

CHAPTER 9. RESEARCH FINDINGS IN RELATION TO LOGISTIC THEORIES.

9.1 INCOMPREHENSIVE ESTIMATION OF SCOPE OF THE PROJECT.

The first finding of this research work was that there wasn't a clear and comprehensive estimation of the scope of the entire project as at the time the PDO was approved. Changes in both the original engineering design and the project execution methods were on numerous occasions reported. These therefore resulted in significant increases in the work-scope of several of the activities as against what was originally planned and budgeted.

A major example of the above was the decision in 1999 to increase planned output by 30% to 5.67bn cubic meters a year (cm/y) of LNG. The company miscalculated the increased construction costs associated with such an increment. A detailed engineering cost analysis later showed that the calculations were wrong as they did not reflect the new capacity of the plant.

In May 2004, key refrigeration compressors had to be modified to meet the specifications. Also increased, to a huge degree, were the weight of some of the modules resulting in the decision to move the cooling tower off the process barge, due to the large increase in the weight of the topsides plant. This alone resulted in cost increase to NOK58.3 billion and first contractual shipments being rescheduled to December 2007.

These are only just a few of such changes to the originally approved scope of the project as there were other numerous changes hereby not mentioned. The consequence of such changes can only be in one direction – cost and time overrun.

For instance, the first upward cost review of the project in 2002. Statoil in their annual report of 2002 states that, *"the total development costs for the project are estimated to be NOK 45.3 billion......... but following the projects review, the investment cost estimate was increased by NOK 5.8 billion in the autumn of 2002, due to* ***underestimated scope of work*** *and the delayed start-up".*

Another reference to this was the *"underestimations of the scope of work, particularly within the electrical discipline resulting to extra work at Melkøya which prolongs project execution and raises costs in the final stage".* This shortcoming was even admitted by the then project director for Snøhvit, Egil Gjesteland when he gave reason for the cost increase as the increment at an early stage, the capacity of the plant, *"but at the same time, the consequences of such an expansion in a large gas liquefaction facility were underestimated."* Even Statoil's chief executive officer Helge Lund reiterated this shortcoming when he stated that, *"the project, huge in its scale and complexity, had not been sufficiently mature at the time of sanction*".

It therefore follows from the above that Snøhvit was not developed so far, (there were too many changes), as to allow development elements to be well estimated with reasonable certainty prior to the approval of the PDO.

9.2 QUALITY FLAWS IN ENGINEERING WORKS.

The second finding of this work was as regards the quality of some of the works already carried out. It was reported that the *"quality of some of the deliveries were very inadequate and as such extra work was required to bring them up to the necessary standard"*.

Snøhvit construction witnessed the inter-mixing and inter-dependency of hundreds of supply chains, therefore success in the project is subject to the extent of quality of work of every segment of the chain. Good logistic control as regards quality of anticipated engineering, vendor data, equipment and material deliveries, must be in place to ensure the project was within time and budget but that wasn't really the case in Snøhvit.

A typical recorded example where there were quality defects was the case of quality flaws to modules from continental Europe resulting to transfer of work to Melkøya. Another example of quality flaw took place recently and was reported in Hydrocarbons technology journal (2007) was the sea-water leakage in a heat exchanger in the cooling system of the Melkøya liquefaction plant. This consequently led to a closure of the plant on 7 November 2007 for the modification and redesigning of the onshore plant cooling system. The plant re-started production in mid-January only to closed again in March 2008 for the same cooling system difficulties and was finally reopened in July 2008. This prompted Statoil to announce that the project was unlikely to reach full capacity until 2009 because some parts of the plant were only operating at 60% capacity.

9.3 DELAYS IN SUPPLY OF STRATEGIC MATERIALS.

Construction of Snøhvit also witnessed some delays in supply of strategic materials all which gave rise to increase in costs. Between June and October 2004, Statoil reported a cost increase of €510 to 760 million and delay of 6 to 12 months and the reason for it being due to *"measures implemented to deal with failures by contractors and equipment suppliers".* There were already so much delays being incurred that Statoil was quoted as saying that, *"the original intention of having module testing performed at the fabrication yards proved impossible to adhere to without incurring further lengthy delays. Instead it was decided that outstanding work would be transferred to Melkøya, where the work-scope of Aker Kvaerner and its subcontractors was expanded to cover the additional requirements".*

The effects of these delays and flaws for Snøhvit were captured in Statoil annual report of 2004 when the reasons for the cost review were given. The report showed that the *"total development costs for the project are estimated to be NOK 51.3 billion for all phases, of which NOK 22.3 billion has been invested as of December 31, 2004".* Statoil increased the estimated development cost by NOK 6 billion in 2004 after a detailed assessment of cost and progress. The updated estimate takes into consideration consequences of cost and schedule delays that occurred due to **test**

failure of compressors, late delivery of drawings and materials and productivity below expectation.

9.4 COMPETENCE AND RELIABILITY ON NEW TECHNOLOGY

Perhaps this is the most contributors to cost overrun in Snøhvit. Even though the engineering and technology concept adopted for Snøhvit was built up by well understood elements, it still remains that the concept was a new and untested one and as a whole without any industrial references. The Mixed Fluid Cascade (MFC) process was touted as an onshore processing marvel using the latest up-to-date technology but this uniqueness unfortunately was a recipe for errors. The implementation of the new technology, (mixed fluid cascade, MFC), introduced major factors of uncertainty of which enough attention was to paid to in the budgeting period. It was the opinion of Statoil executives that the technology adopted for Snøhvit was not comprehensively researched as claimed by the technology provider (Linde) before the approval. Statoil claimed that they were led to believe that they had absolute control of the technology thereby awarding them the contract. But it was during the projects construction proper that it became clear how incompetent the main contractor was as regards the execution of the task. It was also noted that the scope of the job was way too big for Linde (as a company) to handle.

In the past, new technology was adopted and judged purely on engineering criteria, unlike today where a more systematic approach referred to as "Technology Qualification" is used. "Technology Qualification" uses the system of the technology within a systematic risk based qualification to compensate for the lack of operation experience. By this method, it shows that it can meet the specific reliability targets without actual implementation in the mass market. But evidence has shown that as construction continues to advance, clients and stake holders start experiencing the risk of paying up-front for an exciting concept that may or may not prove commercially ready years later.

This was the case with Snøhvit. The technology (MFC) regardless of how inventive it was has never been implemented before and as such, contained many facets that were wrongly executed. This problem also has ripple effects on other aspects of the project. According to Engsbretsen et all, (2002), Snøhvit was *"the first offshore development ever where CO_2 is separated onshore and re-injected".* This concept eventually succeeded but not after billions of money was spent in righting the numerous mistakes and problems that arose as a result of adopting an untested technology.

9.5 INADEQUATE PLAN OF EXECUTION IN A HARSH ENVIRONMENT

Snøhvit was developed in an area of specific ambient winter conditions. Freezing temperatures of -5°C to -15°C and high winds blowing from the North, up to a velocity of 25m/s, and wind chill factor up to -45°C are normal occurrences. These particular ambient conditions naturally cannot be conducive for man and material both during the construction phase as well as during plant operation.

The problems associated to this harsh environment led to the fabrication of the majority of the components for the process plant at other places and were only coupled together in Melkøya. It was also for this reason that they decided to install as much as possible of the process plant onto a steel barge before being taken to Melkøya. This helped to reduce the amount of construction effort and time on site.

Nevertheless, there were many more other facilities vital for the success of the entire operation which can only be carried out in Melkøya and as such came under the influence of the harsh environment.

There were recorded delays attributed to this effect and good analyses of the work schedule showed a lack of or complete negligence of the degree of disruption that can arise due to bad weather conditions.

One such example is in the construction of the LNG storage tanks. Data obtained from Snøhvit construction schedule showed that they estimated it to take 28 months between starting on site (with the LNG Tank raft) to the moment the LNG Tank is ready for commissioning. Details show work should start on April 1st 2003, and completed on August 1st 2004. But this means having to work all year round even in winter time. The time schedule also shows that the roof will be prepared and lifted in May 2004. This period is always marked with high wind velocity and as such may prove too difficult to accomplish.

The schedule also showed that site piping erection works starts ± 18 months after contract award, with detail engineering isometrics completed 24 months after contract award. But this involves starting the erection works in January 2004 (in full winter period) and completing the piping works during the winter period of 2005.

Analysis of the weather conditions in Hammerfest shows that these calculations were not feasible. It is not really practicable to work during the extreme winter months of December to February. Rightfully, Statoil had many records of work stoppages as a result of bad weather. An example was when Statoil stopped work at the gas liquefaction plant on 19 January as a precautionary measure. Such stoppages all contributed to cost and time overrun and this should have been envisaged and accounted for during the design and briefing stages. The industry therefore should and must prepare for such unforeseen eventualities in such harsh environment.

9.6 DISRUPTIONS BY INTEREST GROUPS

Environmental and regulatory compliance costs were not given sufficient the expected consideration during Snøhvits contract negotiation period by both the client and engineering firms.

According to Buch (2002), ”*the Barents Sea is one of the world's most precious and vulnerable sea areas, and furthermore one of the last natural areas in Europe which is not yet depleted by human intervention and pollution*. ”He further noted that the sea areas just outside Melkøya in the Barents Sea are *home to some of the richest with* *respect to seabirds. Besides this, the Barents Sea is the most important breeding area to a number of commercial fish species making the waters and area around Barents Sea an important ecological site".*

As a result, there were environmentalist groups that wanted to put a stop to oil and gas drilling activities in order to forestall damage to this pristine environment.

One such group was the environmental foundation Bellona. They filed a complaint with the Brussels based ESA, the surveillance watchdog of European Free Trade Association (EFTA) against Snøhvit project. They reasoned that there is "*reason to believe that the chemical combinations and the oil being spilt during production will have negative effects on the biological life in the sea. As the Barents Sea is the most important breeding area to a number of commercial fish species, it is obvious that this type of pollution will stand in harsh conflict to the need for clean breeding area".*

Based on the law suit, the partners in the Statoil operated Snøhvit field in the Barents Sea resolved on 21st March to halt work on the project at Melkøya until the ESA had clarified the framework terms. Statoil stated in their news journal of 1/8/2002 that *"delays as a result of the EFTA Surveillance Authority's investigation into the tax regulations for the Snøhvit project have led to extra costs of between NOK 500 million and 1 billion".*

The news journal further noted that *"the extra costs are a consequence of the almost four-month stoppage where no contracts were entered into and nor were any purchase orders issued during this period."*

The effect on Snøhvit as a result of ESA actions include extra costs of preparing the plant area at Melkøya, increased engineering costs, and future costs for making up the delays such as ensuring sales of about 5 billion cubic meters of gas per year to clients in the USA and Spain - a deal worth about NOK 5 billion was not affected.

9.7 GOVERNMENT INTERFERENCE

Snøhvit is owned by Statoil of which the Norwegian government controls two third majorities of shares. Statoil and its activities are subject to regulation by the Ministry of Petroleum and Energy, its Petroleum Directorate, and the Petroleum Safety Authority (PSA). The PSA considers the health and safety of workers, as well as the natural environment. The Ministry of the Environment also oversees petroleum activity through the Norwegian Pollution Control Authority (SFT). Therefore there is inherently a big logistical challenge of mixing and balancing the interests of both Statoil and the government. The annual report of Statoil (2005) highlighted this challenge when it stated that, *"if the Norwegian State were to take actions pursuant to its extensive powers over activities on the Norwegian Continental Shelf or to change laws/regulations, policies or practices relating to the oil and gas industry, our NCS exploration, development and production activities and results of operations could be materially and adversely affected"*.

The situation described above now and then arises of which Statoil in their annual report of 2005 affirms this when it stated that, *"the interests of their majority owner, the Norwegian government are not always aligned to the interests of Statoil".* The conflicting roles of the state – directly profiting from oil and gas production by promoting its expansion in an era of declining production, and simultaneously regulating the industry – raises questions about the ability of the state to accomplish both missions. Though agencies operate independently, conflicts and unbalanced outcomes are inevitable. Snøhvit witnessed some situations in which interests of both the government and Statoil differ which in turn led to cost increase: and some of them are stated below:

a) WoodMac report noted that Norway employs a separate tax base for onshore and offshore facilities. The onshore rates, which cover standard industrial activities, include a 28% "corporation tax" while offshore upstream oil and gas activities are subject to an additional "special tax" at a rate of 50%. Norwegian authorities currently favor taxing the entire project, including all LNG terminal facilities, at the higher offshore tax rates which obviously are not favorable to Statoil.

b) The royal decree of December 19, 2001, where the Norwegian government decided that Norwegian oil production should be reduced by 150,000 barrels per day from January 1, 2002 until June 30, 2002. This amounted to roughly a 5 per cent reduction in output and for Statoil, owners of Snøhvit; it was a completely unfavorable situation which has a run-on effect on their other projects like Snøhvit.

9.8 POOR GENERAL MANAGERIAL CONTROL

It can be argued that almost every new upstream project has its fair share of risks which are simply inherent in complex industrial design but excellent project management should be able to capture (at least to a reasonable extent) the various risks associated with post-approval construction and operations. In the past, cost in per volume terms had decreased consistently as economies of scale developed but these present times has seen costs increasing significantly. In the past three years, materials and project management costs has gone up 60% - 80% while construction labor has become 30% more expensive. Cost and delay risks go hand in hand with the rush to begin construction without detailed assessment of the challenges ahead.

Snøhvit witnessed so many recorded lapses attributed to poor managerial control of which a typical example is the late mobilization and poor productivity at the main yard. The chief executive of Statoil Helge Lund admitted that, *"control of the project has been insufficient and we have not managed to correct the imbalances in the project quickly"*. The result of such lapse in a mage structure with billions in budget money can only be two things - delay and cost overruns.

The general summary of our finding was contained in this statement of Erling Øverland, the acting chief executive of Statoil when he said that, *"Snøhvit is one of the most extensive and technically-complex projects we've ever launched, we have underestimated its complexity and we acknowledge that the project was not sufficiently matured when the decision to develop was taken in 2001."*

CHAPTER 10. CONCLUSION AND RECOMMENDATION

10.1 CONCLUSION

As regards causes of cost overrun in mega projects, two major conclusions can be drawn from this research.

a) Complete project information before the start of the work leads to more accurate capital cost budget estimates. But then, the most serious problem when a budget is being estimated is that little information is often available. Therefore, there is need to allocate and spend more time in the early briefing stages of the project design to clearly define a project's scope and complexity.

b) Changes to original plan should be seen and regarded as the greatest risk in construction. Regardless of how much design information that is available for and during estimating, the gains accruing from them can be significantly depleted and negated by any design changes that are subsequently made. Changes in themselves should not be taken as threats only, they can be an avenue for cost savings and increase in value but that depends on how effective such changes were managed.

10.2 RECOMMENDATIONS

Due to the complex nature of LNG mega projects, they are always challenging and risky coupled with large number of interfaces and interdependencies. Therefore, scope changes at the design and planning stages have to be expected and efforts at monitoring and controlling put in place by project teams.

This was captured by Jergeas and Ruwanpura (2010) when they stated that "*clients and interest groups must adhere only to processes that detect and curb systematic cost underestimation, scope changes and schedule deviations as early as possible and take necessary and timely actions".*

CHAPTER 11. REFERENCES

1. Bengt Lie Hansen. (May 2004). **"THE GIANT SERPENT ORMEN LANGE: MANAGING THE NEW KEY PROVIDER OF NATURAL GAS TO EUROPE FROM BENEATH THE DEEP WATERS OF THE NORWEGIAN SEA"** an article presented at the Offshore Technology Conference, 3 May-6 May 2004, Houston.

2. Bent Flyvbjerg (2007) "**TRUTH AND LIES ABOUT MEGAPROJECTS"**
Inaugural speech on September 26, 2007.

3. **BUSINESS DICTIONARY** (2010). Copyright ©2010.

4. Cato Buch, (2002) **"SNØHVIT: REASONS FOR BELLONA'S OPPOSITION".** An article published in Bellona journal. 29th of August 2002.

5. Chris Hendrikson, (1998). **"PROJECT MANAGEMENT FOR CONSTRUCTION FUNDAMENTAL CONCEPTS FOR OWNERS, ENGINEERS, ARCHITECTS AND BUILDERS"** Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh Copyright C. Hendrickson 1998.

6. C. Krauss, S.L. Myers, A.C. Revkin and S. Romero (2005): **"AS POLAR ICE TURNS TO WATER, DREAMS OF TREASURE ABOUND"**. New York Times, October 10, 2005.

7. E.Heiskanen, (Sept. 2006). **"SNØHVIT CO_2 CAPTURE & STORAGE PROJECT".**

8. Frimpong, J. Oluwoye and L. Crawford. (July 2003). **"CAUSES OF DELAY AND COST OVER-RUNS IN CONSTRUCTION OF GROUNDWATER PROJECTS IN A DEVELOPING COUNTRIES; GHANA AS A CASE STUDY"** an article in International Journal of Project Management. Vol. 21 issue 5.

9. Fact 2009, **"THE NORWEGIAN PETROLEUM SECTOR"** by The Norwegian Ministry of Petroleum and Energy, Einar Gerhardsens plass 1, P.O. Box 8148 Dep, NO 0033 Oslo.

10. Flyvbjerg, B., Holm, M.K.S. and Buhl, S.L. (2002), **"COST UNDERESTIMATION IN PUBLIC WORKS PROJECTS: ERROR OR LIE?"** Journal of the American Planning Association, Vol. 68, No. 3, Summer 2002. © American Planning Association, Chicago, IL.

11. George F. Jergeas and Janaka Ruwanpura (Feb 2010), **"WHY COST AND SCHDULE OVERRUNS ON MEGA OIL SANDS PROJECT?"** an article in Practical Periodical on Struct. Des. And Construction. Vol. 15, issue 1, February 2010.

12. Halvor Engebretsen, Bjørn Fossan and Steinar Nesse. (March 2002). **"EIA FOR THE WORLDS' NORTHERNMOST LNG PLANT, THE SNØHVIT PROJECT IN AN ENVIRONMENTAL SENSITIVE AREA AT 71°N".** A paper presented at the SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, 20-22 March 2002, Kuala Lumpur, Malaysia ©2002, Society of Petroleum Engineers Inc.

13. Henry H. Perritt, Jr 1996 **"KEEPING THE GOVERNMENT OUT OF THE WAY: PROJECT LABOR AGREEMENTS UNDER THE SUPREME COURT'S BOSTON HARBOR DECISION**" Copyright © 1996 by the American Bar Association.

14. Jean-Jacques Laffont and David Martimort, (2002***).*** **"THE THEORY OF INCENTIVES – THE PRINCIPAL – AGENT MODEL"** Princeton University Press.

15. Mary Evans, (2005). **“OVERDUE AND OVER BUDGET, OVER AND OVER AGAIN.”** © The Economist Newspaper and the Economist Group. Jun 9th 2005.

16. Nicholas John M., (2001) **“PROJECT MANAGEMENT FOR BUSINESS AND TECHNOLOGY”,** 2nd edition, Prentice Hall, New Jersey.

17. Nils Olsson, Kjell Austeng, Knut Samset, and Ola Lædre. (2003) **“ENSURING QUALITY-AT-ENTRY: CHALLENGES IN FRONT-END MANAGEMENT OF PROJECTS”.**

18. **“OGC”** The Office of Government Commerce journal © Crown Copyright 2010.

19. Piet Van den Bossche. **“HOW TO SECURE THE PROJECT TIME SCHEDULE TAKEN INTO ACCOUNT THE EXTREME COLD WINTER CONDITIONS?”**

20. Richard E. Westney **“WHY PROJECTS OVERRUN AND WHAT TO DO ABOUT IT”** an article in the publication of Westney consulting group.

21. Rob van Deventer and Humphrey Lloyd (1993). **“LAW OF CONSTRUCTION CONTRACTS”** Juta Legal and Academic Publishers.

22. Robert E. Scott, (2003) **“A THEORY OF SELF-ENFORCING INDEFINITE AGREEMENTS”** Columbia Law Review, Vol. 102, November 2003.

23. Rose, Timothy M. and Manley, Karen (2005) **“A CONCEPTUAL FRAMEWORK TO INVESTIGATE THE OPTIMIZATION OF FINANCIAL INCENTIVE MECHANISMS IN CONSTRUCTION PROJECTS”.** An article presented at the International Symposium on Procurement Systems. The Impact of Cultural Differences and Systems on Construction Performance. 7-10 February, 2005, Las Vegas, NV USA.

24. Roy Scott Heiersted and Sigbjørn Lillesund, (2004) **"CONCEPT SELECTION FOR NORWAY'S FIRST LNG PLANT– SNØHVIT LNG PROJECT".** A Statoil Research and Technology Statoil ASA, N-4035 Stavanger, Norway Feb 2004.

25. Simon Jackson (2002) **"PROJECT COST OVERRUNS AND RISK MANAGEMENT".** School of Construction Management and Engineering, The University of Reading, Whiteknights, PO Box 219, Reading, RG6 6AW UK.

26. Singh, Ram (2009), **"DELAYS AND COST OVERRUNS IN INFRASTRUCTURE PROJECTS: CAUSES AND CONSEQUENCES".**

27. Wiley, (2004) **"ENCYCLOPEDIA OF SOFTWARE ENGINEERING",** Wiley & Sons, online edition.

28. Williamson, Oliver. **"MARKETS AND HIERARCHIES: ANALYSIS AND ANTITRUST IMPLICATIONS".** N.Y.: The Free Press, Paperback edition, 1983.

INTERVIEW QUESTIONS

We are students of Molde University currently researching for our Msc thesis on the Logistics Challenges in Constructing Facilities in Mega-Projects with particular reference to **COST AND TIME OVERRUN IN SNØHVIT LNG PLANT IN HAMMERFEST.**

The questions are directed to members of the Investment Committee appointed by the Ministry of Petroleum and Energy in 1998 to investigate why investments on the Norwegian Continental shelf have increased compared to original budget and plans.

The questions are structured to cover all stages of the project from design to construction but with special attention to the findings of the Investment committee of 1998. Answers are given by ticking the box that suits the questions. In some cases, more than one answers can be given as seem fit.

It must be stated here that answers given shall be treated in strict confidence and only used as part of our research into causes of cost and time overruns in oil and gas projects.

Thanks.

The objectives of this questionnaire are,

- To look into the main factors that can lead to cost overrun in mega projects like Snøhvit. This will be done by using the main reasons cited by the Investment Committee for the cost overrun in the boom to see whether those factors affected or were applicable to Snøhvit.
- To look at other factors of cost overrun that was not considered in the boom and their effect on cost overrun in Snøhvit.

QUESTIONS

1) Was cost overrun in Snøhvit due to additional investment due to anticipated increase in income?

a) Strongly Agree ☐

b) Agree ☐
c) Disagree ☐
d) Strongly Disagree ☐
e) Don't know ☐

2) Was the Plan for Development and Operation (PDO) approved for Snøhvit unrealistic as a result of exaggerated optimism based on positive trends during the preparation of decision making basis and decision making process?

a) Strongly Agree ☐
b) Agree ☐
c) Disagree ☐
d) Strongly Disagree ☐
e) Don't know ☐

3) Was the Plan for Development for Operation (PDO) approved for Snøhvit unrealistic as a result of unrealistic ambitions regarding substantial, further improvements and little comprehension of the uncertainty resulting from thin project maturing during the preparation of decision making basis and decision making process.

a) Strongly Agree ☐
b) Agree ☐
c) Disagree ☐
d) Strongly Disagree ☐
e) Don't know ☐

4) In the planning process for Snøhvit offshore plant, Compact LNG (new technology for freezing techniques) was approved. This technique was challenging therefore they found good reason to organize this project different by contracting the whole engineering design to Linda and the fabrication and assembly to take place in Spain. Was this decision a factor in Snøhvit cost overrun?

a) Strongly Agree ☐

b) Agree ☐

c) Disagree ☐

d) Strongly Disagree ☐

e) Don't know ☐

5) Was the logistic of moving this whole package from Spain to Hammerfest in Norway a contributing factor to the cost overrun in Snøhvit?

a) Strongly Agree ☐

b) Agree ☐

c) Disagree ☐

d) Strongly Disagree ☐

e) Don't know ☐

6) How would you rate the cost estimation method adopted for Snøhvit?

(A) There was poor cost advice.

(B) There was inadequate contingency allowance.

(C) There was inadequate assessment of risks.

(D) Base method used for calculation doesn't suit the project.

(E) There was stubborn client attitude.

(F) It was good and up to standard.

(G) Any other suggestions? Please state.

7) How important was brand new technology, complexity of the project and/or difficult to budget technology as factors in cost overrun in Snøhvit project.

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

8) Is the second boom in petroleum industries during which period Snøhvit was constructed, a main factor in Snøhvit cost overrun?

YES ☐

NO ☐

Don't know ☐

9) If yes, how important was these general activities in oil industry resulting in increase in cost (for example high cost of hiring plate-form) as factor in Snøhvit project cost overrun.

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

10) How important was lack of competence in one or more of the EPC contractors a factor in Snøhvit project cost overrun.

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

11) How significant was the new information coming up during the development that led to changes in the project affect cost overrun in Snøhvit project.

a) Very significant ☐

b) Significant ☐

c) Not significant ☐

d) Highly irrelevant ☐

e) Don't know ☐

12) Was lack of risk assessment and risk sharing pattern between the Operator and EPC contractors an important factor in the cost overrun in Snøvhit project?

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

13) The technology adopted for Snøhvit was completely new. Were the contractors always in good control of the technique from beginning to end?

a) Strongly Agree ☐

b) Agree ☐

c) Disagree ☐

d) Strongly Disagree ☐

e) Don't know ☐

14) How important was the first delay in the early stage of development by Linda to Snøvhit cost overrun?

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

15) How important was the contribution of Linda to the problem of the other contractors or suppliers?

a) Very important ☐

b) Important ☐

c) Not relevant ☐

d) Highly irrelevant ☐

e) Don't know ☐

16) Was the boom in the oil industry between 2004 and 2008 during which period Snøvhit project was developed an important factor in the cost overrun?

a) Very important ☐
b) Important ☐
c) Not relevant ☐
d) Highly irrelevant ☐
e) Don't know ☐

17) Due to the complex nature of the project, was the time limit set for the plants completion realistic?

YES ☐
NO ☐
Don't know ☐

18) If NO, do you thinks there was

a) Unrealistic design development periods. ☐
b) Unavoidable delays by employer and client. ☐
c) Unrealistic construction time frame. ☐
d) Unrealistic materials supply time frame. ☐
e) Don't know ☐

19) Considering the fact that Snøhvit LNG plant is located in a remote virgin environment, (MELKØYA ISLAND), do you think adequate studies and arrangements were put in place for unforeseen site conditions, constraints and restrictions?

YES ☐
NO ☐
Don't know ☐

20) If NO, was there recorded interruption(s) attributed to nature?

YES ☐
NO ☐

Don't know ☐

21) It was of the opinion that the location of the plant in remote northern Norway was an effort from the government to boost migration and employment in the area. Do you think the cost estimates were deliberately lowered to get approval from parliament?

YES ☐

NO ☐

Don't know ☐

22) It was of the opinion that the location of the plant in remote northern Norway was an effort from the government to boost migration and employment in the area. Do you think the contractors have used this against the clients by deliberately adopting less cost efficient methods in order to increase their gains?

YES ☐

NO ☐

Don't know ☐

23) The projects construction and materials procurement routes consists of hundreds of intermixed supply chains– clients, contractors, subcontractors, suppliers, sub-suppliers, service providers, third and forth party logistics providers etc. Do you think adequate investigation as regards competence was carried out before awarding of contracts?

YES ☐

NO ☐

Don't know ☐

24) If NO, were there recorded delay(s), lack of or late supply of materials from any of the above?

YES ☐

NO ☐

Don't know ☐

25) Did the project owners and contractors maintain a cordial relationship with the people of Hammerfest or other interest groups throughout the construction time?

YES ☐

NO ☐

Don't know ☐

26) If NO, was there any time delays directly or indirectly connected to attitudes of the interest groups.

YES ☐

NO ☐

Don't know ☐