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Preface

This is our master thesis in Logistics at Molde University College. This thesis presents a solution to the valuation of Ormen Lange Project at Nyhamna by using real option analysis. The investment at Nyhamna is an ongoing project and most of the costs are estimated since we have no right to access the data. Considering our limitation in the field of financial options and pipeline transportation system, we do have a lot of challenges to analyze this project through real options analysis. Hence, we would like to appreciate the following people who give us a great support during these months.

Firstly, we would like to appreciate our supervisor, Professor Arild Hervik. He gives us new ideas and helps us understand deeply of our work. Without his support and encouragement, we cannot finish our thesis.

Secondly, we would like to thank Mr. Iva Helge Hollen, Operation Manager of Shell, who gave us some important information in Ormen Lange project. Actually, we met him when we visit the process plant at Nyhamna one year ago. Because of this experience, we can improve our thesis constantly. In addition, we also appreciate Mr. Sten Arve Eide from Gassco, who confirmed the cost we estimated in the quantities' part of our thesis, giving information of Gassco project development.

Subsequently, Ms. Maria Sandsmark of Møreforsking Molde AS, who gave us two useful articles about real option theory and a few suggestions.

Finally yet importantly, we sincerely thank our parents for their support and heartfelt encouragement in the past two years.

Molde, May 2010
Lijie Wang and Tingting Zhang

Summary

This thesis focuses on how to apply real options in the decision making processes in order to choose infrastructure solutions in gas pipeline system. Two main theories are described in this thesis which is real option theory and traditional NPV (net present value) method. Real option theory is a decision tool to help managers deal with uncertainties and is used in a quantitative manner in this thesis. Compare to traditional NPV (net present value) method, it has more flexibility in the decision making processes.

After common real options are discussed with respect to some simple examples, this thesis presents a framework of how to deal with uncertainties concerning different options. It analyzes the feasibility of Nyhamna becoming a hub based on the cost efficiency and accounts for interactions among the option: defer, expand, abandon, contract, switch use and growth. Finally, the project's value under different alternatives is quantified based on the limited data. The calculation results present two available solutions. One is to expand the capacity at Nyhamna and the other is to wait until new capacity available in an alternative hub, Åsgard.

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Part 1-Introduction

1.1 Problem description

The main objective of this thesis is to focus on uncertainties, using real option theory and apply that in decision processes to choose infrastructure solutions in gas pipeline system. It presents a framework of how to make decisions under uncertainties by using different options. Real option analysis helps managers to deal with the concept of a hub system in developing gas infrastructure for a new area. We use Ormen Lange Project at Nyhamna as a case study to see if real options give support to develop Nyhamna as a hub. We focus on cost efficiency to analyze Nyhamna as a hub. We also look into the alternative where the real option can be waited until new capacity will be available in an alternative hub, Åsgard. We will try to quantify the project's value under different alternatives, using real option analysis.

We had interviews with the head leader of Ormen Lange Project (Mr. Iva Helge Hollen) and a representative of Gassco (Mr. Sten Arve Eide). Since they need time to work on this project and decide whether Nyhamna could be developed as a hub, part of this information is confidential and not available for us as students. For some extent, we have found data on relevant projects on the internet. After getting these data, we have tried to construct them as good as possible. Hence, this thesis emphasizes on analyzing the values of different options at Nyhamna based on some assumptions. In addition, we have tried the data to apply the options at Nyhamna in competition with an existing hub at Åsgard.

1.2 Gas value chain

The petroleum sector is the largest industry in Norway. Petroleum activities have contributed significantly to the economic growth and also to the financing of the Norwegian welfare state. The productions of natural gas liquids and natural gas started in 1971 and made over NOK 7000 billion until now (Facts 2009). There were more than 60 fields in production on Norwegian continental until 2009. The financial crisis has a negative impact in the petroleum industry, especially on the oil prices in 2008. Consequently, the petroleum industry faces many challenges. The problem in the oil market situation is low oil price and high cost of production and transportation. As a result, it is difficult to invest in new oil projects and there might be less oil in the market in the future. However, gas export is expected to increase and to reach a level between NOK 115 to 140 billion scm (Facts 2009). The gas production maybe increased concerning on increasing gas demand. The number and size of new gas fields might also be a critical factor for the gas production.

The initial vision for the thesis was how to deal with uncertainties for gas infrastructure system. Real option theory and traditional net present value methods are the main tools to help managers to deal with uncertainties. Since Gassco is responsible for planning and developing gas infrastructure in the cost efficient way, our starting point was to understand the network of petroleum market and the processing of gas from gas field to market. Figure 1.1 shows that how gas follows the value chain to the customers. There are five steps and they are analyzed as follows.
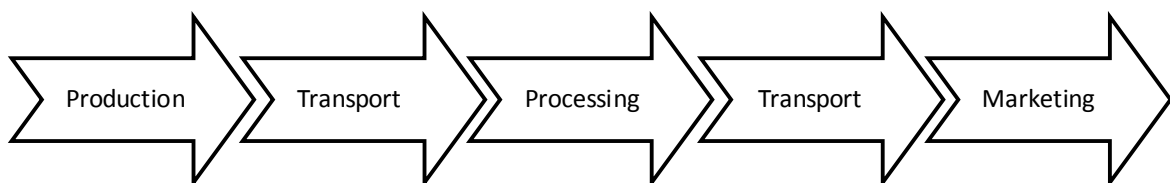
Figure 1.1: The value chain of petroleum market

The first step is production. Nearly 238.6 million scm (standard cubic meters) of oil equivalent petroleum production was produced on the Norwegian continental shelf in 2009. The total volume of gas transported to receiving terminals in other European countries was

96.6 billion scm in 2009. The Norwegian government estimate that the total petroleum demands will increase considerably in the future.

The second step is to transport gas to onshore plant. NGL (natural gas liquid) is transported by pipelines from offshore to onshore facilities after separation and depressurization, being operated in Kårstø and Kollsnes complex. The length of gas pipelines is 7800 kilometres in total. Natural gas liquid has its own export submarine system with professional processing procedure. Dry gas is transported via receiving terminals to customers.

The third and fourth steps are to process gas on plant and transport them to customers. Wet part of gas will be separated from dry gas through different separating processes. Dry gas is transported through pipelines to receiving terminals and natural gas liquids are exported by vessels. Gassco allocates capacity equally to every petroleum company and petroleum companies deliver gas to customers through the same pipeline system. The objective of Gassco is to optimize the society economic, on the behalf society.

The final step is the gas sales in the market. In the European petroleum market, petroleum gases can be divided into three categories. 60% of the demand is from fuel for industry and households, 30% is from petrochemical feedstock and 10% is from automotive fuel (directly, mixed with petrol or converted to high-octane products) (Source: Norwegian Petroleum Directorate). Throughout the whole value chain, Gassco plays an important role as an operator for safe and efficient gas infrastructure system in Norway.

1.3 Players in the petroleum industry

The total amount of natural gas exports from Norway to Europe through integrated transport system were 94.6 billion standard cubic meters (scm) in 2008. There is also a substantial, long-term need for additional gas pipeline capacity (Gassco[1]). The petroleum industry of Norway ranks as the third largest with its oil production, including natural gas liquid and condensate in the world. Through a lot of complex processes, raw material resources could be made into different products. It is easy to notice that the petroleum products make people's life more convenient. The petroleum industry plays an important role in the entire society of Norway.

Figure 1.3 shows the Norwegian national organisation of the petroleum sector. The main players related to our thesis in the petroleum industry are shown in the following.

The Ministry of Petroleum and Energy (MPE) ---Government

The Petroleum Directorate (NPD) ---Government

The Petroleum Companies (licenses) ----SatoilHyrdro ASA etc.

Gassco--- pipeline infrastructure system

It is clear that these players are controlled by the Norwegian government. Since NPD is a subordinate of the Ministry of Petroleum and Energy, these two players will be combined and regarded as one player as the following analysis.
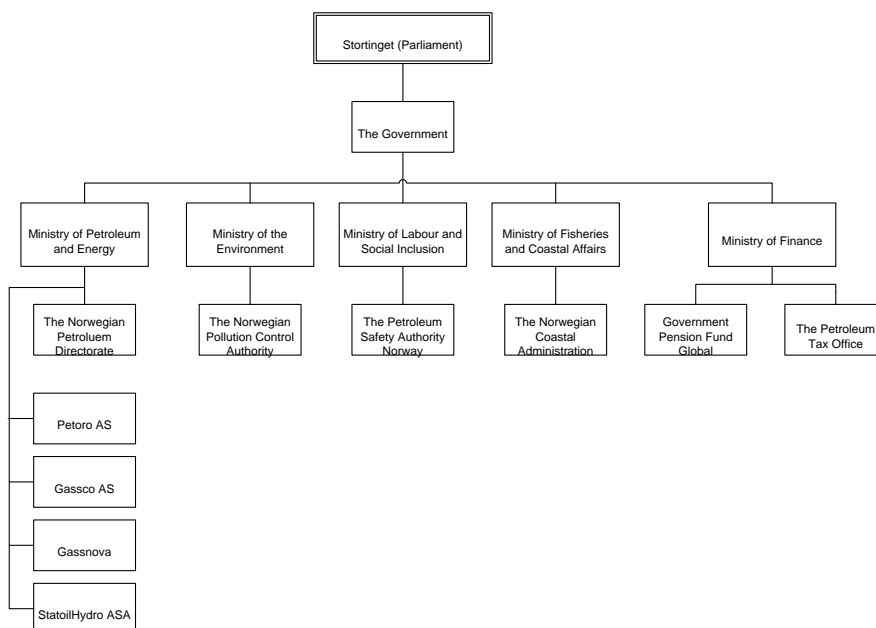
Figure 1.2: Norwegian national organisation of the petroleum sector (Facts 2009)

1.3.1 Government

Ministry of Petroleum and Energy is responsible for energy, including petroleum and natural gas production in the North Sea. The main objective of this organization is to achieve a coordinated and integrated energy policy. In addition, it has a particular responsibility for the state owned corporations and oil companies such as Gassco, Petoro AS and StatoilHydro ASA (Source: Ministry of Petroleum Energy).

Norwegian Petroleum Directorate (NPD) is a Norwegian government administrative, which is responsible for the regulation of petroleum resources on the Norwegian continental shelf. The main task for this agency is to manage petroleum resources to be allocated in an optimal way with minimum environmental impact. Meanwhile, it acts as an advisor who exercises authority in connection with exploration and production in the gas fields (Source: Ministry of Petroleum Energy).

Since Norway is already an important gas supplier, controlling and managing these resources has become a major issue for Norwegian government. Gas transportation system is a core part of gas business because most of gas products should be transported to the consumers through this system. Therefore, the government should rely on their unique power to organize the gas business in a way ensuring an efficient gas market. Compared to the previous years, exploration activities on the Norwegian Continental Shelf has been increased and new gas fields are found, especially in mature areas. The government realizes that this represents a positive trend and should encourage the industry to follow up with investment to bring resources to the market (Ministry of Petroleum Energy). The government precedes the licenses that allow petroleum companies to search for or develop petroleum in specific areas. It needs to take on a long term perspective for issuing the exploration licenses.

1.3.2 Petroleum companies

The petroleum companies (national and international) are responsible for all the investments in gas pipeline infrastructure and also have to fund Gassco. Initially, the Norwegian government selected a model in which foreign companies have used for petroleum activities on the Norwegian continental shelf. With the participation of Norsk Hydro which was a wholly owned state oil company, the government involvement has been strengthened later. This means that the Norwegian government has their own oil

companies and has the ability to operate the petroleum activities.

When the oil companies decide to invest in discovering new gas fields, they have to apply a license from Norwegian government. The authorities require these oil companies to offer ideas of discovering new fields and the technical solutions at the same time. Without permission from the authorities, these companies cannot develop new gas fields. Based on this, the government enable to understand and evaluate the companies' decisions. It is important for the authorities to know these decisions are enough safe for the society and external environment. Generally, oil companies do not apply for licenses individually and they usually cooperated to develop the same area.

Through the interview with Mr. Ivar Helge Hollen, he mentioned that Shell cooperates with other oil companies such as StatoilHydro ASA to develop Ormen Lange. It is obviously that there are cooperation and competition among various oil companies by different technical, organisational and commercial expertise. A group of companies get the licenses to develop Ormen Lange instead of an individual company. This group could exchange ideas and experience, share costs, risks and profits because they have the same objective which is to maximize the total profits when developing the Ormen Lange Project. On the other hand, these companies may also have competitions in this industry and this may lead to the best result of maximizing the value of petroleum resources.

1.3.3 Gassco

Gassco was established in 2001 and started to take over the administration and operation of pipeline transportation system from Norway to Europe on 1st January 2002. It is owned by Norwegian government. The responsibility of Gassco is to develop and operate the gas infrastructure system. The objective is to develop the gas infrastructure system in a cost efficient way. The company may act on the behalf of the society and try to develop the most cost efficient pipeline system.

As an operator, Gassco plays several roles in the petroleum industry. First, Gassco is responsible for operating the Norwegian gas transport system on behalf of joint ventures. Since the petroleum companies have the plan to develop new gas fields, these companies may invest in gas infrastructure and Gassco is the operator for the gas pipeline transportation system. This means Gassco does not have to pay for these investments.

Second, Gassco has the power to plan future pipelines and transport-related facilities, including processing plants and receiving terminals. Third, Gassco allocates the right capacity in a given time to pipelines and transport-related facilities. The last role of Gassco is to treat all companies equally during the transportation and to deliver the gas to the right location safely, with the correct quantity and quality (Gassco[2]).

Gassco would like petroleum companies to invest in over capacity in pipeline system because these companies may get cost advantages if they invest over capacity of gas infrastructure in the beginning. Gassco gives information to petroleum companies that the investment cost for developing in gas pipeline infrastructure system. Gassco does not focus on the ability of petroleum companies to discover the new gas fields and to use the excess capacity for gas transportation. The main objective of Gassco is to optimize the economics in this market instead of maximizing its own profits. In addition, Gassco has the power to stop the infrastructure development by the government's authority.

We had an interview with Mr. Iva Helge Hollen, the operation manager from Norsk Shell, before starting writing this thesis. Meanwhile, we also sent questionnaires to Gassco. Both of these questionnaires are listed in Appendix 1 and 2. Nyhamna is a developing project and lots of investment decisions have not made yet. Therefore, it is not possible to get the exact investment cost from these companies. We decided to change our plans and tried to get some history data from internet. In the beginning, we preferred to analyze the competitions among Nyhamna, Kårstø and Kollsnes in the petroleum industry. Without enough information, we have to give up this plan. The main issue of our thesis then became to analyze whether or not to Nyhamna as a potential hub. Based on the results of a quantitative study of Nyhamna caset, we will present the possible real option values of investing Nyhamna as a hub by both qualitative and quantitative study.

1.4 Methodology and data collection

This thesis studies whether to invest Nyhamna as a potential hub, using Ormen Lange Project as a reference. Under various uncertainties, managers have to determine the most appropriate valuation method of this project. The valuation methods include traditional NPV method, simulation, decision tree analysis, financial option and real options.

This thesis consists of three main parts, including theory review, gas hub development and Nyhamna case study. The first part is the literature review. This part discusses three approaches for dealing with uncertainties. They are traditional net present value method, financial option method and real option theory. In this part, the shortcomings of traditional net present value have been analyzed. Real option theory could remedy these shortcomings and help managers to make right decisions with flexibility.

The second part of this thesis is a link between the theory and reality. This part describes the basic concept in a gas hub system and the basic cost in the hub system. In addition, the decision processes to invest a hub system have been analyzed after understanding the processing facilities in the petroleum industry.

The last part contains four sections which are the background of Ormen Lange Project, the onshore and offshore facilities, the advantages and disadvantages of developing a hub and value different real options at Nyhamna based on the limited data.

The data collection process is really a challenge for us, especially in the second part and third part. In the first theory review part, the main articles' sources are from online scientific databases, such as Sciencedirect, ProQuest and so on. There is no problem to find quantitative literature on real option theory because there are a large number of books and articles have been written on this subject over last 15-20 years. However, it is really difficult to find relatively qualities' articles in real option theory. A lot of articles in this area are based on the model and data analysis.

The most challenge for us is to get relevant information and data for the Nyhamna case. Part of data collected in third and fourth parts are from the internet such as the website of different oil companies. Moreover, the interviews, telephone calls and discussions with our

supervisor are really helpful for us to deeply understand the problems of our thesis and give us new ideas. In the business as the petroleum industry, large amount of confidential data is owned by different oil companies and we have no right to access these data. Since we cannot get the actual cost data of Gassco and other oil companies, we have to change our original plan and try to analyze the different options for Nyhamna case based on the limited information. Besides, the calculation of different options' value is based on some assumptions.

Part 2-Theory review

2.1 The Net Present Value method (NPV)

Investment decisions are usually made through the standard discounted cash flow techniques. The most common method of decision making involved Basic Net Present Value (NPV), Simulation, or Decision Tree Analysis (DTA). The method of net present value is the sum of expected future cash flows minus the initial investments (Inass El Farissia, Jean-Michel Sahutb and Mondher Bellalahc, 2008). According to Bert De Reyck et al. (2008), traditional investment theory demonstrates the concept of net present value (NPV) by using a cost of capital based on the inherent project risk. Meanwhile, it is also an economic standard method for evaluating long-term projects. It is an easy way to make a decision based on the net present value. Managers may consider what the decision should be taken if the value is positive and what the decision should be taken if the value is negative.

The calculation of NPV (net present value) consists of three important elements. These elements are time of the cash flow, discount rate and the net cash flow. The formula of calculation is shown as follows.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - I$$

t= the time of the cash flow

T= the total time of the project

r= the discount rate

C_t = the net cash flow at time t

I= the (single initial) investment outlay

Managers are easily to make a decision based on the above calculation. If the NPV (net present value) is positive, it means a company could get profits after investing and this company should invest in this project. On the contrary, the investment should be dropped while the net present value is negative. Furthermore, when the net present value is zero, the company may neither get nor lose money from the investment and this project may not be invested in.

Based on the formula, it is clear that the following issues should be taken into consideration. First, how to forecast the future cash flows. The second issue is how to treat inflation. The last one is how to determine the discount rate (Arthur Sund and Jørgen K. Walquist, 2007). If all these three issues are resolved, the calculation might be correct and could help managers to make good investment decisions.

Besides, it is important to note that the information cost could be taken as an additional discount rate in the discounting of risky streams. In fact, the investors may compensate for their investments through information cost. If the investor knows nothing about that project, he may not invest. In this situation, information cost should also be accounted for in the computation of the present value of cash flows since it has impacted on the net present value. If the oil company spends 5 million in getting addition information of the potential gas field and the total investment is 100 million, then this company might have to require more than 5/100 or 5% for additional return above riskless interest rate. Hence, a new discount rate should be (r+5%) in this case (Inass El Farissia, Jean-Michel Sahutb and Mondher Bellalahc, 2008).

2.1.1 Shortcomings of the NPV method

Traditional NPV (net present value) approach is simply used for measuring the excess or shortfall of cash flows under present value terms. The managers could make decisions of the project (invest or abandon), depending on the NPV whether it is negative or positive. Although, net present value considers all the cash flows, the time value of capitals and the risk of the future cash flows, it still exist limitations for implementation. According to Dixit and Pindyck (1995), NPV method assumes an irreversible investment that means once the companies decide to invest, they may give up the possibility of waiting for new information. This method ignores the value of flexibility and only considers the investment as a static process. The opportunities of investment are taken as "now" or "never". Once the project is rejected, it will not be invested forever. In other words, it means the company loses the opportunity to invest forever. In addition, even the NPV proves to be positive, the decision makers still may not process the project immediately because they may wait for getting more information. In this situation, the value of time wasting is not reflected on the standard NPV calculation. Furthermore, this method does not consider the reality while

many projects could be implemented flexibly through defer, expand, growth, switch or abandon that is performed by real options.

Another shortcoming of NPV method is that it ignores the value of creating options. The strategy is only with do or not to do the investment and there is no third option such as wait and decide later. In fact, many investments could be delayed and processed by getting more information in the future while the value of project would not be lost. In addition, since the decision maker decides to invest, the project will be run in a long term without considering the market environment. There is a possibility that the result is positive and a company may do the investment based on the calculation but the market environment is changing year by year. Perhaps after several years, the market is depressed and the company could not get expected profit. The best way in this situation might be stop the project for a while and wait until the market environment becomes better. Under traditional net present method, since this company has already invested the project, he has no opportunity to stop and run later on. Even the market condition is worse than expected and the price is very decreasing, the project still has to be continued.

The last shortcoming of NPV method is that it is difficult to determine an appropriate risk discount rate. The NPV is used originally for calculating interest on saving accounts. When it is applied for analyzing high uncertainty projects, the result could be incorrect. This uncertainty usually could be reduced or eliminated by waiting for new information before making the final decision. The NPV analysis tends to be used in where the uncertainty is in consequential, the investment amount and timing is established and the near-term outcome is more certain (Scott Mathews, 2009). It seems that this method has poor ability to deal with risk. The risk-adjusted discount rate has to be determined when to calculate the net present value. In fact, there is a possibility that the outcome is better or worse than expected. In other words, project risk is not always the same and it could have upside and downside. As an investor, He may not pay attention to the high risk while more focus on the downside risk and make an effort to reduce or eliminate the risk. In other words, most investors prefer less risk to more risk such as people would like to pay a premium to buy insurance. Hence, how to determine the appropriate discount rate is also a serious problem when using NPV method. In many cases, company may assume a constant risk-adjusted discount rate each year. This means risks will never be changed in each period and uncertainties are resolved continuously at a constant rate over time. Different

discount rates should be used in different periods because there are different situations in different periods. It is still a difficult problem to find the proper discount rate in projects.

Under uncertainty, the objective of a company is to maximize the shareholders' wealth by taking market-oriented risk attitudes. Take stock market for example, the basic idea of reducing risk is to invest more than one stock when these stocks' returns are not perfectly correlated. It is clear to explain through the following mathematical form.

$$Var(r_1+r_2)=Var(r_1)+Var(r_2)+2cov(r_1,r_2)<Var(r_1)+Var(r_2), \text{ if } cov(r_1,r_2)<0$$

Here r_1 and r_2 represent two different assets whose returns are negatively correlated. Hence, the variability of group of stocks can be substantially less than the average variability of the individual stock returns. Similar to this, in petroleum industry, there are many different risks such as technical risk, gas price, transportation and so on. The above idea could be extended to petroleum industry that the total risks of group of assets may be less than the average variability of the individual asset, depending on the extent of correlation between asset returns. The total risks could also be measured by two parts, which are market risk and firm-specific risk (Trigeorgis Lenos, 1996).

That is, Total risk=Market risk+ Firm-specific risk.
However, firm-specific risks sometimes may affect the whole market and cannot be removed or reduced through diversification (Arthur Sund and Jørgen K. Walquist, 2007). It is much clearer through the expression of capital asset pricing model.

$E(r_j)= r+\beta_j[E(r_m)-r]$
$E(r_j)$ is the expected return from asset j,
$E(r_m)$ is the expected return from the market portfolio
r is the risk-free interest rate
$\beta_j \equiv cov(r_j,r_m)/Var(r_m)$ is the asset's volatility relative to the market

Although the beta (β) of many assets could be found stably in many cases, it is difficult to be determined accurately (Trigeorgis Lenos, 1996).

2.1.2 Sensitivity Analysis

Sensitivity analysis is also an approach to deal with uncertainty and complexity. NPV is determined through estimating of the cash flows, depending on different variables. Sensitivity analysis is the process to observe the key primary variables, which may affect upon NPV. In others words, the process is to change one key primary variable each time and keep others the same, then identify the result of NPV. This approach gives a picture of the possible variation in or sensitivity of NPV when a given risky variable is wrong estimated. There is a possibility that a variable itself maybe very risky, but it has small affected overall project's NPV. On the contrary, a non-risky variable may have a big impact on the whole project's NPV. It is easy to find how large forecast errors of a variable through this analysis before making a decision of investment.

However, sensitivity analysis still has its limitations. First, it only considers the impact on NPV of one variable each time and ignores the misestimates of more than one variable together at the same time. Second, if there are dependences among all the variables, it is meaningless to examine them in isolation (Trigeorgis Lenos, 1996). This means that one variable may influence to another one. In the petroleum industry, there are some connections among transportation risks, price volatility, and technical issues. In fact, these factors may have effects to the whole project at the same time because they are correlated. For example, the oil companies could not transport gas on time because of the technical issues. Therefore, the customers may not get the enough quantity of gas what they want. In this situation, the demand of gas may lead to exceed supply and this may result in to increase gas price volatility. Therefore, once one variable is changed, the other variables could be changed because of inherent dependences and this could have significant impact on NPV. Because these variables are not independent, the accuracy of one variable's estimate depends on another variable. When only focusing one variable each time, the result of NPV may have no difference. It makes no sense to analyze these variables separately. In addition, because of false estimates of a variable, forecast error in one year may generate higher errors in the following several years that may result in greater impact on NPV.

2.1.3 Monte Carlo simulation

Monte Carlo simulation has been used for risk analysis since 1940s which is an important statistical technique to evaluate the uncertainty (K. Rezaie, M.S. Amalnik and A. Gereie, et al., 2007). In general, Monte Carlo simulation uses repeated random sampling of key primary variable that may have great impact on NPV and makes strategies through analyzing the probability distributions of the cash flows or NPV. It is widely used in petroleum industry for dealing with uncertainty in investment decisions. Typically, in some real investment projects, managers may have an idea about the range of values but not aware of the meaning of exact numbers. Monte Carlo simulation could generate any number of forecasts by the overall cash flow distribution.

Monte Carlo simulation usually follows these steps when implementing in petroleum sector (Trigeorgis Lenos, 1996).

- Step 1: Create a cash flow model of the project, using a set of mathematical equations and identifying all important cash flow components such as temperature or volume structures in the actual pipes. The objective of this model is to maximize the total net present value for all involved fields including transportation costs.

- Step 2: Based on the past data, specify probability of distribution of each important component which is heavily impacted by uncertainty.

- Step 3: Try to determine discount rates and discount method.

- Step 4: This step is to get a random sample from the probability distribution of each cash flow component for each period. The simulation is run by inserting the random model for each uncertain forecast.

- Step 5: Repeat these processes for many times and finally could generate the probability of project's cash flows or NPV. The output through Monte Carlo simulation is shown in figure 2.1.
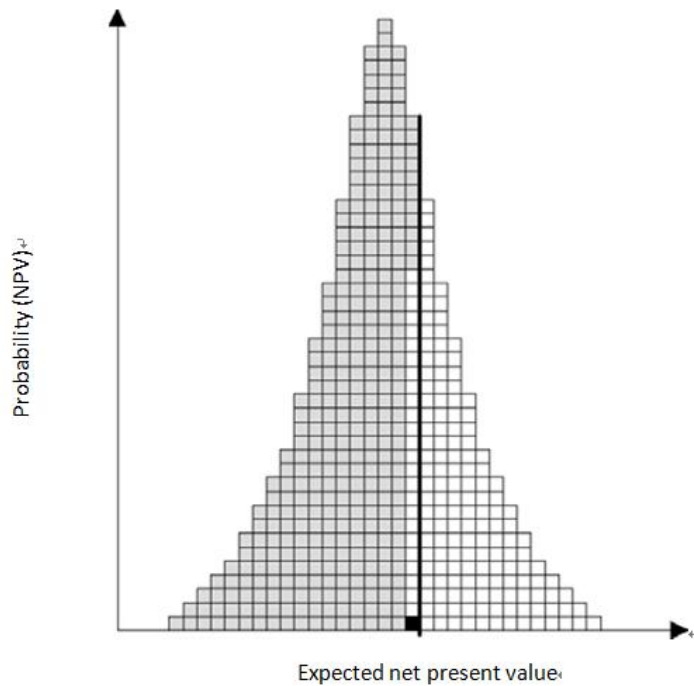
Figure 2.1: Expected net present value (Trigeorgis Lenos, 1996)

Although it is a good tool to handle complex decision problem under uncertainties, it does not mean that it has no limitation. In Monte Carlo simulation model, analyzing one uncertainty will select various values but may ignore the interrelationship with other uncertainties. In fact, different kinds of uncertainties may have different levels of dependencies. For instance, time and cost are two uncertainties in a particular project which is obviously that they are highly related. When decreasing the time of project, the cost might be increased at the same time (K. Rezaie, M.S. Amalnik and A. Gereie, et al., 2007). It is not always easy to capture the inherent interdependencies among these uncertainties. Sometimes, it is really difficult and complex to correctly get these inherent interdependencies.

2.1.4 Decision tree analysis

Another approach to deal with uncertainty and complexity is decision tree analysis (DTA) This method could help managers to make decisions easily. Based on calculated series possible values, companies could use decision tree analysis to make outcomes easy to be understood and interpreted. Moreover, it is particularly useful for analyzing complex sequential investment decisions. DTA forces management not only to focus on the initial decisions like conventional NPV, but also make strategies for subsequent decisions. These decisions problems are not independent and could not be posed in terms of isolated

decisions. The reason is that today's decision we made depends on the future decisions. That means under uncertainty, decisions taken in the future may be influenced by present decisions (John F. Magee, 1964).

Figure 2.2 illustrates the basic structure of the decision settings. Management is faced with a decision of choosing among so many alternative actions. The consequence of each alternative action depends on the future uncertainty events, using past information or additional future information obtainable at some cost (Trigeorgis Lenos, 1996). The following figure gives a clear concept that how decision tree works. It is a decision tree for developing new gas field problem in petroleum industry.

The tree is made up of a series of nodes and branches. The initial decision is shown at the left and the decision of one project is to proceed as follows. Now the oil companies are planning to decide whether invest in to develop a new gas field. If the project is approved, then moves to a second stage of decision at Point A. Otherwise, their competitors may be introduced to get a license and invest in this project. In this situation, they may lose the opportunity to develop new gas field and their competitors might develop this new gas field and may seriously damage their market share.

At the right of the tree are the outcomes of different sequences of decisions and events. Assuming there is no change between now and the time of Point A, managers in oil companies may have to decide whether to invest in overcapacity. If the oil companies could find a new gas field, then they may need that extra capacity. If they cannot find new gas fields, the best way is to invest in exactly capacity needed and spend less money. Even they can find new gas fields, there are still many aspects should be considered such as quality and quantity of the gas. These outcomes are based on the present information and it is not necessary to identify all the events. In the decision tree, mangers only need to focus on the decisions and events or results which are important to them and compare consequences of different courses of action. This decision tree does not give decision makers the answer whether to invest in overcapacity or not, rather, it helps them determine which alternative at any particular choice point to get the greatest expected profit (John F. Magee, 1964).
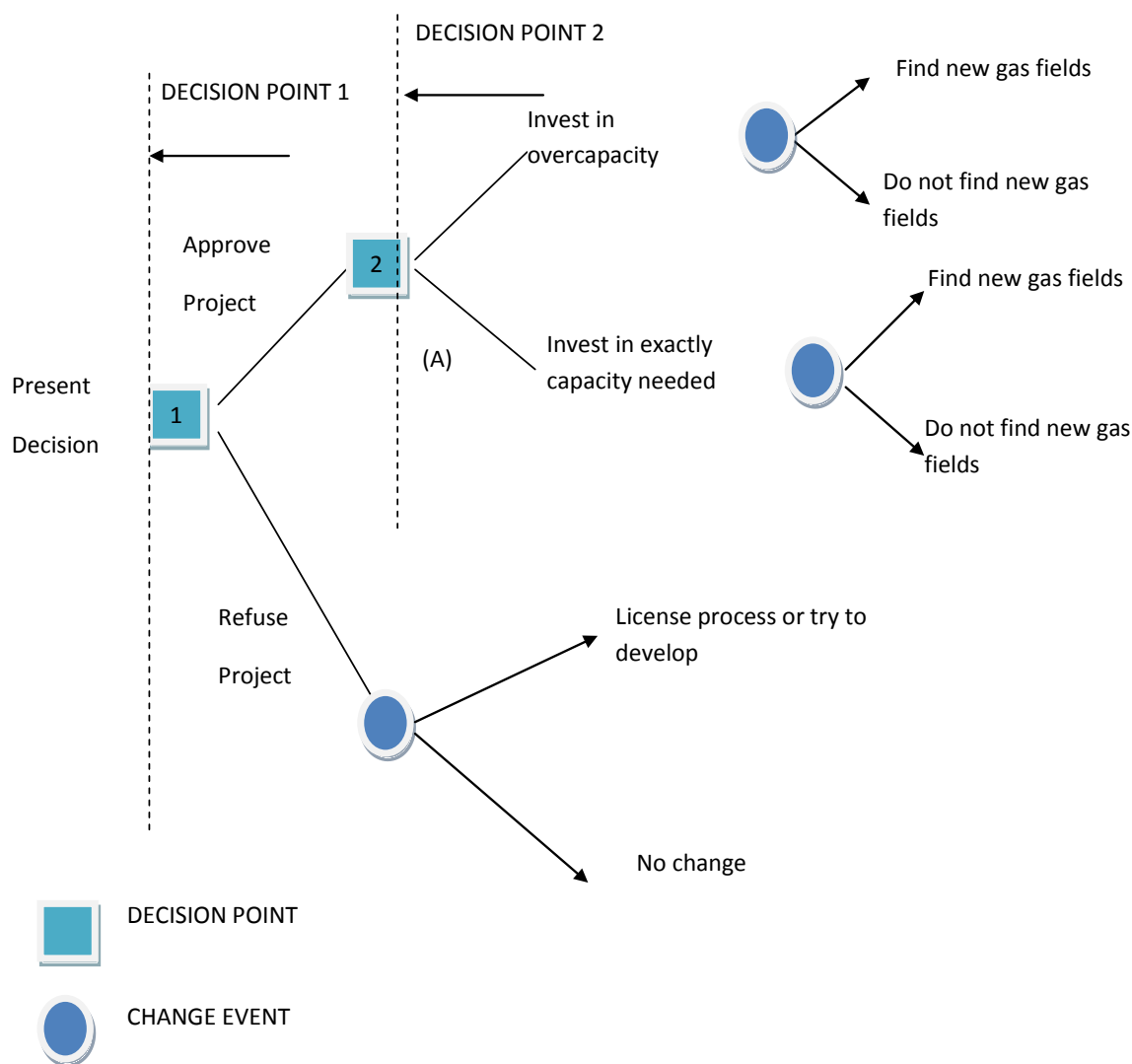
Figure 2.2: Decision tree with chains of actions and events

2.1.5 Traditional NPV vs Decision tree analysis

Several approaches of deal with uncertainties have been described above. In the following, we will use a simple example to make a deeper understanding of NPV. A petroleum company considers investing in new capacity but it is worried about the size of market opportunity and whether to find new gas field that may fill up that capacity soon. Depending on the outcome, decide whether to invest or not in the future. The initial investment cost is \$0.1 million. If the project is successful, this company may get cash flow \$0.5 million from year 1 to year 5. Assume the discount rate for both phase of the project is 5% and risk is fully diversifiable so that we can use risk-free rate in this case.

The managers would like to know whether invest now or wait one year to get more information and then make a decision. The cost for waiting one year will be decided later. Based on the traditional NPV method, we can get following net present value.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - I = \sum_{t=1}^{5} \frac{C_t}{(1+r)^t} - I_0 = \sum_{t=1}^{5} \frac{0.5}{(1+0.05)^t} - 0.1 = \$1.16 million$$

$I_0=0.1$	$C_1=0.5$	$C_2=0.5$	$C_3=0.5$	$C_4=0.5$	$C_5=0.5$

Year 0   Year 1   Year 2   Year 3   Year 4   Year 5

r=0.05
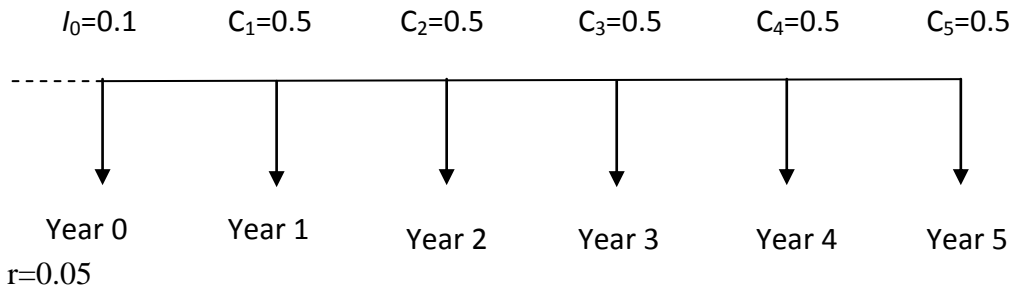
Figure 2.3: Cash-flow of project

Since NPV is positive, it seems that this company should go head to do the investment. In fact, this conclusion is not correct, however, because the calculations above ignore the option that wait and keep open possibility of doing not invest if the market environment is not so good.

Decision tree analysis is also an approach to help management determine which alternative at any particular choice point make the greatest profit. It is quite an easy way to present all the possibilities of outcome as an expansion to a simple calculation of NPV. We still use the same example in the following and see how it works. After the initial investment, this petroleum company finds that the successful chance of this project is 30 percent. In the next phase, this company will invest $3.5 million in building up a processing plant which may generate expected annual cash flow of $0.5 million. Assuming no important change in the company's situation, but management in this company has a deeper consideration of the cash flow forecasts. There is a 60% chance of a large market in the long run and a 40% chance of a low demand, offering a year-5 expected value of $10 million and -$4 million separately. Here the appropriate risk-adjusted discount rate is assumed to 10%.

Figure 2.4 shows the basic decision tree in which problem this petroleum company is facing with.
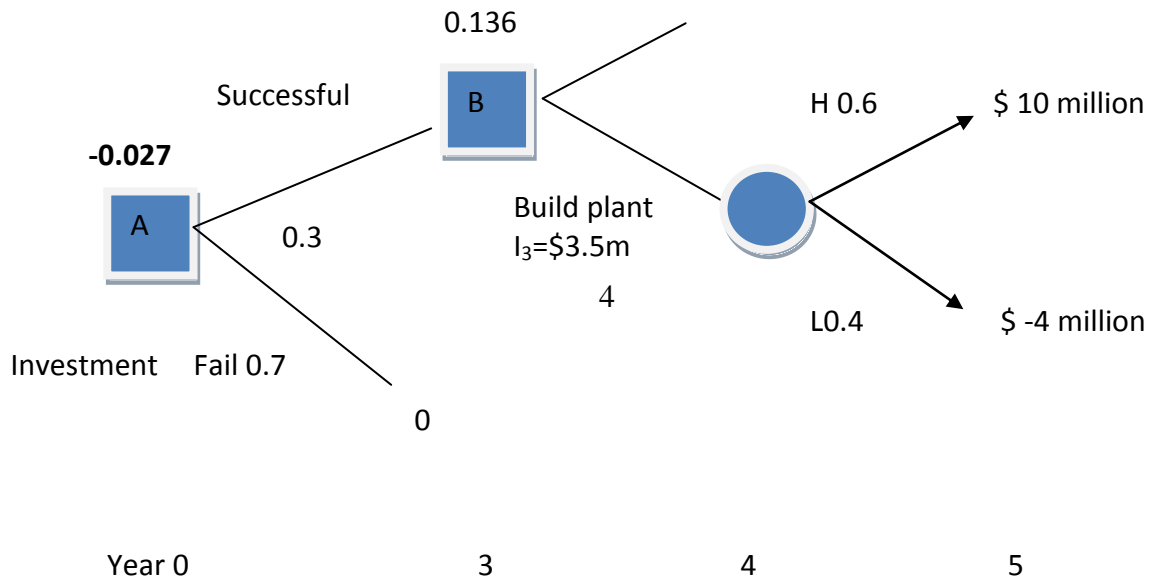
Figure 2.4: Decision tree of project

Under decision tree analysis, we start from the back of the tree and NPV for each outcome is multiplied by the probability. It could be calculated, starting from the right of the decision tree and roll back to the left. Because of the market demand, expected cash flow in the fifth year is the outcome multiplies probability and accumulates these two values. Therefore, the present value in year 5 is

$$E_5(PV) = 0.6*10+0.4*(-4) = 4.4$$

Step back to year 4, using risk-adjusted discount rate k=0.1, we can get the expected NPV that,

$$E_4(NPV) = \frac{E_5(PV)}{1+k} = \frac{4.4}{1+0.1} = 4$$

Now we know the net present value in the fourth year and roll back the third year which is at node "B". To build a plant, it will cost $ 3.5 million. Similar to last step, the expected NPV at node "B" in year 3 is

$$E_3(NPV) = \frac{E_4(NPV)}{1+k} - I_3 = \frac{4}{1+0.1} - 3.5 = 0.136$$

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Finally, step back to the initial node "A" which we may get the expected NPV at present:

$$E_0(\text{NPV}) = \frac{E_0E_3(NPV)}{(1+k)^3} - I_0$$

$$= \frac{0.3*0.136 + 0.7*0}{(1+0.1)^3} - 0.1$$

$$=-0.027, \text{ or } -\$ 0.027 \text{ million}$$

Through this calculation, we get the net present value is minus $0.027 million and this negative value means that the managers in this company should refuse this project. Here there is only one choice that to invest now or never invest. According to the result of NPV, this company should not invest forever. In fact, the result of NPV is still not correct because of the wrong discount rate.

The discount rate should be an important factor in this case and it is difficult to determine the right discount rate. It is assumed that the discount rate is the same for all stages but actually different stages should have different rates. The reason is that high risks require high discount rate and low risks require low discount rate. It is not reasonable to use the same rate because different levels of risks exist in different stages of the project. Another reason is this method is lack of considering changes in the project's own riskiness over time. Managers pay more attention on the risks which have great impact on the entire project but ignore those risks that are associated to the project. Therefore, if the project takes a wrong risk-adjusted discount rate, the calculation will be in a wrong direction.

On the other hand, even the net present value is positive, it is not necessary to run the entire project forever. Actually, there is an option that stops the project for a while and waits and sees how is the market will be if supply exceeds demand and gas price is low. If the price goes up again, this company could start to run the project again and invest more. Otherwise, he could shut down the processing plant and sell this project to other petroleum companies if possible and he could also get money from selling this project. Although the result is negative in this case, it does not mean that it is not feasible to invest in this project. Considering the flexibility to abandon to the project in this case, what if its salvage value at any time exceeds the present value of expected subsequent cash flows, including the

abandon value at the end of fifth year (Trigeorgis Lenos, 1996). Taking this condition into account, the initially undesirable project seems become acceptable. The above discussion shows that the traditional NPV rules kill the flexibility option such as waiting one year or abandon the project before the end of useful life time. Of course, there are situations in which this company cannot wait or wait for a long time to invest because his competitor may enter this market and invest first. To delay with less time and the cost for delaying will affect the investment decision (Pindyck Pobert S., 1991). In the next section we will explore this point into detail with general model. The opportunity cost will be defined in which is worth to invest next year rather than invest right now or never.

2.2 Financial Option

As we described in the previous section, the traditional net present value method is lack of flexibility in the investment's decisions. Financial options have already been used in many different industries for a long time. Using this method in petroleum industry could give mangers a new way of minimizing the total investment cost and maximizing the profit during the decision making processes. According to Mustafa Mesut Kayali (2006), the financial option whether it is a call or put gives his owner the right, but not the obligation, to buy or sell the underlying asset at a pre-determined price on or before the given date.

The special vocabulary associated with options is described as follows:

- Exercising the option: The action of buying or selling the underlying asset through option contract is called exercising option. The option owner will exercise the option only when he can get more payoff than he had before. Otherwise, the option will not be exercised and will be expired at a given date.

- Striking or exercise price: It is a fixed price in the option contract that the option owner could buy or sell the underlying asset.

- Expiration date: It is a specified date that the option owner has to exercise the option, otherwise the option is dead. An American option can be exercised at any time up to and including the expiration date while a European option only can be exercised on that expiration date.

- Call option: An option that the option owner has the right to buy an underlying asset over a certain period.

- Put option: An option that the option owner has the right to sell the underlying asset (Ali Akgunduz, Banu Turkmen, and Akif A. Bulgak, 2007).

It is easy to notice that the option owner is not obligated to exercise the option unless the result is better than expected. When the outcome is positive which means the price of underlying asset is higher than exercise price, he may choose to exercise the option in this case. The owner's wealth is increasing with the increasing price. On the contrary, the

option contract as insurance when the negative outcome happens. The option owner decides not to exercise the option but the total loss of him is always limited which is the premium paid to buy an option. Hence, this option gives investors flexibility to manage their wealth. According to the obtained information, they could choose whether to exercise the option (Mustafa Mesut Kayali, 2006)**.**

The underlying asset could be one of a large variety of financial or real assets. In the airline industry, the underlying asset to an option could be the airline tickets. In the stock market, the underlying asset to an option might be the stock price. The following example in stock market is base on the Trigeorgis Lenos (1996). Suppose the exercise price (E) of one stock is $55 and it will be expired tomorrow. The current price of stock is selling for $S=\$49\frac{1}{8}$ and the option owner would not want to exercise the option immediately because it is lower than the exercise price and he may get less asset than he has before. There is a possibility that the stock price either increases to $S^+=\$60$ on the expired date or falls down to $S^-=\$40$. The option contract would be expired ($C^-=0$) when it falls down to $40. On the contrary, if the stock price increases to 60 dollars, the value of a call option would be positive that is a balance between the exercise price and the price of the stock.

The value should be $C^+=S^+-E=60-55=\$5$. This means that the value of the option is $5 for one stock and may become more valuable when the price of stock moves up to $70 or down to $35. As the price becomes $70 or $35, the positive value is $C^+=S^+-E=70-55=\$15$ while the C^- is always 0 and the total loss of the owner is always limited to the premium that the owner has paid to buy the option.

Call option

S⁺ 60   C⁺ = 5 (more valuable on the upside)

S

S⁻ 40   C⁻ = 0 (expire worthless)

E=55

Put option

S⁺ 60   C⁺ = 0 (expire worthless)

S

E=45   S⁻ 40   C⁻ = 5 (more valuable on the downside)
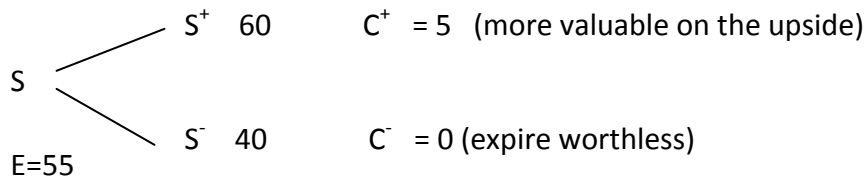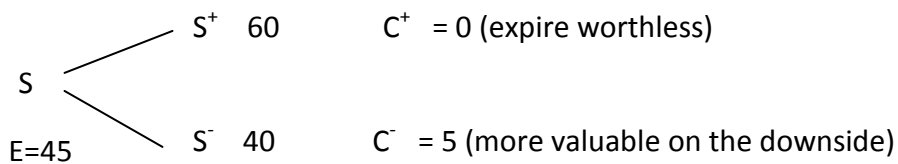
Figure 2.5: Call option and put option

Put option is different from call option. It is similar to insurance which only increases owner's asset by falling down the price of stock. Figure 2.5 shows the difference between call option and put option. In put option, suppose the exercise price is 45 dollars, then the option would be expired worthless in case of price of stock is $ 60. However, the positive payoff on the downside will increase since the price of stock falls down below the exercise. In other words, the value of the put option will be 5 dollars (C^-=E- S^-= 45-40= $ 5). If the price of the stock falls to $30, then the value of the put option will increase to $15.

The opportunity of investment in petroleum industry is similar to a call option on a common stock. It gives the managers right which they need not exercise to make an investment and receive the cash flow which fluctuates stochastically (Pindyck Robert S., 1991). For example, a petroleum company has an option to build up a processing plant and the price is shown in the following figure.
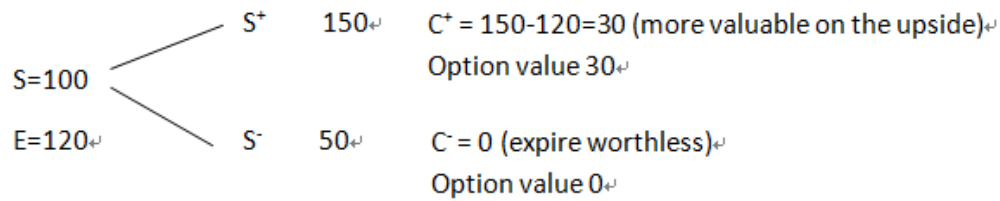
Figure 2.6: An option to build up a process plant in petroleum industry

The current gas price is $100 and has the possibility to go up and down in the future. If the gas price rises to $150, this company will exercise the option by paying certain money to invest. If the gas price falls to $50, this company will not exercise the option. Suppose the exercise price here is $120, the maximum value of this option over the period would be $C^+=$max $(S^+-E, 0) =30$ while $C^-=$max $(S^+-E, 0) =0$. The problem here is what this company should be willing to pay today to have the option to invest in building up a new processing plant. In the previous section, we use the traditional NPV method to calculate value and the result is not correctly actually. It will be helpful to recalculate this value using standard option pricing method which is Black-Schole's model. This model is a mathematical description of financial area and is widely applied to the valuation of investment projects, considering these investment projects as options on a firm's assets or growth opportunities with an exercise price equal to the initial investment cost (Mustafa Mesut Kayali, 2006). We will use such methods to analyze investment problems of gas pipeline infrastructure development later on.

2.3 The Real Option Theory

The traditional net present value method often undervalues investment opportunities which may result in a few companies lose competitive power in their market. One of the reasons is that these companies ignore the flexibility of investments. The concept of "Real option" was developed by the model of financial options by Fischer Black and Myron Scholes and it was modified by Robert Merton. Subsequently, it was defined by Stewart Myers in 1977, who applied the principles and methodology of option pricing theory for real investment decisions such as the markets of services and products. NPV as a traditional investment decision tool, by contrast with the real option theory, NPV cannot explain that market exist high level of uncertainty, but ROT (Real Option Theory) remedy this limitation. In terms of Avinash K. Dixit, Robert S. Pindyck (1994), "*the net present value rule is easy, but it makes the false assumption that the investment is either reversible or that it cannot be delayed*". Tom Copeland and Vladimir Antikarov (2003) defined the definition of a real option that it is the right, but not the obligation, to take an action.

The real option theory is implemented in many industries, and it is widely used as a decision tool in many investments. Compare with financial option, real options relevant six levers, which are expected present value of cash flows from investment, exercise price, time to expiry, uncertainty of expected cash flows, risk-free interest rate and value lost over duration of option. Figure 2.7 is mainly based on Keith J.Leslie and Max P.Michaels (1997 pg.9). It illustrates six levers of real options and the strategic value of real options.
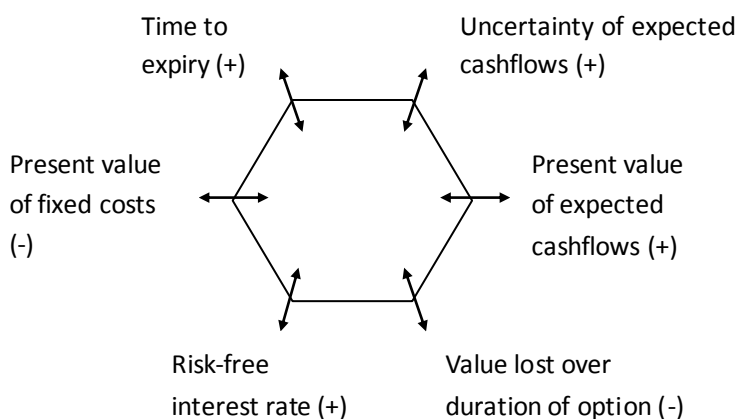
Figure 2.7: The six levers of real options (Keith J.Leslie and Max P.Michaels, 1997 pg.9)

According to Figure 2.7, the "+" or "-" in the () show that extend the option's duration, increase uncertainty of expected cash flows, present value of expected cash flows, monitor the impact of changes in the risk-free interest rate and reduce present value of fixed costs, value lost by waiting to exercise. A company makes a decision by pulling the levers that control its value.

The advantage of real option is that the company has right to realize future payoffs in return for further fixed investments, but without imposing any obligation to invest. Gassco project is also concerning about whether the gas company investment new fields and new infrastructures or not. The gas companies such as Shell, Statoil could buy a real option which is they will have the right to realize payoffs at any time over the next few years by making further fixed investments, but with no obligation to develop the block.

2.3.1 The Real Option Process

The real option assumes the industry faces a high uncertainty marketing which means high risks. Johnathan Mun (2006) referred eight simple steps can be segregated in the real options process, which includes qualitative management screening, time-series and regression forecasting, base case net present value analysis, Monte Carlo simulation, real options problem framing, real options modelling and analysis, portfolio and resource optimization and reporting and update analysis. Figure 2.8 illustrates these eight steps of real option processes, concerning how to deal with risks. Meanwhile, these processes will be explained as follows.

The qualitative management screening as the first step of process play the role of risk identification. Based on company's goal, competitive advantage, weakness and business strategy, the management evaluates strategies and the list of projects also through qualitative screening. Time-series as a forecasting function in the process, based on project cases, apply time-series and regression analysis, using historical data to predict future risks. Subsequently, implement traditional models such as net present value (NPV), discount cash flow model to evaluate project. NPV can calculate future costs, revenues and evaluate the feasibility of project.

The above three steps are mainly about traditional analysis and the fourth step is risk analysis step by using dynamic Monte Carlo simulation. The outcome data of traditional model is as inputs data into the real options analysis. The critical advantage of Monte Carlo simulation is correlated, the data is acquired from traditional analysis will be correlated by Monte Carlo, which could improve the accuracy of these data. The result of simulation is a distribution of the net present values. The real option framing is the next step. In order to mitigate risks, the managers could choose options including expand, contract, abandon, switch and restart based on the different strategies in different stages. The company has the right to implement this simulation to optimize his options. If the company has more than one project, the portfolio optimization will make asset allocation more efficiency. The final step is to report and update these analyses which could help the management make decisions to control risks.
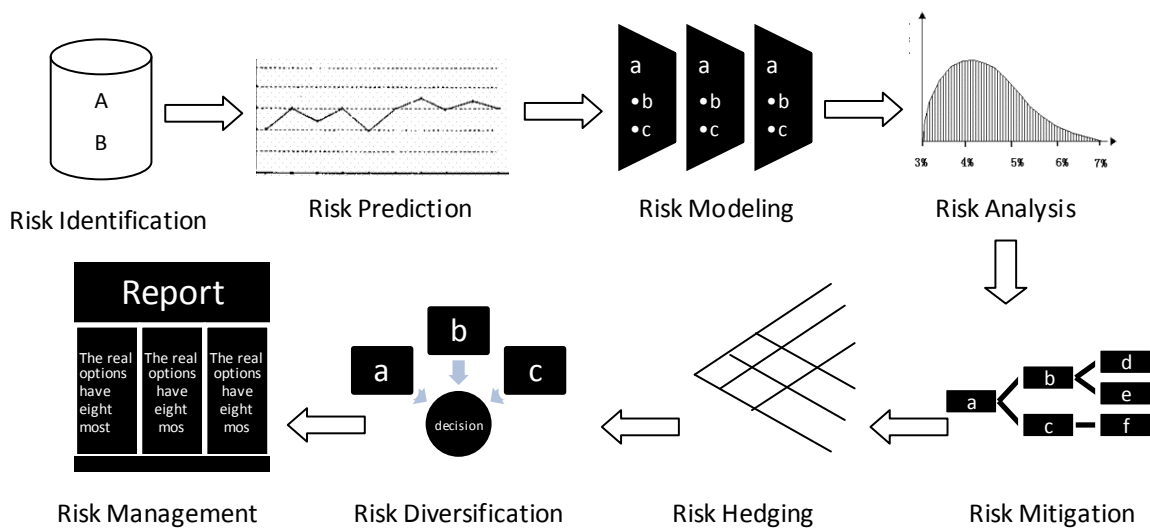
Figure 2.8: Eight Steps of the Real Option Process (Johnathan , 2006)

2.3.2 Real Option Models

The real options have eight most indigenous to the petroleum sector, including the options to defer, default, expand, contract, shut down and restart, abandon for salvage value, switch use and corporate growth options. Brennan and Trigeorgis (2000) give an example about flexible management in a large company by using real option analysis. We assume that the company has one-year license to extract oil and refinery operation. The expense

include I_1, I_2, I_3, I_C, I_E in a year (T_1=1). Figure 2.9 presents the critical options in the project which is based on Brennan and Trigeorgis (2000) pg.9-14.
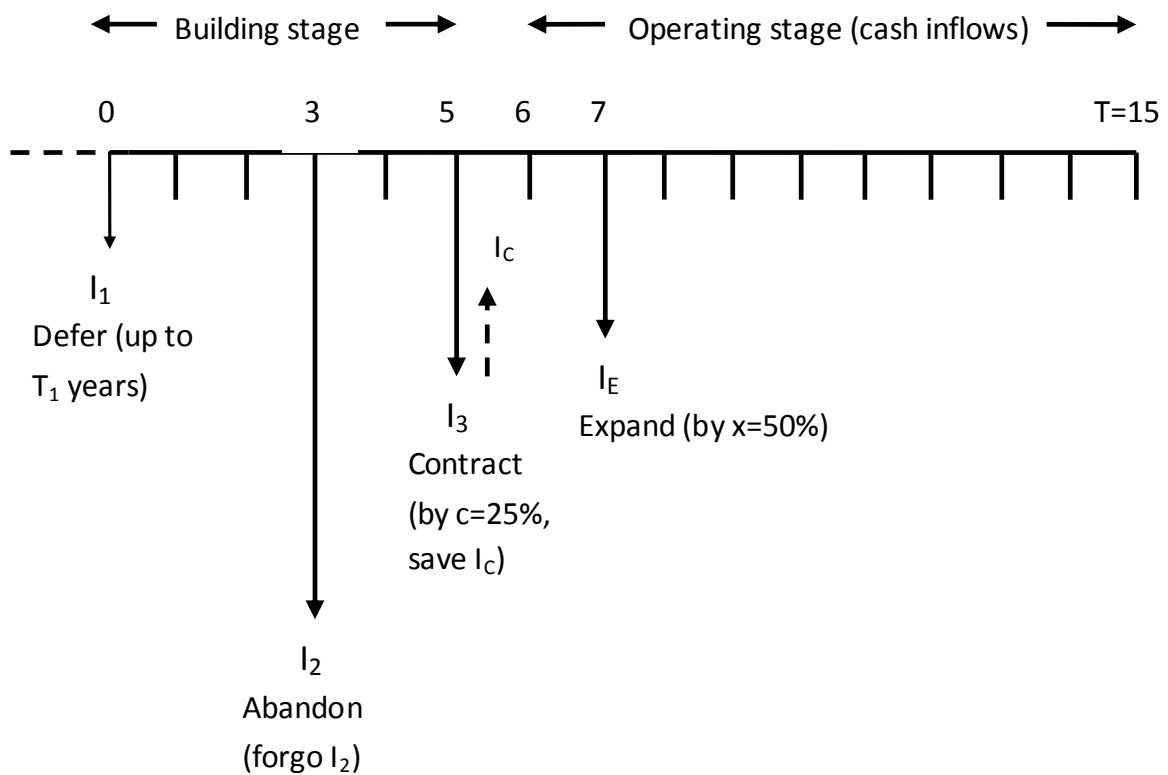
Figure 2.9: *"a generic project requiring a series of outlays (vertical arrows, I's), allowing management the flexibility (collection of real options) to defer, to abandon, to contract or expand investment, and to switch use."* **(Brennan and Trigeorgis, 2000)**

T_1=1 Suppose the oil company has a one-year lease to start drilling on undeveloped land with potential oil reserves for up to a year

I_1= Certain Exploration Costs

I_2= Expense for the construction of a new processing facility

I_3= Last expense

I_C= saving a portion (c %) of I_3 if market is weak

I_E= the rate of production increase x % if the oil price is higher than expected

Subsequently, in terms of Brennan and Trigeorgis (2000) and the table 2.1 common real options in pp.3, the identification of real options is presented.

The following table may describe all the types of real options briefly and the details would be analyzed subsequently.

Table 2.1: Types of Real Options (Lenos Trigeorgis, 1993)

Category	Description	Important in
Option to defer	Management holds a lease on (or an option to buy) valuable land or resources. The management can wait (x years) to see if output prices justify constructing a building or plant	All natural resource extraction industries, real estate development, farming industry and paper manufacturing industry.
Option to default	A generic project with a series of outlays which consists of building stage and operating stage. Each stage could be considered as an option on the value of subsequent stages. In addition, these options could also be valued as a compound option.	All R&D intensive industries, especially in medicine industry and long-term development projects(e.g., large-scale construction projects)
Scaling Option (e.g., to expand, to contract, to shut down or restart)	If the market condition is better than expected, the management could expand the scale of production or accelerate resource utilization. On the other hand, if the market condition is worse than expected, the management could reduce the scale of operations. If the market is even worse and there is no possibility to earn profits of this project, the management has the option to shut down the production and restart until the market condition is getting better.	Natural resource industries such as mine operations, facilities planning and construction in cyclical industries, fashion industry, consumer goods industry and commercial real estate.
Option to abandon	If market condition decline severely, management can abandon current operations forever and sell part of valuable equipments and other assets in second hand markets.	Capital intensive industries (e.g. railway industry and airline industry), financial services, new product introduction in uncertain markets.
Option to switch (e.g. outputs or inputs)	If prices or demand change, management can change the output mix of the facility (product flexibility). Alternatively, the same outputs can be produced using different types of inputs (process flexibility).	Output shifts: consumer electronics, toys, specialty paper and machine parts. Input shifts: oil electric power, chemicals, crop switching, sourcing.
Corporate Growth Option	Although the cash flow of early project is lower than expected, corporate growth options open up company's future growth opportunities (e.g., new product or process, oil reserves, access to new market and competition power)	All infrastructure-based or strategic industries, especially high-tech, R&D or manufacturing industry with multiple product applications (e.g. computers, medicines),multinational operations and strategic acquisitions

Option to Defer

Brennan and Trigeorgis (2000) describe option defer *"management holds a lease on (or an option to buy) valuable land or resources. It can wait x years to see if output prices justify constructing a building or a plant or developing a field."* Although the result of net present value is positive, sometimes the company may still have to wait and invest later. The reason is that there are high uncertainties of the project and the company may want to have more information and see whether he could get more pay off in the future. It is an important strategy to use option to defer in many industries, especially in natural-resource extraction (gas and oil companies) and real estate developments.

For instance, suppose an oil company has a one-year lease to start drilling on undeveloped land with potential oil reserves for up to a year. Based on uncertainty oil price, the management makes different decisions. When the oil price increases highly enough, the management will excise the option of extract oil, and the expense of investment is I_1. On the contrary, if the oil price decreases, the company will defer to invest and wait in order to save cost of planning (infrastructure costs). Brennan and Trigeorgis (2000) defined that the investment opportunity's value will be max (V- I_1, 0), V is the gross present value of the completed project's expected operating cash flows. When the gross present value (V) is much bigger than the expense of investment (I_1), the option will be implemented. In other words, this means the company gives up deferring (loss extra investment opportunity costs).

Option to Default

A generic project may require a series of outlays, which consists of building stage and operating stage. Suppose a company is in the operating stage and he still has a series investment. Since the oil price decreases, the managers in this company may have an opportunity to exercise an option to defer. Actually, Trigeorgis (1996) explains that each stage can be viewed as an option on the value of subsequent stages and valued as a compound option. The option matches to long-development capital intensive projects such as large scale construction or energy generating plants.

Option to Expand

Considering the situation of market, when it becomes better than expected, the management will exercise the option to expand because they want to get more profits. In addition, they could use this strategy to expand the scale of production or accelerate resource utilization. According to figure 2.9, the company may increase x % to the rate of production for enlarge the scale when the oil price is higher than expected. In this situation, the expense of extra investment here is I_E. Then the investment opportunity's value will change to $V + \max(xV-I_E, 0)$. This means that the basic value of project (building stage) is certain which is V and plus a call option of future investment. Under the circumstance, the management prefer to invest in expensive technology for expand flexible value of production. This strategy helps companies to find new market and increase their competition power in the future. The option is implemented in different industries, such as facilities planning, fashion apparel and consumer goods. Besides, even if the value of NPV is negative or closer to 0, it is still worth to considering the investment in the growth market.

Option to Contract

The strategy of option to contract is opposite from the strategy of option to expand. The analysis is still based on the figure 2.9. If the project is in the process of operating stage and the market condition is worse than expected, it is better for the management to exercise the option to contract. Since this company may not get expected profits under bad market condition, this option would help this company avoid losing more profits. In this situation, this company could contract c % of scale if the oil price is lower than expected, and cost saving of planning would be I_C. The value of this option will be $\max(I_C-cV, 0)$. The management minimizes cost in order to reduce risks in an uncertainty market.

Option to Shut Down and Restart Operations

When the market condition is even worse than expected and the company may not get any profit or already lose money in the market, the management could exercise the option to shut down. Management could shut down the project temporarily and restart the operations when the market condition is getting better. When the prices rise again and the net present value becomes positive, probably it is a good opportunity to restart this project again.

Suppose the cash revenue is C and the variable operating cost is I_V, then the option value here is max(C-I_V, 0). The above three options could be combined to one option, which could alter operating scale in the market.

Option to Abandon

There are lots of unexpected uncertainties such as unstable oil prices, technology revolution and poor management. A company could exercise the option to abandon when the market condition is far worse than expected and there is no possibility that it will become better in the project's life time. In other words, management may give up this project, while they could still get profits from selling facilities of this project in the second hand market. Since the management could not earn expected profits, shut down operations help them avoid future losing and exchange for the salvage value. Assume the current value of project is V and its salvage value is A, then the option value is V+ max (A-V, 0) or max (V, A). Figure 2.10 based on Han T.J. Smit, Lenos Trigeorgis (2004), represents the option to abandon production's capacity. The straight line represents the operating cash flows, and the shaded and blank areas reflect the abandonment option. The current expanded present value equals the sum of these components, captured by the curve.
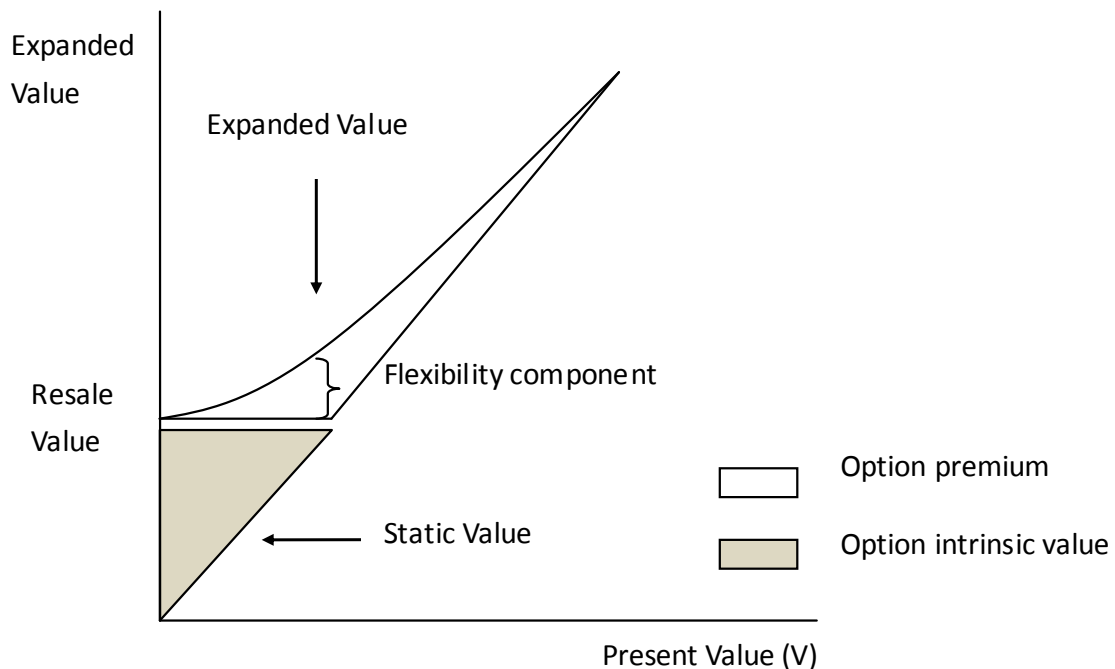
Figure 2.10: The option to abandon production capacity (Han T.J. Smit, Lenos Trigeorgis, 2004)

Generally, more general-purpose capital assets would have a higher salvage. This option may lead to lose technologies, organizational capabilities and block future development. Option to abandon usually is implemented in the capital-intensive industries such as airlines and railroads, financial services, new product introductions in uncertain markets.

Option to Switch Use

If prices or demand change, management can change the output mix of the facility (product flexibility). Alternatively, the same outputs can be produced using different types of inputs (process flexibility). For instance, an oil factory may use alternative forms of energy such as fuel oil, gas or electricity to convert crude oil into a variety of products such as gasoline, lubricants or polyester. Brennan and Trigeorgis (2000) demonstrate that it is flexible to switch from the current input to the cheapest future input, or from the current output to the most profitable future product mix. The outputs shifts include consumer electronics, toys, specialty paper and machine parts. The inputs shifts include electric power, chemicals and sourcing.

Corporate Growth Options

From the strategy point of view, although, the cash flow of early project is lower than expected, corporate growth options open up company's future growth opportunities (e.g.new product or process, oil reserves, access to new market and competition power). That means there is an opportunity for a company to get more profits in the future market even the cash flow is lower than expected. In addition, although the NPV of project is negative, in terms of the experience in the first stage product, it is still worth to invest in the project. A few early investments such as undeveloped land, oil reserves are a link in a chain of interrelated projects. The option is appropriate for all infrastructure-based or strategic industries (high technology solutions, multinational operations and strategic acquisitions). Brennan and Trigeorgis (2000) indicate corporate real option could be achieved at various stages during the value chain.

2.3.3 Framework of Real Options Valuation

According to M. Armstronga, A. Galli and W. Bailey et al. (2004), real options are a way of helping to make investment decisions when it is subject to high uncertainty such as oil and gas fields. Applying real options method in petroleum industry, the managers can actively manage the risks and uncertainties much easier than before. Although this is true, before using real options to evaluate the project, managers still need to know why do they prefer to use real options than traditional NPV method and check what kind of advantages would they get through this method. Figure 2.11 shows the framework of real options method which includes five major steps.

- *Step 1:* the first step is to find out the most important uncertainties and risks of this project. The uncertainties are usually about market demand, gas price and economic conditions and so on.

- *Step 2:* try to recognize the approximate probability distribution of each uncertainty. The risk neutral probability of gas price should be determined. What's the probability of the stable gas price, lower gas price and higher gas price? In addition, the risk neutral probability of cost should also be determined.
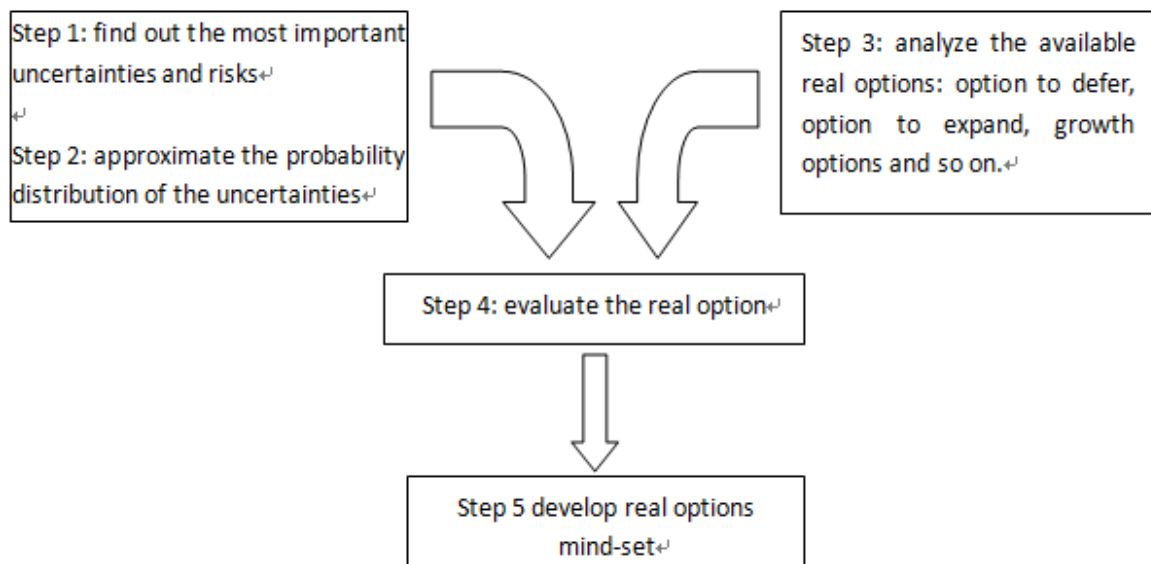
Figure 2.11: Framework of real options method (Tao Wang, 2003)

- *Step 3:* identify the available real options to the project. As mentioned before, there are several types of real options. In this step, management should consider the most valuable option for the project.

- *Step 4:* Based on Scott Mathews (2009), an estimation of the real option value can be expressed in the following formula: *Real option value= + NPV Risk Adjusted Probability*(Operating Profits-Launch Costs).* There are two major methods which are Black-Scholes formula and binomial model to evaluate the real options. If the real option value is positive, the project is feasible but it's not necessary to invest immediately. The opportunity of investing is related to the future project development.

- *Step 5:* The final step is to determine the best strategy for the project by comparing the value of options and cost options. The calculation is based on many approximations and assumptions and sometimes it is not easy to get enough data to do the calculation. It is necessary to notice the false precision of the real option value.

2.3.4 Application of Real Option valuation

In this sector, we present examples to explain how the real options implement in the investment projects and how to help managers make right decisions. The following example is based on Han T.J Smit and Lenos Trigeorgis (2004). It is a classic example of real option which is valuing a research and development (R & D) program. Managers in that company have to decide whether to invest in this program, using real option theory. This program is described in details as follows.

R & D program

The R&D program involves two stages investment which are R&D and commercial projects. As can be seen from figure 2.12, the first capital outlay is $15 million in current year and there is $50 million at the end of year one. In addition, there is another investment which is $1200 million ($I_2$) at the end of year two. This company will get pay off from year three to year six and the expected cash flows of four years are CF_3=$200 million,

CF$_4$=$500 million, CF$_5$=$700 million, CF$_6$=$200 million respectively. Compare outlays with potential revenues, it seems that this company has a low return on investment. However, developing new technology may open up the company's future growth opportunities and enhance its competition power in the market.
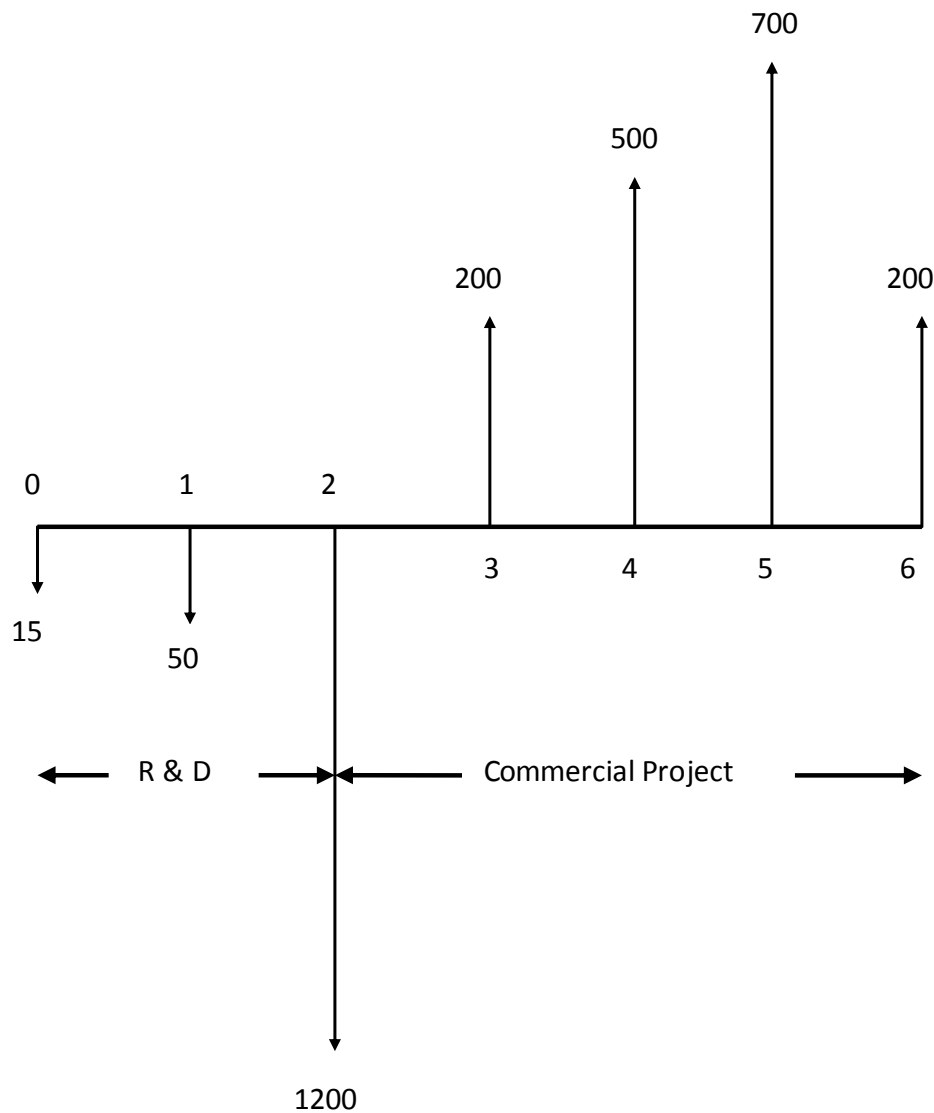
Figure 2.12: The outlays and expected cash flows of R&D project

If we assume that the company decides to invest in two stages, at the beginning of project, the value is V$_2$=$1127 million (discount rate k=15%), we get NPV=$1127 million - $1200 million =-$73 million (t=2). The negative result shows that it is not worth to invest. Furthermore, we also calculate the present value when t=0, technology value= $852 (discount rate k=15%). Suppose the risk-free rate is 4%, the two stages present value equals $1109 million + $63million = $1172 million, and the NPV$_0$=$852 million -$1172

million =-$320 million. The result is even lower and this means it is not feasible to invest in the project.

Actually, this company does not have to invest in these two stages consequently. Considering real option method, this company has the right to invest in this project but that is not obligation to invest. The company could invest in the first stage and wait a few years and see whether to invest in the second stage. The problem of this company is how to make a decision after investing in the first stage. The value of this project has a possibility to go up and down, concerning the market condition. In this situation, the two factors are assumed to be 1.5 and 0.67 (u=1.5 or d=0.67). Therefore, the possible values of commercial project are shown as follows.
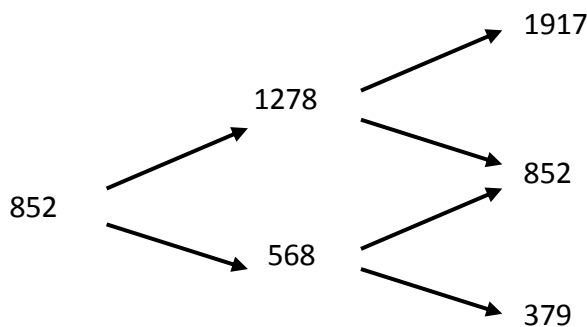
Figure 2.13: The value of commercial project

Subsequently, the management has an option to decide whether invest in commercial project (expand option) or not at the end of first stage (R&D stage). Assume the risk-neutral probabilities is p=0.45 and risk-free interest rate is 4% in this case. Using decision tree analysis, then we derive three situations based on three expected in figure 2.14.
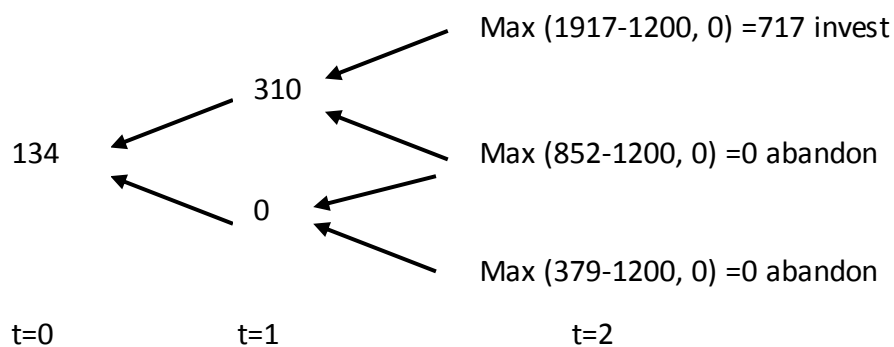
Figure 2.14: Net value of the option to invest in commercial project

Start from the end of year two, since the expected value $852 million and $379 million are lower than the investment cost $1200, the management should abandon investing in this project at the second stage. Another option is to invest in the second stage when the expected value is $1917 at the end of year two.

Step back to the end of first year (t=1), the present value is calculated as follows.

$\{0.45 \times (1917-1200) + 0.55 \times 0\} / (1+0.04) = 310$.

Step back to the current year, the value is calculate to $(0.45 \times 310 + 0.55 \times 0) / (1+0.04) = 134$.

Finally, the net present value at the current year is NPV= MAX (134-63, 0) =$71 million, the outlays of R&D stage is $63 million.

Despite of the negative NPV (-$320 million) in the first stage, it becomes positive by using real options. This example intends to present investment research and developing new technology, which benefit to the company, enhancing competition position.

Case in gas company----infrastructure dimensioning

Many petroleum companies spend a lot of money to get new technology, find new fields, build new infrastructure, and use an option to switch their mix of outputs. The management use real option to make capital and investment decisions. According to the Keith J. Leslie and Max P. Michaels (1997), the following case is presented that how to estimate values of project in petroleum industry and how to make right decisions based on these values.

Suppose a petroleum company buys a real option (license) which means he has the right exercise the option at any time over five years by making further investment, but no obligation to develop the block. The block will affect 25 million unit of gas, and the current price is $10. If this company plans to invest, the cost will be $300 million. Therefore, NPV=$25 million × $10 million- $300 million=-$50 million.

The result of net present value is negative by using simple method. This means it is not worth to invest in this project. However, the two important sources of uncertainty which are quantity and demand of the gas are ignored in this case. The part above, we have referred to the six levers of real options. Based on the price of a financial option estimated formula Black-Scholes, we calculate the real option value. Black-Scholes formula:

$$Se^{-\delta t} * \{N(d_1)\} - Xe^{-rt} * \{N(d_2)\}$$

S= stock price

X= exercise price

δ= the rate of dividends

r= risk-free rate

t= time to expiry

N (d) = cumulative normal distribution function

The model of financial options and real options, and the six levers of real options have already been noted before. Consequently, based on the Black-Scholes formula, the formula of real option value is defined in following.

ROV= $Ee^{-\lambda t} * \{N(d_1)\} - Fe^{-rt} * \{N(d_2)\}$

Where $d_1 = \{\ln(E/F) + (r - \lambda + \sigma^2/2)t\}/\sigma * \sqrt{t}$

$d_2 = d_1 - \sigma * \sqrt{t}$

E= Present value of expected cash flows

λ= the rate of lost over duration of options

F= Present value of fixed costs

r=risk-free interest rate

t=time to expiry

σ=uncertainty of expected cash flows

N (d) = cumulative normal distribution function

The uncertainties of quantity and demand of gas may result in a 30 percent standard deviation and the fixed cost every year is $7.5 million. Therefore, the rate of lost is 7.5/250=0.03. Besides, the risk-free interest rate is 5%.

According to the formula, real option value could be calculated as follows:

ROV (real option value) $= 250e^{-0.03*5} * \{0.58\} - 300e^{-0.05*5} * \{0.32\}$ =124-74=$50 million

Comparing to these two results, there is $100million difference. The result of real option value presents that the two sources of uncertainty will change the decision of company. Actually, in the gas dimension, if the company decides to invest in over capacity or pipeline infrastructure or develop a new hub, there are much sources of uncertainty in the late stage of investment, such as marketing environment, customers demand, the price of oil, nature environment, which is enough to make a company change decisions. For instance, in the case of Nyhamna, the Langeled pipeline takes the gas to the customers in UK. When the company decides and develops the double pipelines, which means the gas output increases, but the investment is more expensive. However, the gas company also can buy the license and they have no obligation to invest in the late stage of project, and they depend on the change to excise options. The real options provide a comprehensive valuation model for any strategic situation and uncertainty.

Part 3- Gas hub development

3.1 Basic Concept

3.1.1 The hub concept in the airline industry

It has been recognized that the structure of hub networks now plays an important role in different industries. The concept of a hub has been used widely in the airline industry. Compared with other transportation modes, freight transport becomes more efficient by increasing the uses of hubs. The concept of a hub in the airline industry is that an airport used by several airline companies serves as a transfer point to get passengers to their intended destinations. Giovanni Nero (1999) indicates that a hub system not only increases the production efficiency but also contributes to get significant customer loyalty advantages through frequent flyer programs and non-stop services. The objective of airline operators is to maximize their profits by adopting the hub system.

There is a possibility to expand the size of a hub system through mergers and alliances. From a cost point of view, there are two main advantages. The first advantage is less fixed cost or sunk cost with a new station. Second, the traffic density is much higher which results in higher load factor in different markets. Neil Bania et al. (1998) note that a hub system is a dominant strategy under oligopoly market and could deter entry by other airlines. For instance, some airline companies deter entry even though they are not strong enough to occupy the whole market. A good strategy in this case is to cooperate with some companies to operate all the routes together and deter entry by other companies. Consequently, they would have a cost advantage for operating these flight routes. The unit cost of transporting a passenger or operating a flight on a specific market will be reduced. Moreover, the expansion of a hub network system would have impacted on flight routes in other market. To some extent, using a large multi-hub route network will become a competitive strategy in the airline industry (Giovanni Nero, 1999).

3.1.2 The hub concept in the petroleum industry

Similarly, the concept of a hub in petroleum industry is in the area with enough capacity to transport gas internationally through pipeline infrastructures and vessels. In order to understand the importance of pipeline transportation, it is necessary to understand the role of logistics in a hub system.

A hub system is a network in which gas can be transported to different places. This route system could be across countries and regions in a hub-to-hub progression. A hub is characterized by interconnections among many pipelines and other modes of transportation such as tankers and vessels. In addition, the substantial storage capacity of a hub should be taken into consideration. The availability of storage and different transportation modes in hubs may give them more opportunities to supply gas in the market (CJ Trench, 2001). A hub system could be onshore or offshore but should have enough capacity to allocate all the gas fields. Basically, a hub with large capacity would transport gas of large quantity, thus reducing cost i.e. economics of scale.

Åsgard was developed as a hub when pipelines from more than one gas field were tied into that area. The pipeline carries rich gas from the Åsgard field in the Norwegian Sea to a processing plant (Kåstø). Dry gas is separated from the wet part and transported to other regions through pipelines. The wet part of the gas could be transported by vessels. Similarly, the Kollsnes processing plant is developed as a hub which is located in the west of Bergen. It receives gas from the Troll, Kvitebjørn and Visund fields in the North Sea and separates gas into dry gas, natural gas liquid and condensate. After compression, the dry gas is delivered through pipes to Europe, while the remains go to the process plant at Mongstad.

As noted above, hub systems play an important role in the gas market's efficiency because it offers ability to respond to changes in supply and demand. Therefore, the balance between supply and demand in a hub is the key point to determining price levels in the surrounding regions. The gas price could be influenced by quantity and quality of products and the alternative source of supply. It is easy to notice that any regional supply or demand imbalance would be quickly reflected in prices at the region's hub. Moreover, the capacity of storage and supply options in a hub would become the price signals in the market. All

players in that market would take this as an advantage and balance their supply/demand ratios (CJ Trench, 2001).

There are proposals suggesting the construction of a new hub or possible extension to the existing hubs. The decision to either invests in a new hub or not is based on the cost involved. Considering cost, the expansion of some facilities in existing hubs may have cost advantages than investing a new hub. It is important to consider the overall costs of gas transmission including capital, maintenance and operating costs in the hub. To achieve the most cost efficient way of pipeline infrastructure, two factors should be taken into account based on the cost function in the petroleum industry; large fixed cost and the cost of operating and maintenance. The combination of different elements of cost should be considered in order to minimize the total cost of the project in the long run (Rjgoberto Ariel Yepez, 2008).

3.1.3 Cost analysis

The cost analysis is used for understanding what size of a hub network would provide a cost advantage. With the growth of gas market, more and more natural gas has been traded within Europe as well as North America through pipelines. However, the Asia market is still dominated by LNG (Liquefied Natural Gas) transport. The increasing trade of gas in the world market reflects that gas resources to a larger extent are located too far away from the main consuming regions. This may result in the increasing demand of LNG (Liquefied Natural Gas). For instance, the annual consumption in North America is almost 30 times as in Middle East (Knut Einar Rosendahl, Eirik Lund Sagen, 2009). Therefore, the transportation cost of LNG becomes an important factor in the growing global natural gas markets. On the other hand, gas could be transported in different ways. Pipeline transportation is another popular approach of gas transportation in European market. A lot of researches in the petroleum industry are particularly focused on the economic aspects. This indicates that pipeline transportation of gas is characterized by economies of scale and large sunk costs (Rjgoberto Ariel Yepez, 2008).

The most important elements for LNG (Liquefied Natural Gas) transportation are liquefaction and shipping costs. Shipping cost is mainly depending on distance. The unit cost of LNG shipping was reduced by 40 percent during the last decades. The reason is that LNG goes by higher volume tankers and the cost of building up ships gets lower. Due to the technology development, offshore pipeline infrastructure cost was also reduced in the 1990s. However, onshore pipeline cost was increased because of higher labour cost. (Knut Einar Rosendahl, Eirik Lund Sagen, 2009). The cost of gas pipeline transportation could be reduced by increasing the scale of pipes, depending on the maximum diameter available. Hence, it is important to decide the width of pipelines. Furthermore, the line cost and compressor station cost should also be considered in the gas pipeline transportation. These costs depend on the diameter and the horsepower capacity, respectively. (Rjgoberto Ariel Yepez, 2008).

3.2 Processing facilities

The major processing facilities in the Norwegian Sea include Tjeldbergodden, Mongstad, Sture, Kollsnes and Kårstø. In general, different facilities have different functions in the integrated gas infrastructure system. Beside these facilities in the Norwegian Sea, there are also important assisting infrastructures in Europe. These connect Norway to other European countries, transporting gas from Norway to the customers.

Table 3.1: The major processing facilities in the Norwegian Sea (Gassco[3], Gassco[4])

Processing facilities	Location	System	Capacity	Operater
Mongstad	Lindås and Austrheim in Hordaland	Oil refinery	10 mill tonns/year	StatoilHydro
Kollsnes	Oøy in Øygarden	Kvitebjørn gas export	26.5 mill	Gassco
		Troll Gassrør	No date	StatoilHydro
		Zeepipe IIA	72 mill	Gassco
		Zeepipe IIB	71.0 mill	Gassco
Sture	North-west of Bergen	Plant for recovering and fractionation	No date	StatoilHydro
Kårstø	Tysvær in Rogaland	Åsgard transport	70.4 mill	Gassco
		Statpipe	105 mill	Gassco
		Europipe II	64.8 mill	Gassco
Tjeldbergodden	Aure in Møre og Romsdal	Haltenpipe	7.0 mill	Gassco

Table 3.1 gives about the basic information of major processing facilities in the Norwegian Sea. The connections among them are presented as follows. The shaded area in table 3.1 shows the existing hubs and we are going analyze how they become a hub and what necessary conditions are required for them to be a hub.

Tjeldbergodden

Information from Gassco website indicates that the Tjeldbergodden complex receives gas from the Heidrun gas field in the Norwegian Sea. The gas is transported to the process plant through Haltenpipe pipeline system, with 250 kilometres long (Source:Haltenpipe Pipeline). With an internal diameter of 16 inches, it became operational in December 1996.

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Mongstad and Sture

Mongstad and Strure complex are both located in the Hordaland. Mongstad is in the north of Bergen and the other is in the west of Bergen. The complex receives oil from pipelines from North Sea fields. Sture fractionation plant produces LPG (Liquefied Petroleum Gas) mix for export by ship or delivery to Vestprosess at Mongstad by pipeline. Mongstad and Sture complex support Kollsnes to be a hub, because they have different functions of dealing with gas in the fields of Hordaland.

Kollsnes

The processing facilities at Kollsnes separate natural gas liquids (NGL) from condensate. Dry gas is compressed into pipelines and transported to the customers. The major infrastructures in this field include Kvitebjørn Gas Export, Troll Gassrør, Zeepipe IIA and Zeepipe IIB. Kollsnes complex receive gas from Troll, Kvitebjørn and Visund in the North Sea.

Gas is piped through Europe while the NGL (natural gas liquid)/ condensate travel to the process plant at Mongstad. Kollsnes is not only connected to the plant at Mongstad, but also connected to four other pipeline systems: Kvitebjørn gas export, Troll Gassrør, Zeepipe II A and Zeepipe II B.

Although, location and processing facilities linked to Kollsnes are two critical factors which make Kollsnes develop as a hub. The capacity at Kollsnes is also an important factor. The daily processing capacity at Kollsnes is up to 143 million scm of gas and 69 000 barrels of NGL (natural gas liquid).

Kårstø

The Kårstø processing facilities is operated by Gassco and its technical service provider is StatoilHydro. Compare with Kollsnes, there are several advantages at Kårstø for gas transportation system.

Firstly, Kårstø is located in the north of Stavanger in Rogaland, which is one of the largest world suppliers of liquefied petroleum gases (propane and butanes). This LPG (liquefied Petroleum Gas) is transported to customers internationally. The major processing facilities at Kårstø include Åsgard Transport lines, Statpipe and Europe II. Kårstø receives NGL

(natural gas liquid) from North Sea such as Åsgard, Mikkel and Sleipner. In addition, dry gas is piped into pipelines, while natural gas liquids and condensate are exported by ships.

Secondly, the capacity is another advantage at Kårstø. There were 638 ships to load LPG naphtha and stabilised condensate in 2006. About four million tonnes of stabilized condensate are exported from Kårstø each year and the ethane production is 950,000 tonnes annually. Furthermore, dry gas is exported via Europe II to Dornum in Germany and via Statpipe and Norpipe to Emden.
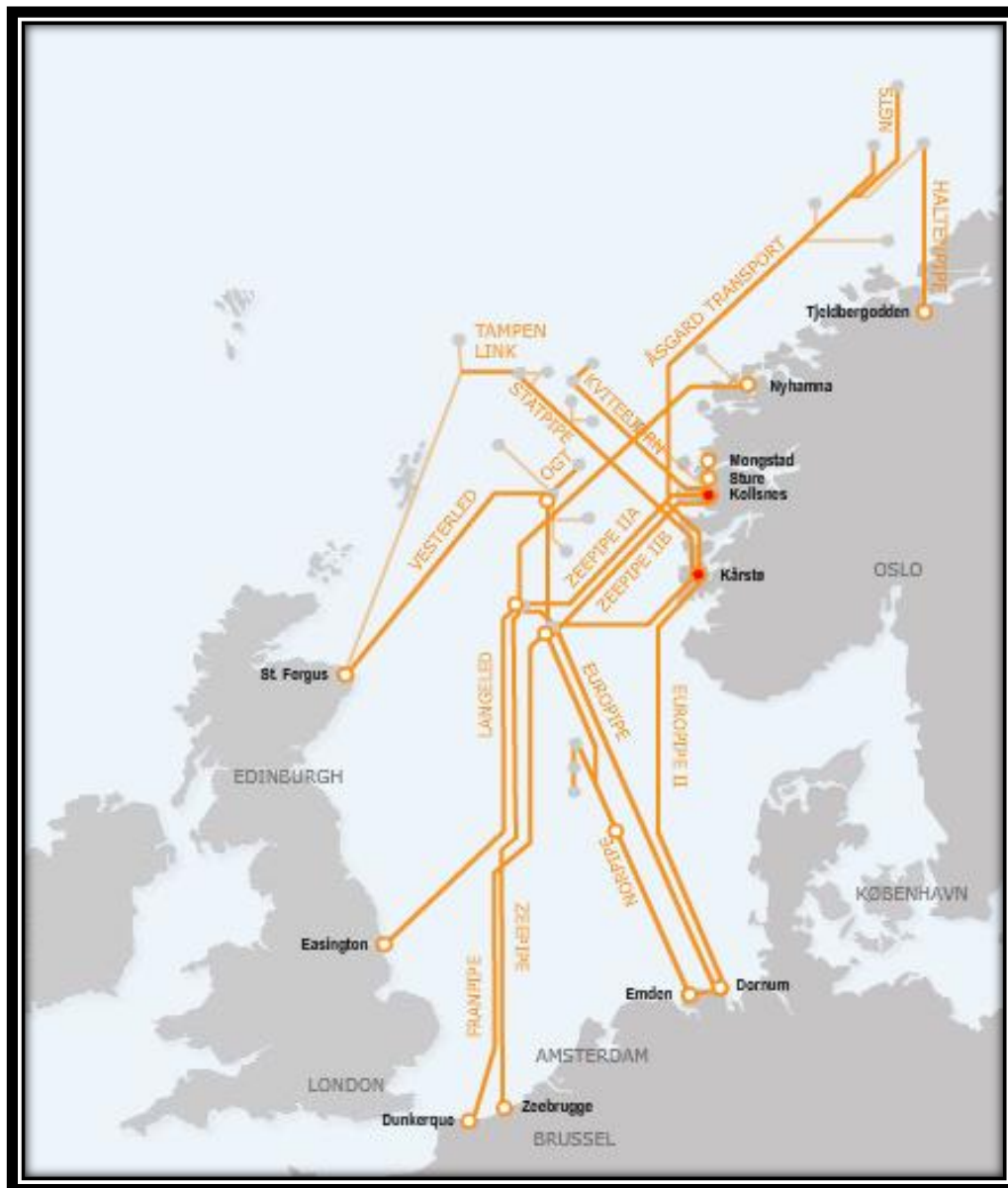

Figure 3.1: The integrated gas transport system (Gassco[5])

Figure 3.1 represents the gas transport system from the Norwegian continental shelf to continental Europe and United Kingdom. It consists of pipelines, processing facilities, platforms and receiving terminals. The figure also shows that Kårstø and Kollsnes have more than three pipeline routes system. In other words, they connect Norwegian gas transportation systems to European countries. Table 3.2 presents major receiving terminals operated by Gassco in continental Europe, including Dornum (ERF: European receiving facilities), Emden (EMS: Europipe Metering Station), Zeebrugge, Dunkerque, Easington and St.Fergus in Germany, Belgium, France, UK and Scotland respectively.

Table 3.2: The major receiving facilities link to continental Europe (Gassco[6], Gassco[4])

Processing facilities	Location	System	Capacity	Operater
Dornum (ERF)	Germany	Europipe II	64.8 mill	Gassco
		Europipe	45.4 mill	Gassco
Emden	Germany	EMS	57.0 mill	Gassco
		Norpipe	44.4 mill	Gassco
Zeebrugge	Belgium	Zeepipe	41.9 mill	Gassco
Dunkerque	France	Franpipe	53.7 mill	Gassco
Easington	England	Langled	69.4 mill	Gassco
St.Fergus	Scotland	Vesterled	36.0 mill	Gassco
		Flags	71.0 mill	Shell

The major receiving terminals in continental Europe

Based on Table 3.2, there are five processing facilities in different locations. Most of these processing facilities are operated by Gassco, while St.Fergus is operated by Shell and Gassco together. It is also clear that the capacities of these processing facilities are different. The systems of Langeled and Flags have the largest capacities which are 64.9 million, 71.0 million respectively. Gas is transported by Europipe I and II to the European receiving facilities (Dornum) in Germany. After reducing pressure and raising the temperature, the gas is delivered to the terminal at Emden, which carries out quality and volume measurement of gas. The Norsea Gas Terminal receives gas from the Norpipe line with pressure and temperature adjustments before it enters a hydrogen sulphide treatment facility.

In Belgium, Zeepipe Terminal JV is used to receive gas from the Zeepipe line system. It removes possible liquid residues and solid particles before adjusting gas pressure and temperature. The terminal also remotely operates the Franpipe receiving terminal at Dunkerque in the Franpipe line.

The receiving terminal at Easington is the landfall for the Langeled pipeline. Gas is adjusted to the right pressure and right temperature before being transferred to the transport operator downstream. In Scotland, the receiving terminal at St Fergus north of Aberdeen receives lean gas from Norway's Vesterled gas pipeline (from Heimdal field). Gas also reaches St Fergus via the Tampen Link line and Britain's Flags system.

3.3 Investing in a hub

The group of oil companies have to decide whether investing Nyhamna to be a potential hub or not by taking the most cost efficient way. The decision mainly depends on the location, capacity and demand of pipeline infrastructure system.

Nyhamna is a located in the Northeast of the island of Akura. It is a process plant which receives gas from Ormen Lange. It is possible that the gas demand will be high during the initial two years at Nyhamna and then the demand may be decreased. For example, if many customers are not satisfied with the quality of gas which received at Nyhamna, these customers may prefer to get gas from other processing plant such as Kårstø. In this situation, the gas demand at Nyhamna might be fallen to a low level. In addition, high initial demand might indicate the possibility of a sustained high-volume market in the petroleum industry. There is also a possibility that the demand is high but the oil companies do not want to invest in overcapacity in gas infrastructure system within the first two years. The reason is that they do not want to take extra. If these companies invest in overcapacity, they may consider when the extra capacity would be used and whether they could get more profits in the future. If these oil companies invest in the exactly capacity needed in the beginning, management may have the option to expand the capacity at the plant later, concerning the market condition. If there is a high possibility to find new gas fields and the market condition is better than expected, it could be a good solution to expand the plant. Otherwise, the petroleum companies may only maintain the operations at the plant.

If the production and transportation are uncertain in the future, management would be also uncertain what to do. With the limitation of current information, it is hard to make a decision that whether to invest in Nyhamna as a potential hub. With enough capacity and more gas fields landed to Nyhamna, the oil companies may get more pay off in the future. It could be a good chance of those companies to go into a new period of profitable growth.

We had an interview with Mr Ivar Helge Hollen on 22th Feb 2010. He is one of the leaders in Ormen Lange project and operation manager in Shell. Shell is one of the operators which own 17 percent in Ormen Lange project. The entire pipeline infrastructure system is owned by Gassco. The licenses for developing Ormen Lange are mainly shared by three

companies. Besides Shell, the other two companies are StatoilHydro and Petoro AS, with 32,595% and 32,954% separately.

With high market share, huge innovative capacity, one of the Shell's business strategies is to maximize profit in the downstream. Shell focuses on sales, marketing, and customer service in all markets. In addition, management do not want to invest in overcapacity and prefer to invest in exactly capacity needed because of the high initial cost and the high uncertainty in the future. The management of this company may also consider that how long they will get the pay off back. Besides, they may also consider the quality and size in the new gas fields before they start investing in that fields. For example, the quality of the gas might not be good if there is too much H_2S and CO_2. Although Mr. Ivar Helge Hollen prefers investing in exactly capacity needed, he has recognized that the expansion of capacity to meet high-volume demand would require more extra cost. More facilities should be modified in the later investment stages and this may result in less efficient operation.

In the following we are going to return to the problem facing oil companies such as Shell and see how management can proceed to solve it by using decision tree analysis. There are two new potential gas fields in Ormen Lange field which are Onyx and Luva. Statiol is developing at Luva and Shell is operating at Onyx. There is ongoing work on both of these two new gas fields. The distance and possible technology are the most important aspects in this case. It is necessary to consider that new gas fields should reach a processing facility at a relatively close distance. The point here is whether to land these two new gas fields to Nyhamna and make Nyhamna become a potential hub. If successful, this may give these oil companies a competitive edge. On the other hand, if they do not develop gas fields, their competitors may do this project and take their market shares.

3.3.1 Decision Tree for decision making

A good decision tree would help management to make decisions easily and clearly. Before drawing a decision tree, the management should follow the following four steps (John F. Magee, 1964):

- First, identify the points of decision and the alternative ways at each point. In the first step, the management are considering to invest in a new hub or develop a fixed place to be a hub.

- Second, identify the probability of uncertainties and the probability of alternative outcomes at each point. In this step, the management should estimate the probability of different outcomes. If the probability of finding a new gas field is very high, the companies may prefer to invest in over capacity. Otherwise, they may refuse to invest in over capacity in gas infrastructure.

- Third, estimate the cost of each action. Each action has different cost. The management have to estimate these cost and profit through different outcomes. If the companies decide to expand the capacity after the initial investment, they may invest with extra cost. Therefore, the management should estimate these extra costs and how long they might recover these extra costs.

- Finally, analyze these outcomes based on the cost and profits before choosing one outcome. There could be several good outcomes and it is difficult to decide the best, especially without real data. Even with the right cost, it does not mean that the result with the highest profit is the best choice in the long run.
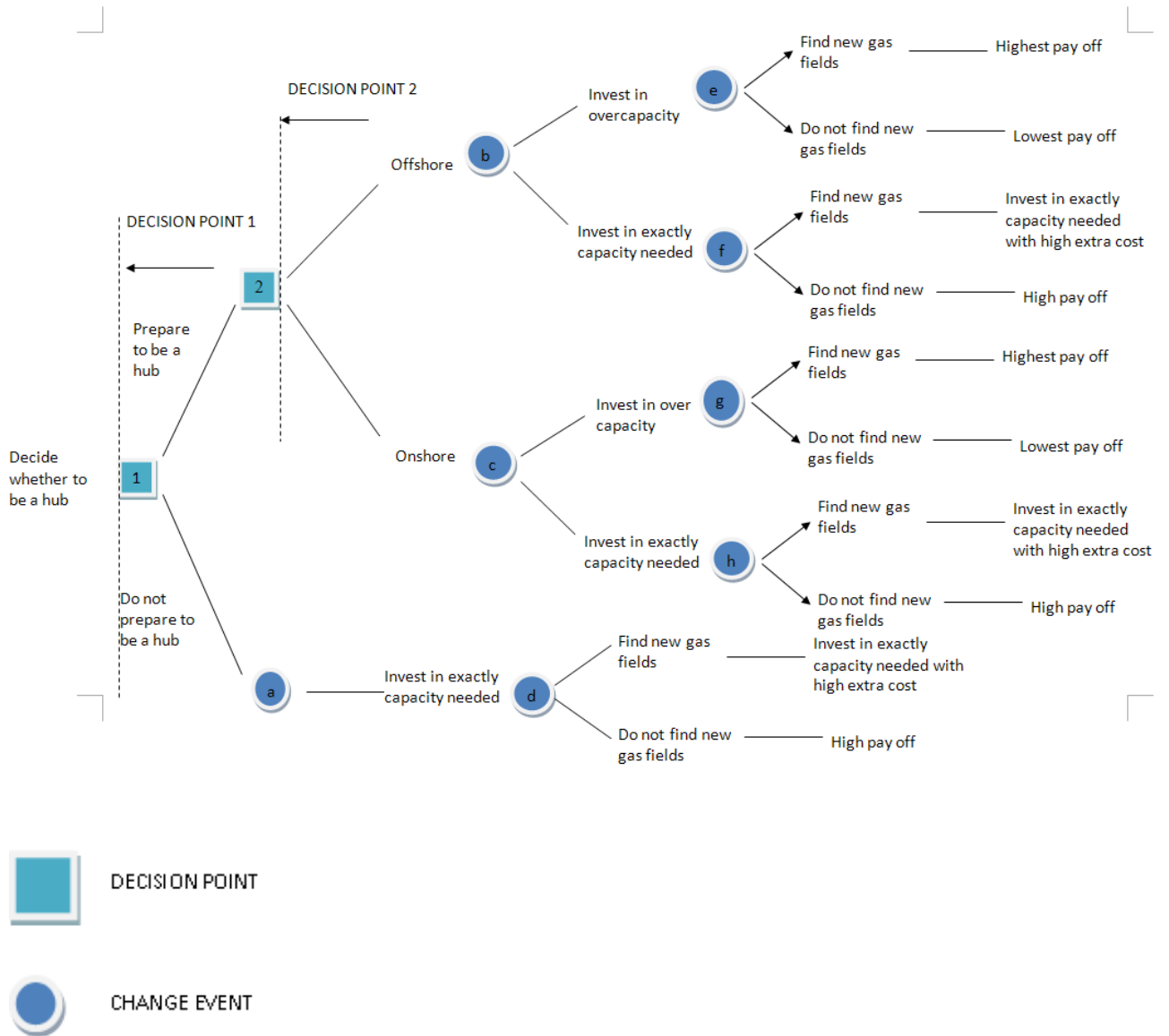
Figure 3.2 Event tree of preparing to be a hub

3.3.2 Choosing Course of Action

Description of decision tree

As it can be seen from Figure 3.2, it is a decision tree with many different actions in different periods. The objective is not to get the answer of whether to invest in Nyhamna as a potential hub, rather, it only helps management to understand which alternative at particular choice point would get the greatest payoff, under current information.

Before analyzing all the outcomes, we would like to describe this decision tree first. The initial decision is whether to invest in to be a hub which is shown at the left. Then the following decision moves to Point 1. If the management do want to invest in to be a hub, the decision moves to Point 2. Assuming that there is no important change in the situation between now and at the time of Point 2, management may decide what alternative outcome is the most important for the company at that moment. In the right side of the tree are all different outcomes of sequential decisions. These outcomes are based on the present information. If the company could get additional information with extra cost, the outcomes could be different. It is not necessary to identify all the events and put them into the decision tree.

In the following, we are going to analyze this decision tree by comparing the consequences of different courses of action. As noted above, the first decision is to decide whether to invest in to be a hub. If the management are prepared to invest in a hub, the second decision could be the location of this hub. They have to decide whether investing in an offshore hub or onshore hub. If the management decide to invest in an offshore hub (Point b), there will be two alternative ways. The decisions are moved on to whether investing overcapacity in gas infrastructure or exactly capacity needed at Point e and Point f. Start at Point e first, the management could get the highest payoff if they could find new gas fields. On the contrary, they could get the lowest payoff if they could not find new gas fields. To make it clearly, the decision processes here are "Point 1-Point 2-Point b-Point e".

Another alternative way is "Point 1-Point 2-Point b-Point f". The first three decisions are the same as above and the last decision is that the management may decide to invest in exactly capacity needed at Point f. The consequences could also be whether to find new

gas fields. If they do not find new gas fields, they will still get the high pay off. Otherwise, the pay off could be low.

Now back to Point 2, the management have the option to invest in an onshore hub instead of offshore hub. These decisions processes would be "Point 1-Point 2-Point c-Point g" or "Point 1-Point 2-Point c-Point h" in Figure 3.2. Mr. Iva Helge Hollen has mentioned that cost of investing an offshore hub would be much higher than an onshore hub.

Now back to Point 1, management have another alternative that they are not prepared to invest in to a hub. They would probably invest in the exactly capacity needed in gas infrastructure system. In this situation, there are still two alternatives outcomes at Point d. If they do not find new gas fields, they still could high pay off. Otherwise, they might to invest in exactly capacity needed with expensive extra cost and get low pay off.

Through this decision tree, it is clear that main issue is that whether to invest in overcapacity in front or later. Besides, the location is also an important factor in the decision making processes. Cost and technology are two main elements to affect the onshore or offshore hub system. Compare the offshore hub with the onshore hub, the cost for developing pipeline infrastructure could be much higher, because of expensive advanced technologies. Hence, it's most feasible to develop an onshore hub.

Four final outcomes

Actually, there are four main outcomes through analyzing this decision tree and these outcomes are shown in Figure 3.3.
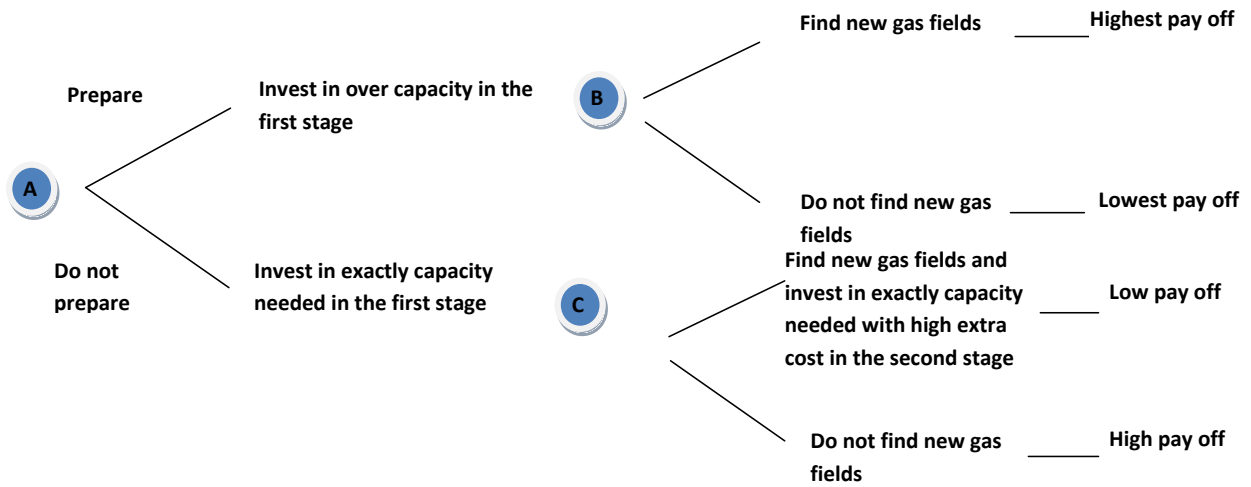
Figure 3.3: Final outcomes of decision processes

- First, the management invest in overcapacity in front of finding new gas fields and they do find new gas fields. This could be a good strategy because they might get the highest pay off. Although the initial investment should include extra cost with extra capacity, the new gas fields will use that extra capacity later and the profits would be better than expected.

- Second, the management are still prepared to invest in to a hub. They invest in over capacity but they do not find new gas fields. Compare to the above outcomes, they may get the lowest pay off by using this decision processes. The reason is that there is extra cost in the first stage and the extra capacity has not been used since there is no new gas field.

- The third outcome is that management are not prepared to invest in a hub and invest in exactly capacity needed in the first stage. They discover new gas fields and need extra capacity. They have to invest in exactly capacity needed again in the second stage but they could only get low pay off. This strategy could be OK even though the extra cost would be very high in the second stage.

- The last outcome is that the management invest in exactly capacity needed when they are not prepared to invest in a hub and they do not find new gas fields. It is also a good strategy. They do not need extra capacity and still could get high pay off, although less than the pay off in the first outcome.

Compare to these four outcomes, the first and last outcomes could be even better than other two outcomes. We assume that the management have the same information at the Point A, Point B and Point C. Based on the current information, the company may get good profits by using these two strategies. However, it does not mean that the management should only follow these two strategies.

High risks always exist with high profits. These risks would not be always the same in the overall project and management have different opinions toward risk. Hence, they may draw different conclusions under the same decision tree shown in Figure 3.2. Many people will participate in a decision process and they may have different values at risk from supplying capital and ideas to data (John F. Magee, 1964). On the other hand, today's decision may influence the future decisions. As it can be seen from Figure 3.5, the first stage's decision may influence the second stage's decision such as management have a high probability to invest in exactly capacity needed again in the second stage.

3.3.3 Estimating the value of becoming a hub

Since the gas production from each project is operated to meet the consumer's demand, it is difficult to make the production to fit the capacities of the pipes and markets (Bjørn Nygreen, Marielle Christiansen and Kjetil Haugen, 1998). The most important point is how to determine the right capacity with less cost. The management may have different options after getting new information at each step. In this case, different from financial options, this project of valuing a hub could be taken as real options. In other words, managers have the right but not the obligation to invest in over capacity of gas pipeline system. We have already analyzed the possible future outcomes of becoming a hub by drawing an event tree. In the following, we are going to estimate the value of a hub if it exists today and how much of this value is likely to move up or down in the project's life time (Tom Copeland and Peter Tufano, 2004).

Data description

Assuming that if a hub system will be developed today, its value would be $ 1 billion (without option). The distribution of possible outcome in each period is fairly standard, the factor for an up movement is given by 1.8 and down movement is given by 0.6. Therefore, in one year later, its value would be worth either $1.2 billion or $ 600 million, depending on the market of the petroleum industry. If the hub's value goes up to $1200 million under high demand of the market, the value of the hub could be either up to $1,440 million or down to $720 million in potential year two. If the hub's value falls to $60 million in year one, its value could be either $ 720 million or $ 360 million in year two. Similarly, the value of a hub would be from $1,728 million to $216 million at the end of year three. These values of the hub are shown in the event tree (Figure 3.4) and it indicates that how much of the hub could be worth in each period. From this event tree, management may have a chance to decide whether to continue doing this project. In the real case, considering market and financial factors, the branches of tree could be even more complex.
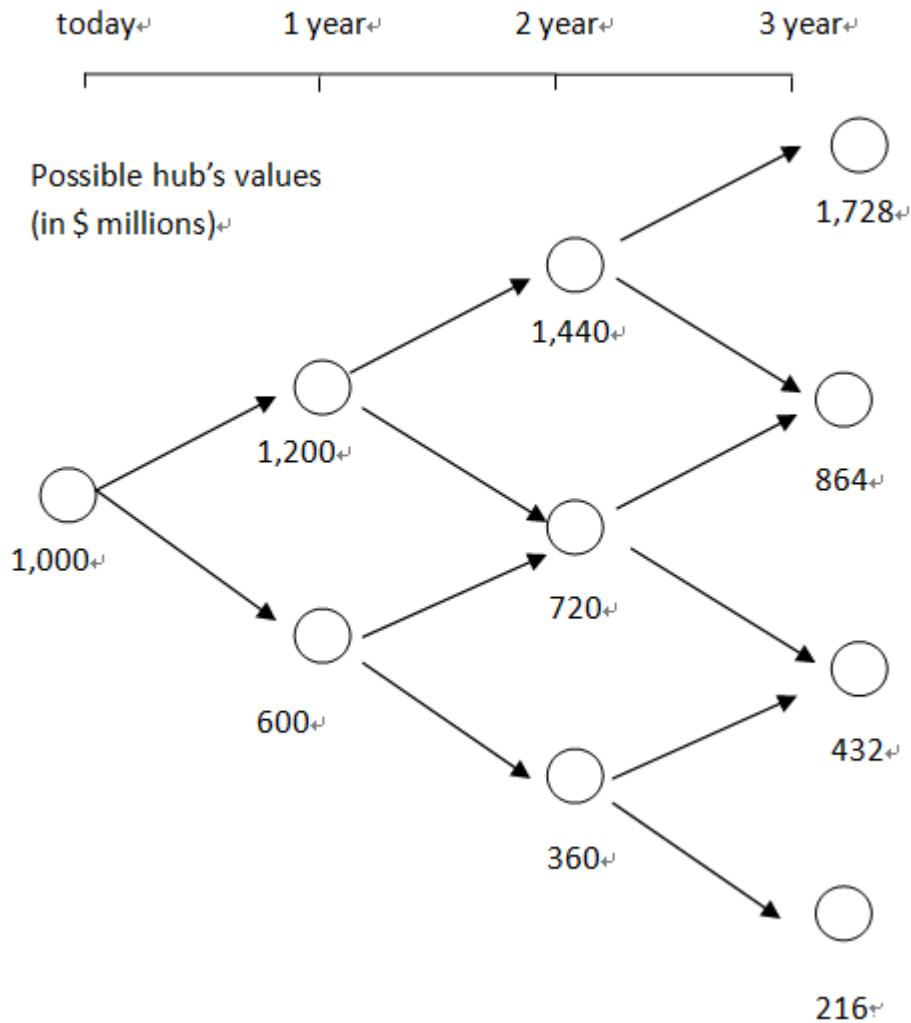
Figure 3.4: Event Tree of valuing a hub

In the second step, we are going to calculate the possible values of the hub system as an option in each stage in the decision tree. There are three investment steps. The first step is investing $100 million for licences and preparation and it needs one year. The second step is that management could invest $300 million in completing the design phase which will also take one year. The last step is that the management have a chance to invest $400 million in overcapacity of the pipelines in the next two years. Management have an option to decide whether to continue doing this project in each stage. Since this is not one time decision, it can be considered as a compound option. The first option for licences in the first year creates the second option. Only exercising the first option, the management have the option to do the next investment in year two.

In order to calculate each value, it should start from the end of year three and rollback to the current year. We need to compare the profit from taking lower branch ("developing as

a hub") with upper branch ("do not develop as a hub"). If the management abandon the project, its value is zero. Otherwise, the value of this project at the end of year three is the difference between the values of the hub at the end of year three minus the cost of investment. For instance, if the hub exists at the end of year three, the value would be $1728 million and the cost is $400 million. Hence, the payoff of investing a hub could be $1328 million ($1728 − $ 400 = $1328). If the value of a hub at the end of year three is only $216 million which is less than investment cost, the value of this project is zero. The reason is that the management cannot invest $400 million without getting any profit. When the project's value is positive, the management may consider investing in a hub project.

Four steps of decision making

All the possible values of each option in different stages are shown in Figure 3.5. A risk-free rate is assumed to be 8%. As can been seen from Figure 3.8, there are four steps during the decision making processes (Tom Copeland and Peter Tufano, 2004).

- Step 1: Management calculate the final project values, concerning $400 million of investment. The positive payoff is range from $928 million to $33 million. For the $216 million scenario at the bottom right of the event tree, the investment is larger than the hub's value, so the project's value in this situation is considered to be zero.

- Step 2: The calculation in this step will be explained later. Based on the results, managers decide whether to exercise the option. It is not easy to determine the discount rate because the risk of an option is different from the risk of the whole project. Hence, we use risk-adjust rate to calculate the present value in each period.

- Step 3: The calculation is similar to the second step. If the value of the option is less than $300 million, managers will not exercise the option and the project's value will be zero. Managers still have right to determine whether to invest $300 million in completing the design phase in this project.

- Step 4: The final step is to use the same calculation method to get a present value of $413 million. Since the initial investment is $ 100 million, it is worth to invest in the project. The net present value would be $313 million.
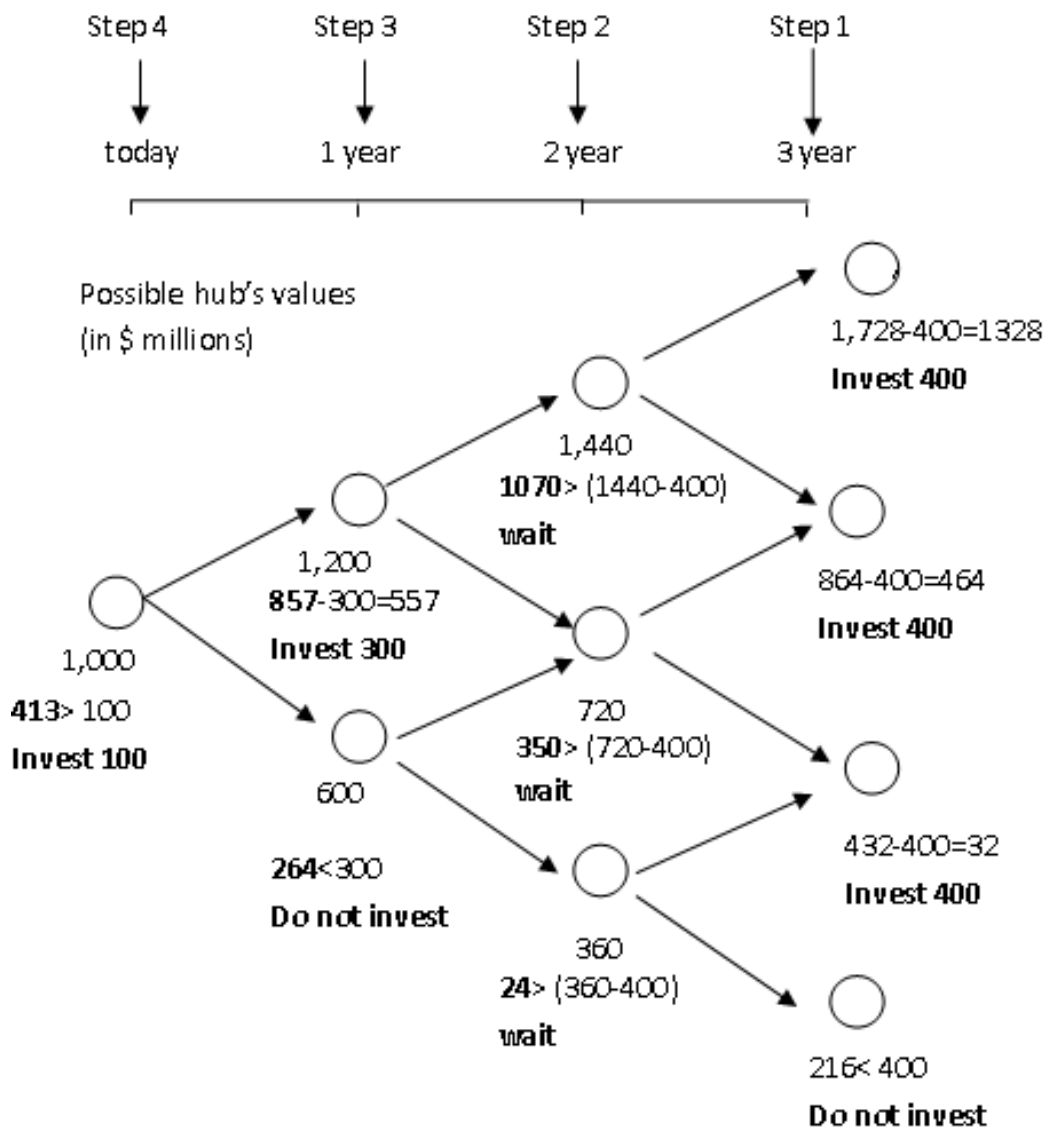
Figure 3.5: Steps of valuing a hub (Modified from Tom Copeland and Peter Tufano, 2004)

Analyze the results

These values from Figure 3.6 will be analyzed into details as follows. Management have the right to wait and invest in the next period, if they are not satisfied with the result. This option could be considered as a call option and the exercise price is equal to the investment I_3. The payoffs of this project could be $1328 million or $ 464 million at the end of year three. Figure 3.10 shows the structure that how to calculate the payoff.

E^+=max $(V^+-I_3, 0)$ =max $(1728-400, 0)$ =1328
E^-=max $(V^--I_3, 0)$ =max $(864-400, 0)$ =464
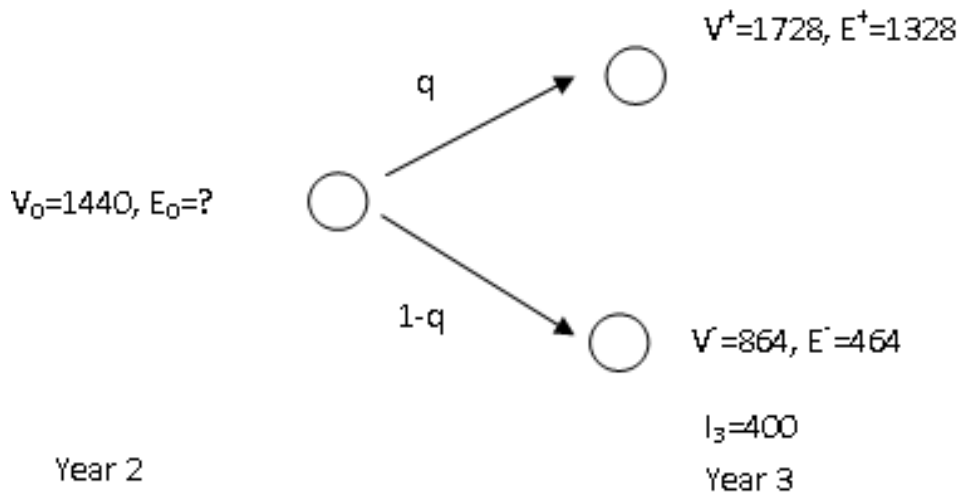
Figure 3.6: Structure of the payoff at year two

It is important to notice that the management do not invest $ 400 immediately in order to get the cash flow of $1728 million or $864 million. They could wait and check if the result is good. If the net present value is positive, they may invest and get $1328 million payoff. If the result is negative, they could abandon to invest and get zero pay off. In this situation, the possibility of the investment is in the following (Trigeorgis Lenos, 1996).

$$P = \frac{(1+r)S - S^-}{S^+ - S^-} = \frac{(1+r)-d}{u-d} = \frac{(1+0.08)-0.6}{1.2-0.6} = 0.8$$

The total value of this option at the end of year two could be:

$$E_0 = \frac{pE^+ + (1-p)E^-}{1+r} = \frac{0.8*1328 + 0.2*464}{1+0.08} = 1070$$

Since $ 1070 million is greater than $1040 million ($1440-$400), the number is greater than the value of exercising the option by investing in overcapacity of pipeline infrastructure system. Hence, the management may keep an open option instead of exercise the option. In other words, they will wait and see if it is possible to invest in the next period.

At the end of first year, management have to decide whether to invest $ 300 million in the design phase. To determine the value whether to invest, it is simply work backward from the possible values at the end of year two and we get $857 million and $264 million respectively. Since the cost of requiring that option is $ 300 million, the management may invest and the NPV might be $ 557 at the end of first year. ($857-$300=$557 million) Another result of that option is only $ 264 million, and this is less than the investment cost and thus they would not exercise this option.

The final step is to calculate the value of the option at the current year. The value is determined by two possible payoffs, which are $857 million and $264 million. Using the same method to calculate, the option to invest $100 million in current year is $413 million and NPV is $313 million ($313 million =$413 million-$100 million). This positive net present value means the management should exercise the option to invest in a hub system.

Part 4-Nyhamna as a potential hub

4.1 Background

4.1.1 Ormen Lange

Ormen Lange gas field is the second largest gas field offshore in Norway and third largest output of gas in Europe. Hydro discovered this field in 1997 and started production in 2007. The location of Ormen Lange is 120 kilometres off Midwest coast of Norway and around 850 meters to 1100 meters depth. Partners in Ormen Lange license are Statoil ASA, Petoro AS, Shell, Norway's Petoro AS and Exxon Mobil Corp. These companies share risks and profits when they decide to do the investment. The development phase in this field is operated by Statoil while production phase is operated by Shell (A. Solheim, P. Bryn and H.P. Sejrup, 2005). Meanwhile, Gassco is responsible for developing the gas infrastructure system in the cost efficient way. The capacity of condensate process during the production is about 6000 to 8500 Sm^3 per day and 70 million Sm^3 for gas per day. Langeled is the world's longest subsea pipeline with 42" to 44" pipes from Nyhamna in Norway to Easington on the east coast of England. The total length of Langeled is 1200km. Moreover, Ormen Lange gas field could cover 20 percent of the gas requirement by UK up to 40 years. (Svein Olav Aslaksen, Gudmund Vigerust, 2007). Since Norwegian gas exported to Europe through the integrated transport system were total 94.6 billion standard cubic meters (scm) in 2007, it is necessary to have a substantial, long-term need for additional gas pipeline capacity (Gassco[1]).
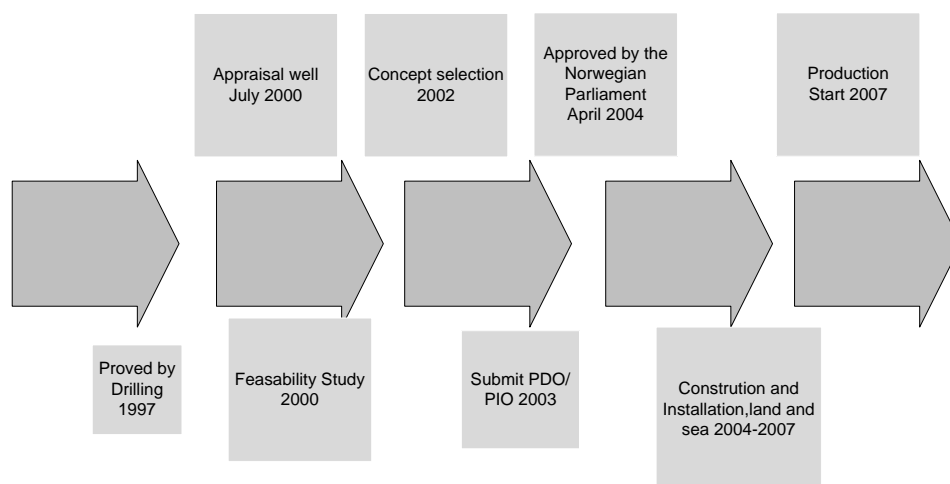
Figure 4.1: History of Ormen Lange development (Source: Svein Olav Aslaksen, Gudmund Vigerust, 2007)

Figure 4.1 describes the main decisions in Ormen Lange project since it has been discovered. The project was approved by the Norwegian Parliament in April 2004. The construction and installation activities were performed on scheduled and they were completed in October 2007. After that it has started gas production and contributes significantly to make Norway become the second largest exporter of natural gas in the world. The Ormen Lange project was divided into three parts. The first is Ormen Lange onshore project which consists of the gas-processing facilities at Nyhamna. The second subproject is Ormen Lange offshore project. It consists of the subsea installations which are about 120km offshore with templates, manifolds and pipelines. Langeled project is the third subproject which is the 1200km gas export transportation system (Ormen Lange Langeled development).

Table 4.1: Short description of Ormen Lange field (Modified from A. Solheim, P. Bryn and H.P. Sejrup, 2005)

| Ormen Lange field	
Location	120km off mid west coast of Norway
Water depth	850m-1100m
License partners	Statoil (28.91%), Shell (17.04%), Petoro AS (36.48), Dong Energy A/S (10.34%) and Exxon Mobil Corp. (7.23%)
Operators	Planning and development phase: Statoil Production phase: A/S Norske Shell
Discovered	1997 by Statoil
Production start	2007
Production capacity	Condensate: 6000 to 8500 m^3 per day Gas: 70 million Sm^3 per day
Development solution	Subsea to onshore processing plant(subsea wells, pipelines, terminals and processing plant) and subsequent transport to UK
Total field investment	NOK 66 billion(including 19.5 billion for the transport system)

4.1.2 Facilities at Nyhamna

Separate Process System

The main facilities in the Ormen Lange fields include processing plant (Nyhamna), Langeled pipeline, six wells (now increased to 10 wells) and two templates. The peak capacity in Ormen Lange has been reached to 70 million cubic meters a day (cmd) (source: DNV).

Nyhamna is a processing plant. Gas together with oil and water is treated at this processing plant. Shell is the operator of separating gas from oil and water at Nyhamna. Gry gas is delivered through pipelines to customers while wet part is shipped by vessels to customers. Ormen Lange gas processing complex may handle 20 billion m³ per year during the peak production. Gas could be carried out via the world's longest subsea export pipeline from Nyhamna via Sleipner in the North Sea to Easington in the UK.

Six subsea wells drilled from a mobile drilling rig have been used since 2005. The number of wells might be increased to over 24 according to the plan. Gas is below the sea surface in 50m-thick layers of gas-bearing sand, at a depth of 2800m. These wells are connected by two seabed templates (subsea installation), at a depth of 800m to 1100m. They are attached to two 30'' multi-phase pipes. These pipes are used to transport gas, condensate and water stream onshore for processing.

Figure 4.2 shows the offshore scope. As can be seen from the figure, gas arrives in the reservoir first and reaches the parts of Storegga to Nyhamna. Finally runs it runs to the separate process plant at Nyhamna.
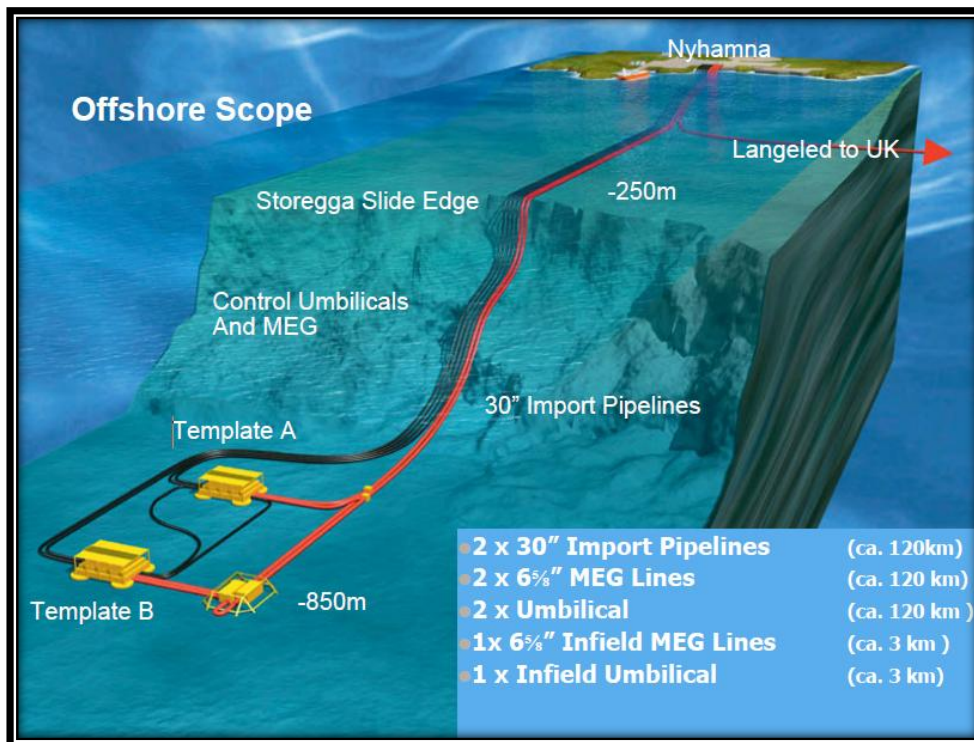
Figure 4.2: The Offshore Scope at Nyhamna (Hydro Oil & Energy, 2005)

The following separating processes in details are based on the video from the website of Shell and some notes from Mr. Iva Helge Hollen, the operation manager of Shell. From this information, it is easy to understand how the natural liquid gas separated and transported at the processing plant. The work for searching natural gas is involving a lot of effort and takes persistency. The explorers are looking for clean sand without sludge which indicates that a reservoir can contain mobile gas trapped in the pores. Groundbreaking work was required with developers by using unmanned modules and building equipments, placing the platform on the ocean floor.

Norway becomes the world's second largest gas exporter after Russia since the daily output reaches70 million cubic meters in Ormen Lange. The low temperature poses the risk that gas might be blocked in pipes. A glycol-based liquid is injected into gas to avoid these blockages when it comes up from the well. The unprocessed well stream which consists of gas and condensate gets through two multi-phase pipelines. These pipes have been laid through unusually rugged terrain. This process took persistence, tremendous resources and a series of technological successes to overcome the challenges in this gas field.

There are five main steps in separate process system at Nyhamna, including Landfall, separate gas from liquid, drying, remove and export through four systems (system-16, system-24, system-25 and system-27). The first step starts from Landfall where gas and condensate and water arrive into two 30'' pipelines. When the untreated well stream arrives at Nyhamna, its first stop is the slug catcher. These slug catchers (system 16- slug catchers) separate gas from the liquids.

The next step is to dry gas. In the system-24, gas is dried to prevent clogging of the pipelines according to customer specifications. All the heavier hydrocarbon components are removed at system-25 Turboexpander after gas is dried. There are two effects of this equipment. On one hand, it could reduce the pressure. Inappropriate pressure may result in a temperature drop and cause the heavier hydrocarbons to condensate in a separator. On the other hand, it could increase the pressure and make gas keeps flowing into the export compressor continuously.

The last step is in the system-27 which is a gas export system. Gas is metering here before it leaves Nyhamna. Through all these steps, gas is completely dried clean and ready to be delivered to different customers. The machine uses 45 megawatts of power and so does the two others at the plant. Gas is delivered to UK through 42" Langeled pipeline.

Four new wells will be used to support the existing six wells because of the increasing gas demand. Gassco and some petroleum companies have begun to identify possible export options for new fields in the Norwegian Sea (TU.no, 2008). There are many options for Nyhamna to upgrade into a new gas hub and this could be a complement to other existing hubs.

Gas transportation and Storage

Since the gas has been separated in the separate process system, the storage and transportation become another important issue in Ormen Lange gas field. Management should make a decision on whether or not to invest in extra capacity, concerning the storage and transportation.

First, a short description of gas separation will be described. A multiphase well stream is transported by pipelines to the onshore processing plant---Nyhamna. The well stream consists of gas, condensate and water. These components are separated in the processing plant when they meet the slug catcher (Svein Olav Aslaksen and Gudmund Vigerust, 2007).

In Ormen Lange gas field, there are two transportation ways to deliver gas to the customers after gas is processed in the processing plant. The rich gas is transported through tanks while the natural liquid gas is transported by pipelines. Gas is different from oil and it exists as a gaseous state at normal pressures and temperatures. It is very expensive to transport gas in its gaseous state by chartering vessels. Pipeline transportation is the most popular transportation mode right now. Langeled pipeline system is the link from Norwegian gas fields to European terminals. Considering the safety and security issues, pipelines are buried underground. In some cases, the cost of investing in gas pipeline infrastructures would be huge when the technical construction is not feasible. For example, it is not reasonable to transport gas from Norway to China through pipelines. The common method is transport gas by tanks. The natural liquid gas could be compressed in high-pressure tanks and shipped to the customers (Oil and Gas[1]).

Gas storage and transportation are two critical aspects to influence the gas price. The petroleum companies could get arbitrage between current gas prices and future gas prices if they could forecast the gas demand accurately. These companies are making gas supply plan with regard to storage capacity. It could be possible that there is no extra capacity to transport natural gas when they are surplus. Furthermore, even there is enough capacity to transport them, it does not mean that there is enough capacity to store them. The storage and transportation of basic pipeline infrastructure system may determine the volatility of natural gas price (William B Tye and Jose Antonio Garcia, 2007). Meanwhile, it is obvious

that the petroleum companies may get cost advantages, using the established pipeline infrastructure system instead of making a one-off investment. Basically, the storage facilities are related to the transportation system. If the storage and transportation facilities are not adequate, the quality of service to the customers could be reduced.

The expansions of storage facilities could reduce the gas price volatility by reducing the probability of gas shortage. In other words, investment in storage facilities may reduce the gas price volatility and enough gas storage capacity may help to balance supply and demand in the entire gas market. The gas storage is an essential way to balance the supply and demand in the petroleum market. There are two main methods to store gas: pipelines and tanks. The most obvious method is to store liquid gas in giant tanks under pressure. (Science: Gas Storage Tanks). On the other hand, gas could also be stored in pipelines which are actually underground reservoirs. Storage capacity is measured in billions of m^3 and it is not necessary to refrigerate the gas to liquefy it. The cost of injection of gas into the reservoirs is not so expensive based on current technology (Oil and Gas[2]).

4.2 Advantages and Disadvantages of becoming a hub

As mentioned before, Åsgard (process plant at Kårstø) has been developed as hubs, concerning their locations, capacities and infrastructure systems. They play the most important roles in the Norwegian Sea and petroleum industry. A large quantity of petroleum products are transported from this area to other European countries every year. In the following, the possible advantages and disadvantages of Nyhamna as a hub will be analyzed, comparing to the existing plants (Kollsnes and Kårstø).

Table 4.2 shows the facts of three processing complex. Compare with Kårstø and Kollsnes, we are going to analyze whether Nyhamna is feasible to become a hub, considering location, infrastructure system and capacity.

Table 4.2: Facts of processing complex in the Norwegian Sea (Gassco[3])

Processing Complex	Location	Infrastructure system	Capacity	Customers	Gas fields
Kårstø	North of Stavanger	Åsgard transport	70.4 mill	Germany	Sleipner
		Statpipe	105 mill		Åsgard
		Europipe II	64.8 mill		Mikkel
Kollsnes	North-west of Bergen	Kvitebjørn gas export	26.5 mill	Belgium	Troll
		Zeepipe IA	72 mill	France	Kvitebjørn
		Zeepipe IIB	71 mill	Germany	Visund
				Netherland	
Nyhamna	Mid-Norway	Langeled	69.4 mill	England	Ormen
	Aukra				Lange

- *Location*: Nyhamna provides opportunities for piping gas from the Norwegian continental shelf via Sleipner East to the UK. It is located in the mid-Norway and it has been constructed to carry gas from Ormen Lange gas field in the Norwegian Sea. Nowadays, 10 gas fields are in use and other four gas fields are under development in the Norwegian Sea. It is feasible to connect more gas fields to Nyhamna and there is available extra capacity in the Langeled pipeline system. The processing facilities at Kollsnes and Kårstø are located in the west of Norway. Each of them receives gas from three gas fields in the North Sea. Although 28 gas fields are located in the southern part of the North Sea, 7 gas fields of them have been shut down and some of them are waiting for redevelopment. Hence, the gas demand might increase at Nyhamna.

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- *Capacity*: The daily capacity at Nyhamna is up to 70 million scm per day and it could be expanded to 84 million scm. Gas from Nyhamna could be delivered through Langeled pipeline to UK. There is still about 20 percent extra capacity available at Langeled pipeline system. The cost saving would be huge if the extra capacity would be used. On the other hand, gas in Ormen Lange field reserves is estimated at 397 billion scm which can supply gas for 30 to 40 years. On the other hand, the daily processing capacity at Kåstø and Kollsnes are 240 million scm and 170 million scm respectively. Both of these two processing plant are filled up and there is no available new capacity to new gas fields.

- *Infrastructure system*: Langeled is integrated into the existing gas pipeline system at Sleipner East. Gas can be delivered with the right quality to UK by Langeled pipeline system. It is the longest underwater gas pipeline in the world and the cost of development is very high. There is only one pipeline route connected to Nyhamna while Kårstø and Kollsnes have several pipelines routed connected to them. If there is more than one gas field connected to Nyhamna, it is possible for Nyhamna to become a hub. Two new gas fields have been already found in the Norwegian Sea: Onyx and Luva. If these two gas fields are connected to Nyhamna, there could be a big possibility of Nyhamna to become a hub. Gassco may have to plan new gas pipelines for landing them to Nyhamna. According to Sten Arve Eide from Gassco, the cost of building new pipelines could be very high.

Although there are many advantages for Nyhamna to become a hub, it does not mean there is no limitation. Sometimes, the advantages might become disadvantages in the future development. There are still some issues and challenges for Nyhamna to be developed as a hub.

From the technical point of view, the first big challenge of Nyhamna development in Ormen Lange gas field is the climate. This field is in the great depth sea and the climate change dramatically such as extreme wind, wave conditions and fracture of sea floor. These elements may affect the gas production. If Nyhamna is planned to develop as a hub, wells might be increased up to 24. It's necessary to solve these technology problems in collaboration with key section of the Norwegian research and industrial communities.

From the cost point of view, Gassco and gas companies have focused on solutions of four new gas fields (Onyx, Luva, Victoria and Gro) They might consider how to choose the right infrastructure system (source: Tu.no, 2008 and Stein Tjelta, 2009). Mr. Ivar Helge Hollen mentioned in his interview that Shell is planning to land Onyx to Nyhamna and try to figure out that whether there is enough capacity for gas transportation at Nyhamna. Actually, Onyx and Luva are two small new gas fields which could use the extra capacity from Langeled pipeline system. Comparing to Victoria and Gro, they are more suitable to land at Nyhamna.

However, it seems that there is no cost advantage to land gas fields to Nyhamna such as Onyx and Luva, if new pipelines to be built. Mr Sten Arve Eide from Gassco confirmed that the cost to land Onyx or Luva to Nyhamna would be very high because of building new pipelines and modifying existing facilities. On the other hand, Onyx is located far from Nyhamna. If landing Onyx to Nyhamna, other gas fields in that area might be also land to Nyhamna in the future. Therefore, the capacity at Nyhamna might not be enough at that time. Furthermore, the quality of gas in Onyx is uncertain now. Another option is to land Onyx and Luva to Kårstø or Kollsnes. In the later section, we will quantify the project if Nyhamna would be developed as a potential hub, by using traditional NPV method and real option analysis.

4.3 Adding financial data

To simplify the calculation, we are going to estimate the following data based on the information we got from the internet, some notes from our supervisor Arild Hervik and Mr. Sten Arve Eide from Gassco. Since parts of data we need are confidential, we have to make a few assumptions during the calculations. The objective of this section is to demonstrate that how to apply real option theory into the hub system at Nyhamna.

The gas delivery at Nyhamna is 15 million scm a day and the gas price level is expected between NOK 3 and NOK 1.5 based on EIA (Energy Information Administration). Hence, the gas price is assumed to 2 NOK per square meters per day. The income of one year at Nyhamna will be around NOK 11 billion ($15 \times 2 \times 365 =$ NOK 11 billion). The capacity at Nyhamna is 70 million scm gas per day at a receiving pressure of 90 bar. There is 20 percent over capacity which would be up to 84 million scm at Langeled pipeline system. Since there is 20 percent of overcapacity, the yearly income would be NOK 13.2 billion if this extra capacity will be used. The landing facilities have been designed in Ormen Lange field for an operating life of 30 years and part of the main infrastructure has been designed for 50 years (Facts 2009). It will be too complicated to calculate cash flows for over 30 years and thus we assume new gas fields will be found in 5 years. Management have an option that either invest in overcapacity before finding new gas fields or invest again after finding new gas fields. The cost will be different in these two situations and it would be much cheaper to invest before finding new gas fields. Since the total cost for investing facilities at Nyhamna is between NOK 5-11 billion and we use the highest cost NOK 11 billion if these petroleum companies invest in front. The cost would be assumed to NOK 15 billion after finding new gas fields. According to these data, the decision tree is shown in Figure 4.3.

Year 0   Year 2   Year 3   Year 5
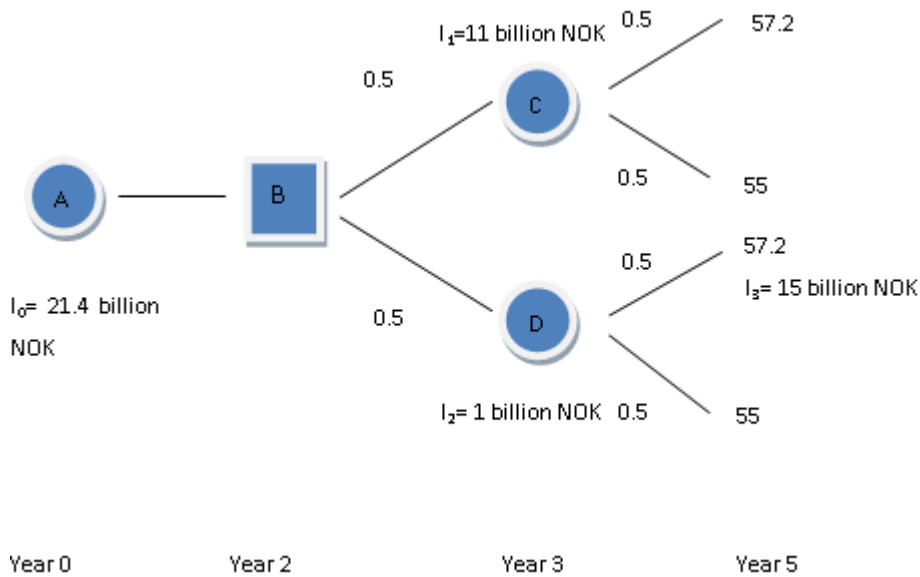
Figure 4.3: Event tree of Nyhamna

A "twin security" is applied in NPV analysis. Both the rate of project and its twin security are the same. The twin security is currently priced in the market at S= NOK 2. The expected rate of return (discount) rate is calculated as follows.

$$k = \frac{E_0(S_1)}{S_0} = \frac{0.5 \times 3 + 0.5 \times 1.5}{2} - 1 = 0.125 = 12.5\%$$

The expected cash flow in the fifth year is the outcome multiplies probability and accumulates these two values. Therefore, the present value in year 5 is

$$E_5(PV) = 57.2 \times 0.5 + 55 \times 0.5 = 56.1$$

Step back to the year four, using the same method, the net present value at Point c and Point D are NOK 32.2 million and NOK 36.4 million.

$$E_c(NPV) = \frac{E_5(PV)}{(1+k)^2} - I_1 = \frac{56.1}{(1+0.125)^2} - 11 = 32.2$$

$$E_D(NPV) = \frac{E_5(PV')}{(1+k)^2} - I_2 = \frac{(57.2 - 15) \times 0.5 + 55 \times 0.5}{(1+0.125)^2} - 1 = 36.4$$

Similar as the above step, the net present value in year 2 which is at point B is NOK 30.4 million.

$$E_B(NPV) = \frac{E_3(NPV)}{1 + k}$$

$$= \frac{qE_c(NPV) + (1 - q)E_D(NPV)}{1 + k}$$

$$= \frac{0.5 \times 32.2 + 0.5 \times 36.4}{1 + 0.125} = 30.4$$

The final step is to roll back to the current year and calculate the net present value at point A.

$$E_A(PV) = \frac{E_B(NPV)}{(1 + k)^2} = 44.8$$

$$E_A(NPV) = \frac{E_B(NPV)}{(1 + k)^2} - I_0 = \frac{30.4}{1.125^2} - 21.4 = 23.4$$

According to the positive result of NPV, it is worth to invest in Nyhamna as a potential hub and the value of this investment opportunity is NOK 23.4 million. Without managerial flexibility, this project will be still approved based on the positive result by traditional NPV method. In the following we are going to use another approach to calculate the net present value.

An alternative solution (Contingent-Claims Analysis)

Actually, the value of the investment opportunity does not involve the actual probabilities q clearly and it could be expressed by the adjusted or risk-neutral probabilities p. Different from the above approach, Contingent-Claim Analysis does not use the discount rate k to evaluate the value of investment opportunity. Instead, it uses an equivalent "risk-neutral" decision tree, discounting the future cash flows by using risk free rate r (Trigeorgis Lenos, 1996). Through the formula, the risk-neutral probability is calculated to be 0.4 and this is different from the probability of q. The risk free rate has not been changed since 1995 in the petroleum project in Norway and it is 7%. In this case, we still assume that the risk free rate is 7%.
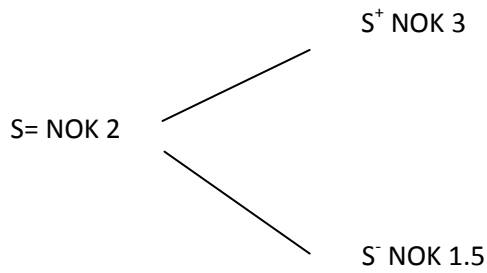
$$P = \frac{(1+r)S - S^-}{S^+ - S^-} = \frac{(1+0.07) \times 2 - 1.5}{3 - 1.5} = 0.4$$

Since the probability is 0.4, the new decision tree is shown in Figure 4.4. The rest of calculations are almost the same as the previous method. Hence, the results will be explained briefly.
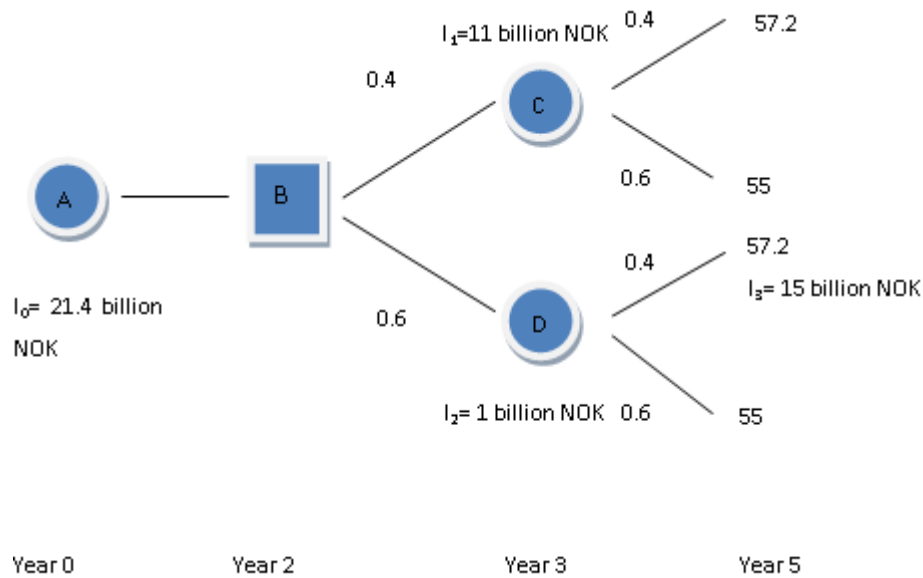
Figure 4.4: Event tree of Nyhamna

Applying the probability of 0.4 and the risk-free rate of 0.7, the net present values at Point C and Point D are NOK 38 million and NOK 43 million respectively at the end of year three.

$$E_c(NPV) = \frac{PV^+ + (1-p)V^-}{(1+r)^2} - I_1 = \frac{0.4 \times 57.2 + 0.6 \times 55}{(1+0.07)^2} - 11 = 38$$

$$E_D(NPV) = \frac{PV^+ + (1-p)V^-}{(1+r)^2} - I_2 = \frac{0.4 \times (57.2 - 15) + 0.6 \times 55}{(1 + 0.07)^2} - 1 = 43$$

Roll back to Year 2, the net present value at Point B is 38.4 million NOK.

$$E_B(NPV) = \frac{p \times E_c(NPV) + (1-p) \times E_D(NPV)}{1+r} = \frac{0.4 \times 38 + 0.6 \times 43}{1 + 0.07} = 38.4$$

Finally, concerning the initial investment, the net present value is NOK 12 million.

$$E_A(PV) = \frac{E_B(NPV)}{(1+r)^2} = 33.4$$

$$E_A(NPV) = \frac{E_B(NPV)}{(1+r)^2} - I_0 = \frac{38.4}{1.07^2} - 21.4 = 12$$

According to this method, the result is still positive and management would accept to invest in Nyhamna as a potential hub. The value of investment opportunity is NOK 12 million in this case. Using traditional NPV method, the result is NOK 23.4 million. Compare to these two results, it is clear that CCA is almost identical to traditional NPV method with respect to decision tree analysis. The value of NOK 23.4 million is higher than NOK 12 million. This means traditional NPV approach here overestimates the value of the option because it uses the constant discount rate of 12.5%.

4.4 Real option analysis

4.4.1 Option to Expand

The financial crisis has a negative impact on the oil price in 2008. In the beginning of 2010, the U.S. Energy Information Administration (EIA) estimated that the oil price would have an increasing tendency in 2010. On the other hand, United Nations Climate Change Conference was held in Copenhagen in December 2009. Standing at the point of the environment protection, the conference advocate appeal to use gas energy instead of oil and this would decrease environment pollution. The holding of the conference may also impact on the gas price and the gas demand would be increased. Facing the situation of petroleum marketing, Norwegian gas companies can take advantages of the increasing tendency of gas price. These companies could exercise an option to expand so that they can get more profits. Investing Nyhamna as a hub would be considered as a call option. The more prices increased, the more profits they could get. Hence, it is a good strategy to exercise the option to expand. In other words, these companies could expand the scale of production or accelerate resource utilization at Nyhamna.

Under the circumstance of better market condition, it is feasible for petroleum companies investing over capacity of pipeline infrastructure system at Nyhamna upfront instead of investing in exactly capacity needed. As discussed above, these petroleum companies should have aware of the increasing gas demand and prepare to expand the scale of production or accelerate resource utilization. We have calculated that the present value of Nyhamna becoming a hub is NOK 33.4 million (without option), which is the gross value of project. We assume that the gas company may increase 20% to the rate of production at Nyhamna for enlarging the scale. The extra investment of 20% capacity here is defined as I_x. The investment opportunity's value will be

$$E = V + \max(xV - I_x, 0)$$
$$= 33.4 + \max(20\% \times 33.4 - I_x, 0)$$
$$= 33.4 + \max(6.68 - I_x, 0)$$

If 6.68 - I_x > 0, that means when I_x < NOK 6.68 million, the investment opportunity's value is increasing and it is worth to exercise the option to expand. In other words, management may get more profits through expanding the scale of gas production. The higher the value

6.68 - I_x (positive) is, the more benefits these petroleum companies group will get. However, when the 6.68 - $I_x < 0$, the opportunity's value is less than the present value without option, we suggest that gas companies should exercise defer of default option even though the marketing situation is better than expected. The reason is that if management expand the production scale, they would get fewer profits. Management has the flexibility either to maintain the same scale of operation or expand the scale to get 120 percent of the project value by paying extra cost at the end of year one. Therefore, we get the following equations. To simplify the calculation, we just assume management has one year call option to exercise. In fact, management could wait for more than one year and get more useful information of gas market and then decide whether to expand the production scale.

$$E^+ = \max(V^+, 1.2V^+ - I_x) = \max(50, 60 - I_x)$$
$$60 - I_x > 50$$

$I_x < 10$ This means management will exercise the option to expand the scale of production at Nyhamna at the end of year one, when the extra cost is less than NOK 10 million.

$$E^- = \max(V^-, 1.2V^- - I_x) = \max(25, 30 - I_x)$$
$$30 - I_x < 25,$$
$$I_x > 5$$

Similarly, the management may prefer to maintain the same scale at the end of year one when the extra cost is more than NOK 5 million. Thus, the value of the investment opportunity will become

$$E_0 = \frac{PE^+ + (1-p)E^-}{1+r} - I_0$$
$$= \frac{0.4(60 - I_x) + 0.6 \times 25}{1 + 0.07} - 21.4$$
$$= \frac{0.4(60 - I_x) + 15}{1.07} - 21.4$$

The value of the option to expand production at Nyhamna is equal to

$$E_0 - 12 = \frac{0.4(60 - I_x) + 15}{1.07} - 21.4 - 12$$

$$= \frac{0.4(60 - I_x) + 15}{1.07} - 21.4 - 12$$

$$= \frac{0.4(60 - I_x) + 15}{1.07} - 33.4$$

Since we do not have the exact number of the extra cost, it is not possible to calculate the exact value of the investment opportunity.

Phase 2 development plans in Ormen Lange project consist of investment of more templates on the seabed, additional wells to be drilled and the installation of a compressor to expand the field's lifetime. Two new templates are planning to be used for phase 2. A new compressor technology will be implemented on the onshore facilities of Ormen Lange. Since there are 20% extra capacity at Langeled pipeline system, landing Onyx and Luva could use that extra capacity. The extra capacity is available for gas transportation to UK. Although there are another two new gas fields called Victoria and Gro, it is better to land Onyx and Luva because they are small enough and fit very well into a hub at Nyhamna. A new compressor technology might be implemented on the subsea instead of floating platform, fitted with compressors. Compressors are used to make the pressure to make gas through pipeline. The management have to invest in more compressors at Nyhamna which in order to pipe gas into Langeled pipeline system. There is no cost advantage to build new pipelines from these two new fields to Nyhamna. The main cost advantage to land them to Nyhamna is using the 20% extra capacity at Langeled and transport gas through Langeled pipeline system. The reason is that the pipeline system has already been established and these costs have been already taken. There might be some cost of investing in compressor system and the cost might be NOK 1 billion.

Consequently, invest in new compressor technology will be an advantage for Nyhamna to become a hub. The license partners in Ormen Lange are still in the process of decision making, "*whether it is technically and economically feasible to compress the gas at depths of 800 meters, instead of bringing it to the surface at a special compressor platform.*" (Shell[2]) The final decision will be made out during this summer and this is also one of the reasons that why we cannot get the data of the cost and details. Therefore, we could only get the possible range of I_x.

4.4.2 Option to Defer Investment

Based on the positive net present value, management may agree to invest in Nyhamna as a potential hub. On the other hand, they may also consider the best time to invest. They may consider whether they will get more pay off when they wait to invest in the second year instead of the current year. The management could defer the investment of overcapacity at the end of year three and wait until finding the new gas fields. Now assume they have the right to defer undertaking the project for a year after finishing the first stage. All the costs are the same as noted before. Another option is that do not invest until finding new gas fields. To simply the calculation, we do not combine these options together and only analyze one option each time.

As calculated before, the present value at current year is NOK 33.4 million. This means if Nyhamna exist as a hub today, the value would be NOK 33.4 million (without option). It is possible that this value would go up or down in the next year. Based on the gas price, the up and down factors are 1.5 and 0.75, respectively. In the first year, the value of this hub would be worth either NOK 50 million or NOK 25 million. If the value falls to NOK 25 million, the year two potential values are NOK 37.5 million and NOK 18.75 million. If the value of this hub goes up to NOK 50 million, the year two potential values are NOK 75 million and NOK 37.5 million.

The potential values of becoming a hub at Nyhamna are shown in figure 4.5. These numbers show how much the hub could worth at each stage of the project's life. At the end of year four, four potential values are NOK 169 million, NOK 84 million, 42 NOK million and NOK 10.5 million, respectively. Since the investment cost is NOK 11 million, management would abandon the investment when the potential value is NOK 10.5 million. If they abandon the project, the value of this hub is zero. Otherwise, the value at the end of year four is the difference between the value of this hub at the end of year four and the cost of investment.
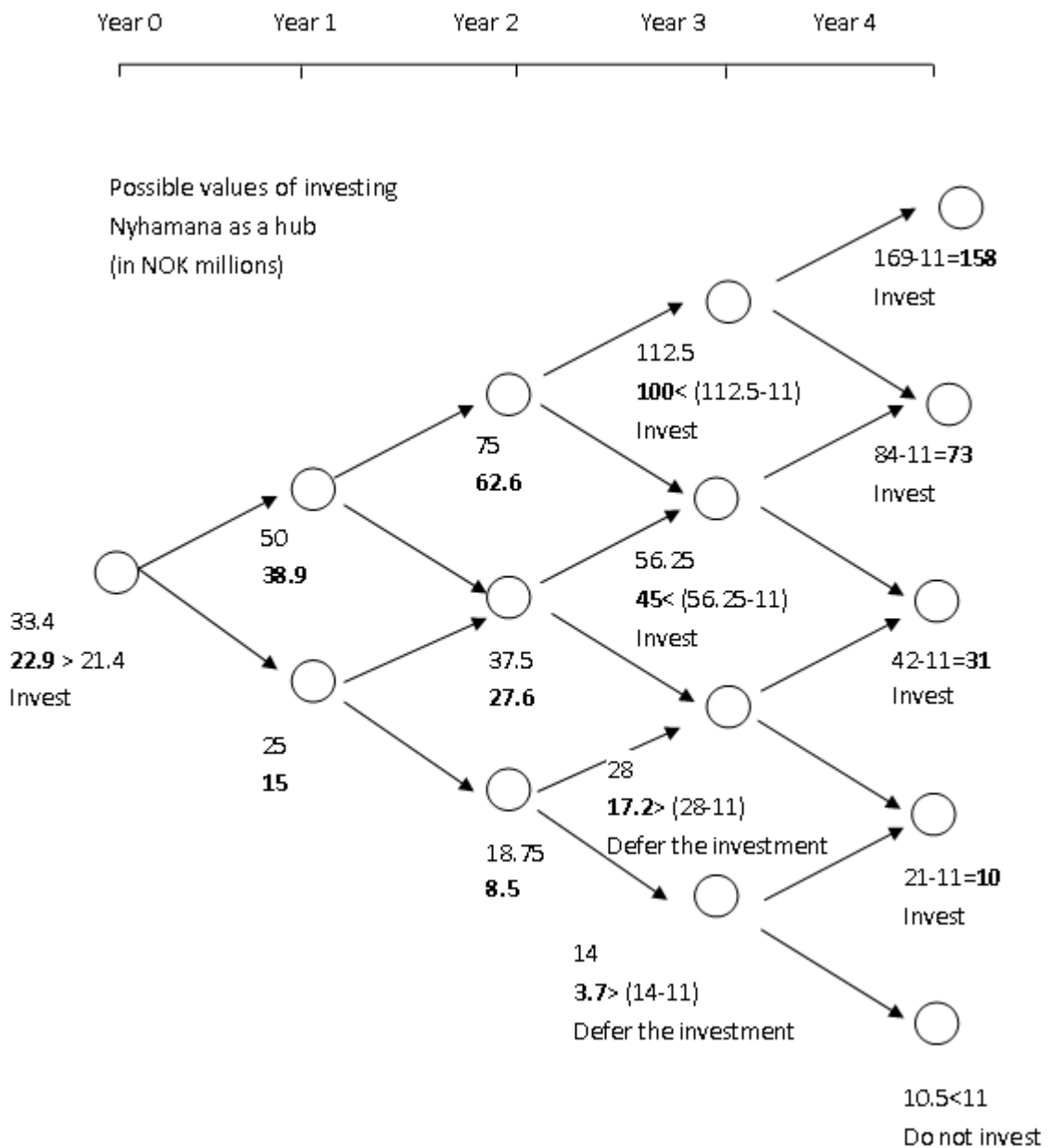
Figure 4.5: Decision tree of valuing a hub at Nyhamna

Work back from the end of year four to determine the project's potential values at the end of year three. In each scenario, if the value is larger than the exercise price, the management may keep the option open which means they will defer the decision of investing Nyhamna as a hub. On the contrary, the management may exercise the option when the value is less than the exercise price. Look at the last scenario at the end of year three, the number is greater than the value of exercising the option by investing Nyhamna as a potential hub. The right choice for management, therefore, is to defer invest and keep the option alive. Similar to this, step back to the current year to calculate the project's present value in order to determine that whether it merits the up-front investment. The

result here is NOK 22.9 million which is greater than the initial investment (22.9>21.4). This positive result means it is worth to invest in Nyhamna as a potential hub. The simplified model described previously helps management to understand the best time to exercise the option. In other words, it is always optimal to delay the option of investing in Nyhamna as a hub until maturity.

As mentioned above, the expanded (strategic) NPV = Static (passive) NPV+ Option premium. That means the value of the option to defer investment for developing Nyhamna as a hub is thus given by

Option premium= expanded (strategic) NPV- Static (passive) NPV

$$= 22.9\text{-}12$$
$$= NOK\ 10.9\ million$$

This result is equal to almost one-third of the project's gross value (NOK 33.4 million).

The objective of using real option theory is to help the management consider about the value of Nyhamna as a hub today and how that value might change over time. The positive result shows that it is a good strategy to exercise the option to defer. The management probably decide not to invest in Nyhamna as a hub right now and they prefer to wait.

In this case, Onyx and Luva may not be able to land to Nyhamna. Instead, they may wait until new capacity available at an alternative hub. It is possible to land them to an existing hub--Åsgard. As mentioned before, the capacity at Åsgard was filled up already and there is no available capacity for these two new fields now. However, the management could wait until 2021 and there might have available capacity at Åsgard at that time. In addition, the management might have to get much cash flow if landing Onyx and Luva to Åsgard because they have to cover the cost of waiting for available capacity at Åsgard.

Another solution is waiting to develop a new gas hub which combines four new gas fields (Victoria, Gro, Onyx and Luva). These four new gas fields are located nearly. Victoria and Gro are two big new gas fields. It is possible to build up a new hub and land Onyx and Luva there. This solution might not be so good because the initial investment cost might be very high.

4.4.3 Option to Contract

Based on the decision tree analyzed before(Figure 3.4), landing new gas fields to Nyhamna and use extra capacity are the key points to determine whether Nyhamna will be a hub. Shell is the operator of the new gas field called Onyx and StatiolHydro operates a new gas field called Luva. It is possible for management to exercise the option to contract at Nyhamna because of the uncertainty in gas market and high landing cost to Nyhamna. In addition, Kårstø and Kollsnes are two existing competitors for Nyhamna. Landing Onyx and Luva to Nyhamna is not the only solution. Another option is to land Onyx or Luva to other existing hubs. The existing hubs such as Kårstø and Kollsnes may have good experience to land new gas fields and thus may have cost advantages. Furthermore, if the market condition is worse than expected, it is a good strategy to contract the production scale in order to prevent losing profits.

The option to contract is opposite from the option to expand. The gas companies may contract scale of investment to save cost when the market condition is worse than expected. We assume the company could contract c% scale of investment and saving cost would be I_C. Therefore, the value of this option will be max $(I_C$-33.4×c%, 0). It does not mean that gas companies could not invest in wells, templates and so on. Management could save cost through exercise this option.

4.4.4 Option to Switch Use

Brennan and Trigeorgis (2000) noted that it is flexible to switch from the current input to the cheapest future input, or from the current output to the most profitable future product mix. In the petroleum industry, the product can be converted into gasoline, lubricant or polyester. The market condition may not be always the same. Gas companies could switch to produce different products in different periods, based on the market condition. For instance, it is a cost efficiency way to transport natural gas liquids by vessels since it is expensive to construct gas pipeline infrastructure. On the other hand, figure 4.6 shows the uses of natural gas in terms of the EIA report 2009. There are four main aspects for using natural gas. As shown by figure 4.6, 21% of natural gas is used for generating electric power and 19% is used in residential. This is a new concept of electric generation industry to release the high levels of populations into the air by using the gas.
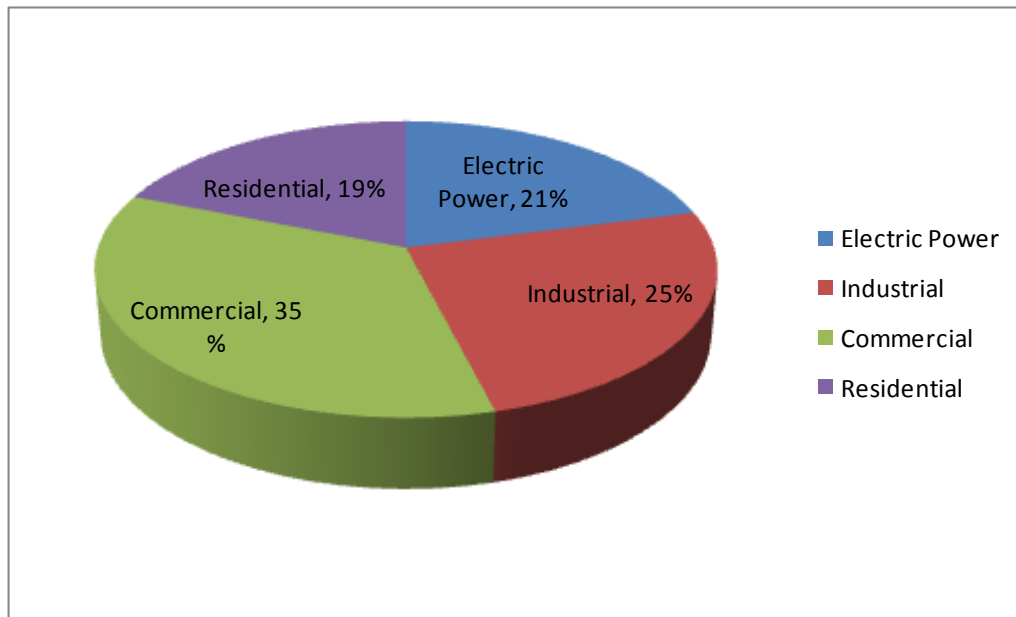
Figure 4.6: Natural Gas Uses in 2009 (Source: EIA-Annual Energy Outlook 2009)

Hence, when the price of electric energy is higher than usual in the market, management may consider investing electrical power stations to onshore processing facilities and developing an energy hub instead of gas hub. It could be a good opportunity to switch to invest in Nyhamna as an energy hub if the investment cost could be lower and get more pay off. However, it is difficult to measure the investment cost and management may need more information to evaluate the value of the option to switch use.

4.4.5 Corporate Growth Options

The main advantage to exercise corporate growth options could open up company's future growth opportunities, especially, in the highly uncertain market. Coming back to the expand option, the opportunity value of the option to expand is negative when the 6.68 - $I_x < 0$. Although the result shows the companies should exercise default or defer options, in the point view of strategy, companies still can choose to invest. The reason is that added value can be achieved in the gas value chain (production, transportation and sales), which may be beneficial for increasing company's competitive advantages in the future.

According to phase 2 development plans of Ormen Lange project, the traditional technology uses a floating platform, fitted with compressor and new technology of compressors is still in the processing of physical tests and running models. Companies exercise corporate growth options can develop new technology to prepare for the future development. The premises in this situation are the new technology that fit for the purpose and is attractive for Ormen Lange Project. Preparing and Investing Nyhamna as a potential hub, the benefits for gas companies and government are hard to be estimated rightl now.

4.4.6 Option to Abandon

Management may also have the flexibility to abandon developing Nyhamna as a potential hub. This option is different from the option to temporarily shut down and restart operation. Once management abandon this project and exchange for its salvage value before the end of its estimated useful life, this project could not restart forever. Considering that the market condition might change in the next year, it is possible that the value of selling a hub's assets on the second hand market may be also fluctuated. Assume the hub's salvage value A is fluctuated over time as follows.
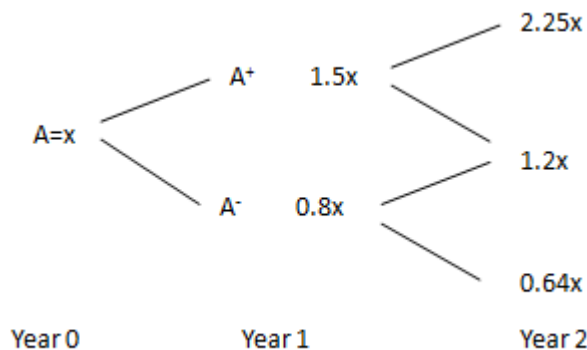
The hub's salvage value A is currently x and it is hard to say whether this value is below or above the hub's value (V=33.4) because we do not have the exact number. The calculations are based on the assumption that the salvage value of this project is x. It is not possible to calculate the exact value. We are trying to find out the possible range of the hub's salvage value. If x is large than NOK 33.4 billion, management could abandon this project immediately. However, if the market condition keeps moving up, it will not be optimal to abandon of developing Nyhamna as a hub in the early stage which in order to get its salvage value. If the market condition keeps going down, management may find that it could be a good solution to exercise this option. For example, if the salvage value 0.8x in

the first year is larger than NOK 25 million (V⁻=25), management may prefer to abandon developing Nyhamna as a hub. In other words, this means that management choose the maximum of the hub's value in its present value V, or its salvage value A, such as

V=33.4

V⁺   50

V⁻   25

Year 0   Year 1
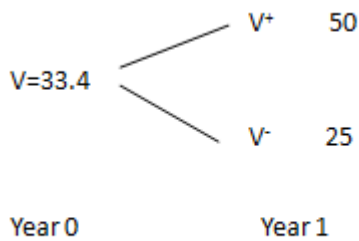
$$E = \max(V, A)$$

$$E^+ = \max(V^+, A^+) = \max(50, 1.5x) = V^+ \quad \text{(Continue)}$$

Based on the equation above, if the management would like to continue developing Nyhamna as a potential hub, the present hub's value should be larger than its salvage value. That means $A^+ < V^+$

$$1.5x < 50$$

We get the result that $x < 33.3$. This means that if the salvage value is less than NOK 33.3 million in the first year, the management will still continue investing Nyhamna as a hub.

Similarly, the management may prefer to abandon this project in the first year when its salvage value is larger than the present hub's value. The equation would be described as follows.

$$E^- = \max(V^-, A^-) = \max(25, 0.8x) = A^- \quad \text{(Abandon)}$$

$$0.8x > 25$$

The result is that $x > 31.25$. When the salvage value is more than NOK 31.25 million in the first year, management will abandon developing Nyhamna as a hub.

Therefore, the value of the investment opportunity (including the value of the option to abandon in the early stage) is then

$$E_0 = \frac{PE^+ + (1-p)E^-}{1+r} - I_0 = \frac{0.4V^+ + 0.6A^-}{1+0.07} - 21.4$$

When the value of the investment opportunity is positive, the project with flexibility to abandon would become desirable.

$E_0 > 0$

$$\frac{0.4V^+ + 0.6A^-}{1+0.07} - 21.4 > 0$$

$x < 6$

Based on the above calculations, when its salvage value is less than NOK 6 million at current year, this project with flexibility to abandon would be approved. In addition, the value of the option to abandon for salvage in year one is therefore

$$\frac{0.4V^+ + 0.6A^-}{1+0.07} - 21.4 - 12 = \frac{20+0.48x}{1.07} - 33.4$$

Since we do not have enough information, it is not possible to calculate this value of the option to abandon.

$$\frac{0.4V^+ + 0.6A^-}{1+0.07} - 21.4 - 12 > 0$$

$x > 32.8$

However, we could know that if its salvage value is more than NOK 32.8milllion, this value of the option to abandon would be positive. In other words, the management would prefer abandon developing Nyhamna as a potential hub at early stage when its salvage value is more than NOK 32.8 million.

Part 5- Suggestions and Conclusion

Compare with the traditional NPV method, real option theory is more appropriate for analyzing high uncertainty projects and it concerns the flexibility during the decision making processes. Six types of real options are analyzed in the decision-making processes, including option to expand, defer, contract, switch, growth and abandon.

In this thesis, we use Ormen Lange Project at Nyhamna as a case and analyze whether Nyhamna would become a potential hub by using different options. Compare to other processing complex, Kollsnes and Kårstø, Nyhamna has both advantages and disadvantages of becoming a hub. Based on the limited data, we quantify the value of Nyhamna as a hub with different options and get a positive net present value NOK 33.4 million (without option), NOK 22.9 million (option to defer) and a possible range of value with other options. According to these results, the possible infrastructure solutions are analyzed in gas pipeline system at Nyhamna and we recommend the following three solutions.

5.1 Recommendations

- The first solution is to exercise option to expand. Management could land Onyx and Luva to Nyhamna and transport gas to UK through Langeled pipeline system. Management may invest new compressors to expand the capacity to 84 million scm at Nyhamna.

- The second solution is to exercise option to defer. Management may wait until new capacity available instead of landing Onyx and Luva to Nyhamna. They may wait until 2021 and land them to an existing hub, Åsgard.

- The last solution is still to exercise option to defer but management could build up a new gas hub instead of Landing Onyx and Luva to an existing hub, Åsgard. They could wait for developing the other two big new gas fields (Victoria and Gro) and develop these four gas fields to be a new hub. However, the initial investment cost of this solution is much higher than the above two solutions.

These three alternative solutions presented above are possible solutions in gas pipeline system at Nyhamna. It is hard to say which one is the best solution for petroleum companies until now. Which alternative solution might be adopted depends on many factors and cost might be the most important factor. Our suggestion is that the management either exercise option to expand, landing Onyx and Luva to Nyhamna (as a hub), or wait capacity available at Åsgard hub until 2021.

5.2 Limitations

Without enough data of cost, we cannot compare all the types of real options in Ormen Lange Project at Nyhamna. This is first limitation of this thesis. Since the project is still in the process of decision making, all the data are confidential to us as students. The value of switch use and growth option could not be analyzed in a quantitative way.

On the other hand, with limited knowledge on Monte Carlo simulation and the lack of data, our thesis could not cover the process of risk forecast accurately. In addition, the value of different options cannot be calculated through Monte Carlo simulation. Hence, there is no opportunity to compare these values of options that whether Nyhamna could become a hub.

5.3 Further development

There is no doubt that real option analysis is useful to deal with high uncertainties in the petroleum industry. It is a good tool for dealing with future decision possibilities and reducing risks in the process of investment.

The challenge of the petroleum industry might to balance between the reduction of greenhouse gas emissions and growing demand for energy in the future. Under this circumstance, the petroleum companies have to upgrade infrastructure, improve wells and develop new technology continually. With the increase of gas price, the petroleum companies need to gradually discover and develop new gas fields to meet uncertain market. One of the most important next steps in this research is to examine the extent to which option is the best solution for both of the petroleum companies and government.

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Appendix--- 1

Questions to Gassco concerning gas infrastructure and hub solutions

1. Describe the strategy for Gassco when they develop a new region of potential gas fields to find the most cost efficient hub system?

2. Can you describe the hub system which has been developed for the Norwegian Sea so far?

3. Describe the cost advantage for developing Nyhamna as a potential hub:

- use of extra capacity in Langeled

- less costly to expand the separation plant

- less costly because of existing infrastructure onshore

- lower costs with new pipelines from new gas fields

4. Åsgard is developed as a hub with extra capacity that was filled up from new fields in a short while. In what sense is Åsgard today a competing hub to Nyhamna in a future scenario?

5. Onyx or Luva or both are potential new fields in a hub. How important are the cost advantages in a hub for developing these new fields?

6. What is the percentage of overcapacity in Langeled today and what are the extra costs to develop alternative levels of extra capacity?

Appendix--- 2

Interview with operation manager of Shell

1. Can you give us a brief story about Ormen Lange Project?

2. What is the main responsibility of Shell in this project?

3. What is the logistics system in Ormen Lange Project?

4. What is the budget of this project?

6. What kind of investment have you done until now in this project?

7. What is the extra investment will be need in this project?

10. Do you plan to invest in a new option? Will it be less costly when integrate the new gas field in the Nyhamna?

11. If considering gas from new field as an option, have you planned for that option?'

12. What has been the main option to adopt the intergradations system?

13. Do you have ex ante plan for extra capacity to make sure it is easy to be expanded?

14. What is your understanding of a hub?

15. What are the reasons to develop the hub system?

16. What is the advantage of developing a hub?

17. What are the uncertainties of developing a hub?

18. Is the hub reliable and cost-efficiency?

19. Have you prepared to integrate for the hub?

20. What is your strategy to develop a hub?

21. What are the large scales effects of the hub?

22. How do you separate the wet parts from gas onshore?

23. Until now, where do you deliver the gas directly to the customers?

24. If there is more than one gas field, will the delivery be safer?

Extra questions

1. What is your main technology challenge now?

2. What is the cost of new gas field development and gas pipelines?

3. What is the unit cost for rich gas, dry gas and NGL (natural gas liquid)?

Appendix--- Definitions

Block

Geographical unit used to identify an area of sea within the continental shelf. a block usually measures 15 minutes latitude by 20 minutes longitude.

Licenses

Physical or legal person has been granted the rights to search for, extract, transport or utilize a petroleum resource.

Operator

The company such as Gassco, on behalf of the licensees, is responsible for the day to day operations of the petroleum enterprise.

Downstream

Collective term for all petroleum operations relate to refining, sale and distribution of products. These include the activities, which take place after oil, or gas leaves the (export) terminal to be processed, refined, transported and sold to consumers.

MPE

Ministry of Petroleum and Energy

NPD

Norwegian Petroleum Directorate

EIA

U.S. Energy Information Administration

Petroleum

Flammable liquid consist of a complex mixture of hydrocarbons.

Resources

Resources are all petroleum deposits that are extractable and saleable according to technical feasibility. The resources are split up into categories according to how mature they are.

Dry Gas

This is a common term for natural gas which contains no liquid hydrocarbons under pressure. It consists largely of methane, but can also contain ethane.

Natural Gas

Natural gas comprises organically-derived, odourless and non-toxic gaseous compounds created by the decomposition of biological organisms. Natural gas contains methane (75-95 percent), ethane, butanes, propane and naphtha.

Rich Gas

This term applies to any blend of dry gas (methane) and NGL (ethane, butanes, propane and naphtha) transported through a pipeline.

LNG

Liquefied natural gas or methane has been converted to liquid phase by cooling it to -163°C. LNG is shipped in special carriers. One tonne of LNG corresponds to roughly 1 400 cubic metres of natural gas in gaseous form under a standard condition defined as an atmospheric pressure of 1.0132 bar and a temperature of 15C. In terms of volume, the ratio between LNG and gaseous methane is 1:625.

LPG

Liquefied petroleum gases consist of propane and butanes which have been converted to liquid phase through a pressure of roughly seven-eight bar or through some cooling. In Norway, LPG is synonymous with propane (95 per cent propane and five per cent butane) because the temperature properties of this gas suit the Norwegian climate. Special LPG carriers are used to ship these products.

NGL

Natural gas liquids are a collective term for various petroleum components which liquefy under small increases in pressure or reductions in temperature. Comprising ethane, propane, butanes and naphtha, and often containing small quantities of heavier hydrocarbons, NGL is shipped in special carriers.

TEG Tetraetylene Glycol

Hydrocarbons

In organic chemistry, a hydrocarbon is an organic compound consisting entirely of hydrogen and carbon.

Oil

Common denominator is for crude oil and other liquid petroleum products.

Scm

The usual abbreviation for standard cubic metre, and a cubic metre of gas under a standard condition, defined as an atmospheric pressure of 1.01325 bar and a temperature of 15°C. This unit provides a measure for gas volume.

Gscm

Abbreviation for giga standard cubic metres, or one billion cubic metres under a standard condition, defined as an atmospheric pressure of 1.01325 bar and a temperature of 15°C. This unit provides a measure for gas volume.

Sm^3

Abbreviation, it is the unit of volume of petroleum. Sm^3 means a standard cubic metre, defined as atmospheric air pressure (1.01325 bar) at 15°C.

Mill.   Million
Bill.   Billion

Resource: Gassco, Ministry of petroleum and energy, National Physical Laboratory