




University of  
Stavanger

Faculty of Science and Technology

## MASTER'S THESIS

Study program/ Specialization: Risk Management / Offshore Safety	Spring semester, 2012  Open
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Titel of thesis:  Project Risk Management. A Study on the risk management approach utilized by ConocoPhillips Capital Projects	
Credits (ECTS): 30	
Key words:  Project development Project management Project risk Risk modeling Risk management ConocoPhillips Project	Pages: 122  Stavanger, 01/06-20122





# Project Risk Management

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*A study on the risk management approach utilized by ConocoPhillips Capital  
Projects*

**by Anders Bjelland**

Master Thesis in Offshore Risk Management  
Stavanger 2012



University of Stavanger

Faculty of Science and Technology  
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*“It’s what you do when you don’t have to do anything at all that gets you where you want to be when it’s too late to do anything about it.”*

*Benjamin Franklin*

## **Abstract**

The oil and gas industry on the Norwegian continental shelf is currently experiencing a record-breaking activity level and optimism fueled by high oil prices and major new discoveries made during 2011. The total investments have been at an all-time high the last couple of years and it will most likely continue to rise due to the amount of modification and redevelopment projects, as well as new field developments.

However, with every great opportunity there are normally accompanying threats that need to be managed in order to ensure success. In such a heated climate as experienced in the oil and gas industry, there are many potential pitfalls related to infrastructure development projects, which are best exemplified by the reported cost overruns and delays affecting the Yme-redevelopment project.

This report asks the question whether the current risk management system utilized by ConocoPhillips is providing value in the execution of major projects by assisting the projects in steering clear of threats with the potential to cause serious cost overruns and schedule delays.

To answer the question, a common background of knowledge related to project and risk management is outlined, before introducing ConocoPhillips as a company, the worldwide project organization and the Norwegian business unit. With the context set, an overview of the project development process is given before going more into the details on the risk management process, the risk analysis modeling and the way risk management is tied into the overall development process.

Based on analysis of current practices, processes and internal requirements, it becomes clear that ConocoPhillips has an extensive and rigorous system set up in order to gradually mature projects until they are ready to be implemented. Risk management plays a key part in the development process where a lot of focus and resources are used to build highly advanced integrated cost and schedule risk models generating P50 values of both project cost and completion dates that are used for project sanction.

The report comes to a conditional positive conclusion, where the risk management system in light of the overall development process is deemed to create value in its contribution of providing predictability in terms of project cost and schedule compared to the project premise. However, although predictability has an inherent value for the project owners and government, the full benefits of risk management are not being realized.

To unlock the full potential of risk management at ConocoPhillips, this report makes recommendations intended to shift the focus of risk management from the current reporting and verification role, to promoting the use of risk analysis in the early concept-screening phase and in the wider context of value based decision-making that must take into account more than just cost and schedule uncertainty.

*“The first step in the risk management process is to acknowledge the reality of risk. Denial is a common tactic that substitutes deliberate ignorance for thoughtful planning.”*

*Charles Tremper*

## Preface

This report represents the final work of my master degree in risk management with specialization in offshore petroleum industry at the University of Stavanger. The study program is cross-functional in terms of its focus on engineering subjects as technical safety and reliability analyses on one side and management and economic subjects as project management and investment appraisal on the other side.

I have previously completed a bachelor degree in civil engineering (2008) and a master degree in industrial economics (2010), both at the University of Stavanger, where the thesis for the master degree was written on the topic of the connection between risk and activity levels. Parts of the rather philosophical and theoretical discussions in that report are to some extent reflected in this thesis, especially in the chapters related to perception of risk and probability theory.

This thesis represents how risk management is handled within the project organization of ConocoPhillips based on the view that I have acquired during my 18 months working for the company, where most of the time has been spent in relation to the project-risking group. My motivation for choosing the topic for this thesis is split in two, represented with the desire to learn and get a better understanding of how we manage risk and to give something back in terms of advises on how we could improve our current practice.

The report tries to incorporate many different aspects of project management and risk management fundamentals both in general and specifically for ConocoPhillips, where in my view, a lot of background information is required to set the appropriate context. The resulting consequence is a report that is rather wordy, but hopefully balanced with sufficient structure to enable readers to home in on the areas of interest. I have learned a lot about project management, risk management, ConocoPhillips as a company, the capital projects management system and especially risk management in capital projects by writing this thesis, and I truly believe that the effort and resources put into the work will quickly pay off, both on a personal level as well as for the company.

With that said, I would like to express my gratitude to all my colleagues in supporting my effort and providing input and their thoughts throughout the process of writing the thesis. Special recognition goes to Ron Allred for his support enabling me to focus on writing the thesis, and to Nathan Langton for his invaluable contribution as a discussion partner and reviewer of the finished product.

Stavanger 1<sup>st</sup> of June 2012



*“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science.”*

*Lord Kelvin*



# Contents

<b>Abstract .....</b>	<b>III</b>
<b>Preface.....</b>	<b>V</b>
<b>Contents .....</b>	<b>VII</b>
<b>Figures .....</b>	<b>X</b>
<b>Tables .....</b>	<b>XII</b>
<b>Abbreviations .....</b>	<b>XIII</b>
<b>1 Introduction .....</b>	<b>15</b>
1.1 Background.....	15
1.2 Objective.....	17
1.3 Problem statement.....	17
1.4 Report structure .....	18
1.5 Methodology .....	18
<b>2 Project &amp; Project Risk Management Foundation .....</b>	<b>19</b>
2.1 Terms and definitions.....	19
2.2 Perspectives on risk.....	20
2.3 Perspectives on probability .....	21
2.4 Perspectives on project .....	23
2.5 Project phases .....	25
2.6 Deterministic project assessment .....	28
2.7 Advanced project assessment methods.....	34
2.8 Project risk management .....	43

<b>3</b>	<b>ConocoPhillips .....</b>	<b>50</b>
3.1	General introduction.....	50
3.2	History of ConocoPhillips .....	52
3.3	Ekofisk .....	53
3.4	Corporate organization structure .....	54
3.5	Project Development & Procurement .....	55
3.6	Norway Capital Projects.....	57
3.7	ConocoPhillips split into two companies .....	61
<b>4</b>	<b>Projects the ConocoPhillips way .....</b>	<b>62</b>
4.1	A governing framework .....	62
4.2	Authority Limitations Manual .....	63
4.3	Project Authorization Guidelines.....	64
4.4	Capital Project Management System.....	65
4.5	Stage gate process .....	68
4.6	Project engagement process and reviews .....	70
4.7	Project manager versus the project integration manager .....	71
<b>5</b>	<b>Project Risk Management in ConocoPhillips .....</b>	<b>72</b>
5.1	Risk management in CPMS .....	72
5.2	Project execution plan & risk management.....	75
5.3	Risk management key deliverables.....	76
5.4	ConocoPhillips risk management process .....	77
5.5	Roles & responsibilities .....	80
5.6	Risk analysis results and contingency .....	83
5.7	Contingency breakdown report.....	84

<b>6</b>	<b>Risk Analysis Model Review .....</b>	<b>85</b>
6.1	Model overview & interfaces .....	85
6.2	Main inputs.....	86
6.3	Probabilistic model parameters .....	91
6.4	Model results.....	97
6.5	Risk analysis tool suite.....	100
<b>7</b>	<b>Discussion .....</b>	<b>101</b>
7.1	Value adding contributions of risk management.....	101
7.2	Benefits of detailed Monte Carlo simulation .....	106
7.3	Project team incentives.....	107
7.4	Real content or just padding? .....	108
7.5	Predictability versus efficiency.....	110
7.6	Capex versus value .....	111
<b>8</b>	<b>Recommendations .....</b>	<b>112</b>
8.1	Project organization .....	112
8.2	FEL stage-gate process .....	113
8.3	Risk management process.....	113
8.4	Risk analysis .....	114
8.5	Risk organization .....	115
<b>9</b>	<b>Summary &amp; Conclusion .....</b>	<b>116</b>
<b>10</b>	<b>Bibliography .....</b>	<b>118</b>

## Figures

Figure 1-1: Development of Investment on the NCS (Data Source: SSB).....	15
Figure 2-1: Project as a part of the overall business development.....	25
Figure 2-2: Simple project phase diagram.....	26
Figure 2-3: Accrued costs vs. the ability to influence the project.....	27
Figure 2-4: Cost of making changes vs. the ability to make changes.....	28
Figure 2-5: Exploration & Production Development Cash Flow.....	29
Figure 2-6: From project objective to the activity level.....	31
Figure 2-7: Basic elements in creating a project schedule.....	31
Figure 2-8: Critical Method example schedule network, critical path in green.....	35
Figure 2-9: PERT example schedule network, critical path in green.....	37
Figure 2-10: Primavera Risk Analysis Monte Carlo Simulation setup.....	39
Figure 2-11: Monte Carlo Simulation Results Graph.....	40
Figure 2-12: Symmetrical distribution.....	41
Figure 2-13: Skewed distribution.....	42
Figure 2-14: ISO Risk Management process.....	45
Figure 2-15: PRAM process flow.....	47
Figure 2-16: PRAM process, example of parallel and iterated phases.....	48
Figure 3-1: Hydrocarbon Value chain Example (Source: ConocoPhillips).....	50
Figure 3-2: ConocoPhillips Production Summary (Source: ConocoPhillips 2011).....	51
Figure 3-3: ConocoPhillips Exploration & Appraisal Portfolio (Source: ConocoPhillips 2011).....	51
Figure 3-4: ConocoPhillips, Mergers and acquisitions (Source: ConocoPhillips 2011).....	52
Figure 3-5: NPD Field resources overview.....	54
Figure 3-6: ConocoPhillips Organization Structure.....	55
Figure 3-7: Project Development & Procurement Organization.....	56
Figure 3-8: Portfolio of PD&P E&P Projects (Source: ConocoPhillips 2011).....	57
Figure 3-9: NCPs double line of reporting.....	58

Figure 3-10: NCP Matrix organization structure .....	59
Figure 3-11: Greater Ekofisk Area Field Map .....	60
Figure 4-1: Governing framework for projects .....	62
Figure 4-2: Investment authority hierarchy .....	63
Figure 4-3: CPMS cube (Source: ConocoPhillips) .....	65
Figure 4-4: CPMS Document Hierarchy .....	66
Figure 4-5: PD&P main goals (Source: ConocoPhillips).....	67
Figure 4-6: ConocoPhillips FEL stage gate process (Source: ConocoPhillips) .....	68
Figure 4-7: FEL and Review process (Source: ConocoPhillips).....	70
Figure 4-8: PM versus PM (Source: ConocoPhillips) .....	71
Figure 5-1: Risk Management Process.....	77
Figure 5-2: Project Risk Roles & Interfaces (Source: ConocoPhillips).....	80
Figure 5-3: Extended Project Risk Management Personnel .....	82
Figure 5-4: Contingency as part of the total cost .....	83
Figure 5-5: P50 & Contingency versus deterministic cost (Source: ConocoPhillips) .....	84
Figure 6-1: Model overview and Interfaces.....	85
Figure 6-2: Risk mapping in Pertmaster.....	90
Figure 6-3: Risk event illustration .....	94
Figure 6-4: Cost Model Iteration Example .....	96
Figure 6-5: Risk analysis tool package.....	100
Figure 8-1: Suggested Organization Structure .....	112
Figure 8-2: Risk process suggestion & FEL Stage gate process .....	114

## Tables

Table 2-1: Cost estimate example .....	33
Table 2-2: Critical Path Method example data .....	35
Table 2-3: PERT example data .....	37
Table 2-4: Monte Carlo Simulation Results Table .....	40
Table 2-5: The Six W's .....	44
Table 2-6: PRAM Phases and its Purposes .....	49
Table 4-1: Project Authorization Guidelines Governing Framework .....	64
Table 4-2: Accountability for using CPMS(Source: ConocoPhillips) .....	65
Table 4-3: Interpretation of PD&P goals .....	67
Table 5-1: Risk Management Deliverables .....	76
Table 6-1: Cost loading matrix .....	89
Table 6-2: Cost Variance Example .....	93

## Abbreviations

AFD	Approval For Development
AFE	Approval For Expenditure
AFF	Approval For FEED
ALM	Authority Limitations Manual
BOED	Barrels of Oil Equivalent pr Day
BU	Business Unit
Capex	Capital Expenditure
CBR	Contingency Breakdown Report
CCE	Current Cost Estimate
CEO	Chief Executive Officer
COP	ConocoPhillips
CPM	Critical Path Method
CPMS	Capital Project Management System
E&P	Exploration & Production
FEED	Front End Engineering and Design
FEL	Front End Loading
FIC	Facilities Installed Cost
GU	Guidelines
HAZID	Hazard Identification
HSE	Health, Safety and Environment
ISO	International Organization for Standardization
JPD	Justification and Premise Document
LLN	Law of Large Number
MHR	Man hours
MS	Management Standard
NCP	Norway Capital Projects
NCPMS	Norway Capital Projects Management System
NCS	Norwegian Continental Shelf
NGL	Natural Gas Liquids
NOE	Networks of Excellence
NPD	Norwegian Petroleum Directorate
NPV	Net Present Value
PAG	Project Authorization Guidelines
PBS	Physical Breakdown structure
PD&P	Project Development & Procurement
PDO	Plan for Development and Operation
PEP	Project Execution Plan
PERT	Program Evaluation and Review Technique
PIM	Project Integration Manager

PM	Project Manager
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMT	Project Management Team
POL	Project Objectives Letter
PR	Procedure
PRAM	Project risk analysis and management
QA/QC	Quality Assurance / Quality Control
QRA	Quantitative Risk Analysis
SAGD	Steam Assisted Gravity Drainage
SSB	Statistics Norway
SVP	Senior Vice President
TIC	Total Installed Cost
USD	United States Dollar
VBA	Visual Basic for Applications
WBS	Work Breakdown Structure



# 1 Introduction

## 1.1 Background

Total investment on the Norwegian continental shelf (NCS) to support exploration and production of hydrocarbons is expected to reach an all-time high in 2012. According to Statistics Norway (SSB), total investments are estimated to reach 186 Billion NOK, which will be a solid jump upwards of 40 Billion NOK from the previous record set in 2011.

As illustrated in Figure 1-1, there has been a small but steady upward trend in the investment level from 1985 until the start of the new century. It's only in the last six years that the investment level has really seen a dramatic increase going from 95 Billion NOK in 2006 to the forecasted 186 Billion NOK in 2012. A part of this increase is most likely due to the rising cost level experienced in the oil and gas industry, which seems to be completely detached from the inflation levels seen onshore. At the same time, serving as a partly explanation for the cost rise, the activity level has never been as high in "modern time" as it is now, and there are most likely more records to be set in the next 10 years to come. The industry optimism is supported by the simplest and most fundamental economic concept; supply and demand.

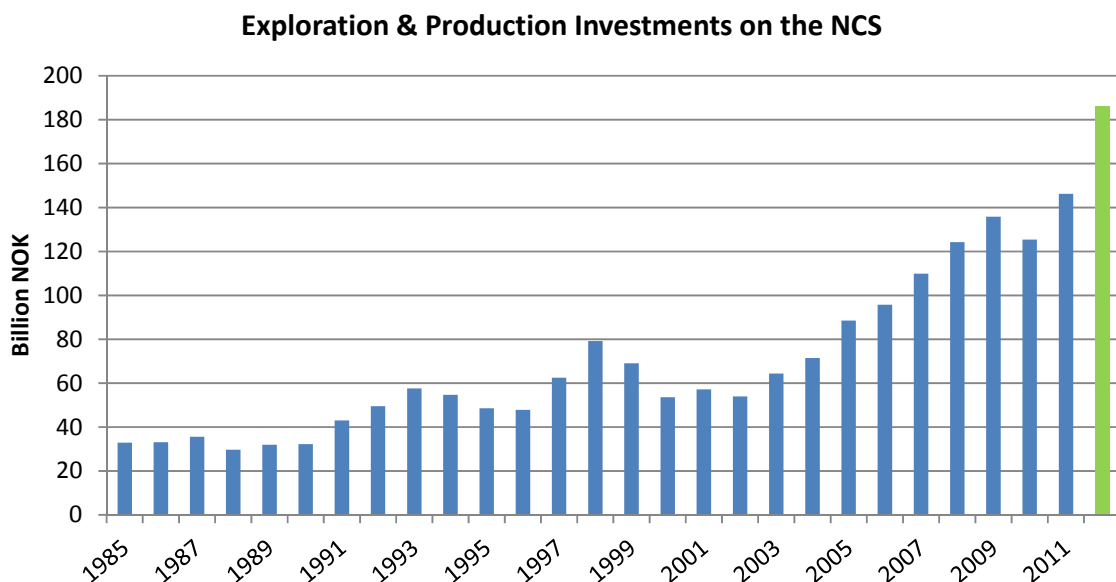


Figure 1-1: Development of Investment on the NCS (Data Source: SSB)

In 2011 the investments was split with approximately 19 % on new exploration wells, 4 % on onshore facilities and pipelines, 26% on new field developments and the remaining 52 % going to continued development of fields already in production, where the latter category was heavily dominated by the Ekofisk, Troll and Åsgard fields.

Investment in new field developments represented by Goliat and Gudrun will reach its peak in 2012, while the existing field development projects with Ekofisk South and Eldfisk II in the lead will continue to ramp up its spending.

All these current projects and major modification & maintenance contracts awarded for the near time future are by themselves straining the supply base towards its capacity level. On top of this, 2011 was the first year since 1997 where the reserves addition from successful exploration activities on the NCS exceeded total production. With 52 exploration wells started during the year, and major discoveries represented by Johan Sverdrup, Skrugard and Norvarg, the optimism is back, and major new field development projects will continue to drive investment on the NCS beyond all previous records, and secure a long term demand in the supply industry.

The biggest challenge in meeting the demand growth of oil and gas infrastructure is seen in the corresponding capacity of the supply industry. There is a widespread shortage of qualified engineers in the market that is not likely to be resolved within the next 10 years. The supply shortage will have the effect of postponing the development of some new fields, contribute to the self propelling spiral of increasing cost level and as a direct consequence stop the development of some marginal fields and enable earlier retirement of existing producing assets.

For the Norwegian society as a whole, the constrained development and subsequent increased cost level will in reality result in a reduction of wealth for the government and the general population via reduced tax on petroleum production profit (78% rate). This wealth will mainly instead be transferred to the employees in the oil industry and contribute in creating wider gaps in society and class disparity.

From a government perspective there are two major concerns related to field development; total development & production costs and field recovery factor, while for the license owners it all boils down to the net present value, adding production profile and oil price as sensitive parameters in the decision analysis.

The constrained development case will most likely have a negative impact on all the above parameters except oil price. In this scenario, it is in the society, the government and the oil companies' best interest that the projects are planned and executed as efficiently as possible.

Significant delays and cost overruns are definitely realistic outcomes if the project is not managed properly. The best current illustration of this is seen in the Yme field development project in the southeastern part of the North Sea. The field was originally produced and then abandoned by Statoil in 2001 before a new license group with Talisman Energy in the lead took over with a plan to further exploit the resources in the ground by using a new-built jack-up production platform. When the original “Plan for Development and Operation” (PDO) was approved in 2007 it was premised that the platform would cost 4.7 Billion NOK and first oil was expected in January 2009. Over three years delayed, the platform is still undergoing major system modification and the current announced cost is approximately 12 Billion NOK. Issues causing this delay are; the deviation between design and as built, inconsistencies between material specification and installed materials and the vulnerability for wave-induced resonance. The mentioned issues are all trademarks of poor project management and a lack of project risk management. As a result of the recently discovered resonance problems, some commentators have actually speculated that the platform might never be put in production at all.

With high base costs, an increasing number of inexperienced engineers, increasing project complexity, stakeholder demand for fast track development and supplier industry incentives, the traditional project organization is stretched to the limit of its capabilities trying to manage the modern project. As a result, there is a growing demand for risk management providing project organizations with insights to the uncertainties, help to navigate clear of threats and to take advantage of the opportunities that come one’s way to enable an efficient project execution that is in both the society and the owner’s best interest.

With the stage set, this report will focus on and analyze the project risk management approach that is utilized by ConocoPhillips Norway and touch base with a broad spectrum of key issues related to project risk management that should be of a general interest.

## **1.2 Objective**

The objective of this report is to give a contribution to how project risk is analyzed and managed in order to effectively execute a project to the best of both owners and society.

## **1.3 Problem statement**

1. Is the current risk management system applied by ConocoPhillips Capital Projects adding value to the organization and society by improving the delivery of major infrastructure projects?
2. What can be done to improve the risk management approach in the future?

In this context, risk management is understood by how one identifies, analyzes and responds to risks.

## **1.4 Report structure**

The report will be split in six parts as shown in the list below.

1. Outlining a project and a risk management foundation in which the rest of this report will be based upon
2. A general introduction to ConocoPhillips as a company and the project organization to set the stage for later discussions and assessments
3. General overview of how projects are managed within ConocoPhillips
4. In-depth description of the risk management process utilized by ConocoPhillips
5. Review of the statistical modeling used to support the risk management process and the tool package supporting this
6. Finalizing discussion to bring all the various elements together and see what can be done in the future to improve the current practice

## **1.5 Methodology**

This report will primarily use qualitative methods, with process analysis of the risk management system as key technique, in addition to document analysis of literature and papers from recognized authors.

Expert opinions in relation to formal and informal interviews will be a direct part of this report and most likely indirect in the way the author will be influenced by the different views. In an effort to get the most unbiased opinions as possible, all reporting of this will be done anonymous.

This report will utilize data and information that is either publicly available or not deemed to be confidential to ConocoPhillips. Where this is not possible to achieve, re-writes will necessarily have to be done and accompanied by a disclaimer.

## 2 Project & Project Risk Management Foundation

To be able to communicate effectively and to ensure a common understanding of complex and integrated challenges and issues, it is necessary to provide context, knowledge and interpretation of key concepts. For some readers this might be a bit redundant, while others hopefully become stimulated and exposed to new thoughts.

### 2.1 Terms and definitions

The following are key definitions used throughout this document. Quoted definitions are selected by the author on the basis of succinctness and alignment with the author's own understanding.

#### **Risk**

Risk is defined as "the combination of potential future events and their associated uncertainty" (Aven, et al., 2008).

Risk should then be expressed within the perspective (A, C, U, P, K) where:

**A** expresses potential future events

**C** is the potential consequences of these events

**U** is the associated uncertainty for both **A** and **C**

**K** is the background knowledge in which the assessment is based on

**P** is the analyst's probability for **C** given **K**

#### **Probability**

Probability is "a man-made construction of thoughts that expresses the analyst's degree of belief about the outcome of a future event". The definition is based on bayesian theory and the assumption that underlying objective probabilities does not exist (Rausand, et al., 2009) and (Aven, 2007).

#### **Project**

A project is "a temporary effort undertaken to create a unique product whilst constrained by cost, time and resources". Based on project definition given by (International Organization for Standardization, 2003) and (Project Management Institute, 2008)

For this thesis, the term "project" will in most cases be limited to the activities leading up to the delivery of the constructed object to the project owner/operational department. Most issues related to the entire life cycle of the project object are outside the scope of this thesis.

**Project owner**

An individual, government, company or a part of an organization that is paying for the project and retains the rights to the project object.

**Project manager**

The person within the project team that is steering the project on a day-to-day basis, and that is ultimately responsible for delivering the project according to the expectations set forward by the project owners.

**Project phases**

A project can be structured into phases over its lifetime, with approval gates between each phase requiring a go or no go decision from the project owners. Project phases can then be viewed as a risk management exercise in balancing the resources used to mature the project over time while owners retain residual control of major decisions to ensure that the right projects are undertaken.

**Project risk**

A project risk is defined as “the combination of potential future events and their associated uncertainty that has the potential to affect the project in its effort to reach its objective”.

## 2.2 Perspectives on risk

What is risk? If you interview ten different risk management professionals, you might end up with ten answers where some are fundamentally different from one another while others just has some small discrepancies between them.

There are several reasons for this; one of the obvious explanations has to do with risk management being a relatively young field that has, and still is, going through a phase of rapid development. A second explanation for the wide gap in interpretation and definitions has to do with risk being a man made concept that is not tied directly to any observable features of the universe.

One definition of risk that is often found utilized in every day literature and news articles is different variants of “consequence x probability”. This perspective is oriented towards the statistical expected value of the different outcomes associated with an event.

Serving as an example of where “consequence x probability” is an adequate definition of risk, one can look to the different gambles offered by the average casino. From a casino’s perspective, where you have full control of the different outcomes and get to repeat each game n number of times each day, one only has to consider the expected value. The small positive house advantage will make sure that the casino in the long term prevails.

As illustrated above, the expected value perspective is in some rare cases an adequate definition of risk, but as a generic definition, it is much too narrow as will be illustrated by the following example:

With the same average casino in mind, what happens if the Norwegian Government Pension Fund sits down at the table and offers the following game? The pension fund will draw one card from a normal stack of cards. If the card is black or ace of hearts, the casino will win, while the pension fund will win in case of all the remaining outcomes. The game will only be played once, and any bets made by the pension fund in advance of the draw will either be taken by the casino or matched and given back to the pension fund. The pension fund seeks an "all in" gamble bringing 3 500 Billion NOK to the table.

The absurd gamble has a positive expected value of 134, 6 Billion NOK for the casino, but does this really mean anything? In this case, the casino either wins 3500 Billion NOK that would be the prize of the century, or it loses 3500 Billion NOK and goes bankrupt. It quickly becomes obvious that the expected value perspective is not valid in this case.

The risk definition this report is based on (A, C, U, P, K,) is much wider and tries to incorporate the uncertainties related to the potential future events and the potential outcomes of these events. This perspective needs to be incorporated in both the analysis and communication of risk.

## **2.3 Perspectives on probability**

How one chooses to define probability and transfer the understanding into practical applications has an implication on how risk can be analyzed and what to include in the analysis. While there are several perspectives on probability to choose from, the classical and bayesian theories are widely regarded as the most common ones.

### **2.3.1 Classical perspective**

The classical perspective, or relative frequency theory which it is also known as, is based on Bernoulli's (1645-1705) ideas and the law of large numbers (LLN), with the assumption that there exist an underlying true probability for a future event to occur, and that this probability can be found by conducting an infinite number of trials. The probability given from an analysis conducted in such a regime should then be interpreted as the analyst's best estimate of the underlying real value. A result of this is that the uncertainty in the analysis is viewed as the difference between the estimate and the underlying truth. In other words, the truth is out there, it is just a matter of discovering it (Aven, 2007).

To be able to provide probabilities in a classical theory regime for practical applications it seems to be a prerequisite that one either has complete knowledge about the event one are seeking

to describe or has access to large amounts of relevant data. These prerequisites are normally fulfilled for simple games with a finite number of outcomes and a strict, predetermined game play. Going back to the one draw card gamble between the casino and the pension fund, it is easy to calculate that the casino has a 27/52 chance of winning, while the pension fund has a 25/52 chance of winning. Complete knowledge of a game is possible, but it is unrealistic as an assumption when analyzing major development projects. It is simply impossible to know the probability of facing a major design change halfway through the construction phase.

When analyzing project risk, one is normally faced with risks that is one of a kind and tied to a specific project where there is little or no relevant data to base probability calculations on. In the classical perspective then, there is not a whole lot an analyst can do without a proper dataset, resulting in paralyzed analysts and project managers incapable of action.

### **2.3.2 Bayesian perspective**

Bayesian or subjective probability theory is often viewed as a counterpart to the classical perspective. The theory was first introduced early in the 1900's and has over the last 30 years gotten an increasingly stronger foothold amongst risk management professionals. In Bayesian probability theory, there exists no real underlying probability for an event to occur, only the analyst's degree of belief. In this paradigm, there is no concept of uncertainty as in the classical perspective. The probabilities presented for the potential events and outcomes of these events is in itself an expression of the analyst's uncertainty towards what will happen in the future (Aven, 2007).

In the Bayesian framework, a probability assessment of 90 % for an event to occur is a representation of the analyst's uncertainty about what the future might bring that can be compared to draw a black ball from an enclosed urn with nine black balls and one white ball (Aven, 2007).

With Bayesian theory, one is not limited to assessing phenomena where one has complete knowledge or a vast amount of data. Other and often more useful knowledge bases such as expert judgments can be used as input in constructing one's degree of belief towards future events, enabling risk analysis of any thinkable phenomena, with or without quantitative data. The quality of the analysis will as always depend on the analyst's credibility and knowledge.

### **2.3.3 Probability perspectives and objectivity**

Supporters of the classical perspective will often criticize the Bayesian perspective for being subjective and just expressing one's opinion, while at the same time claiming objectivity for the classical perspective since it is based on pure data. Both points of reasoning are flawed.



In bayesian theory there exist no real underlying probabilities, hence there is no meaning of discussing objectivity. It is just the analyst's degree of belief, where probability is an abstract man made construction of thoughts (Rausand, et al., 2009) and (Aven, 2007).

For the classical perspective, claiming objectivity is a speculative and unfounded move. Even with the support of data to base the assessment on, there will always be human involvement in the processes leading to the dataset used for the analysis.

Some questions to reflect upon objectivity:

- Will an assessment of contractual risks for a project that is based on an experience database with actual risk events and impacts lead to an objective probability that can be used for the current project?
- Will the objectivity be sacrificed if other pieces of information that is not as easily quantifiable is included in the analysis? E.g. changes made to the standard contracts to reflect past experiences.
- What about objectivity in deciding which data to collect into the database, and the way this is done?
- Is objectivity maintained when choosing a method to analyze and present data?

To conclude, supporters of the bayesian perspective does not believe in objective probabilities, while the supporters of the classical perspective does not have any well-founded basis to claim objectivity on (Bjelland, 2010).

## **2.4 Perspectives on project**

### **2.4.1 Project definitions**

As for risk, there has been a rapid development of, and a wide variety in the definition of a project, where the definitions spread in complexity and scope as shown below.

Hetland talks about three different project theory paradigms in the period from 1960 until 2000, where he is referring to them as (Hetland, 2003):

1. *Project as a task*
2. *Project as an organization form*
3. *Project as an intentional social construction of reality*

While the two first paradigms are described in a tangible manner, it quickly becomes more of a philosophical approach in the third, which forms the basis of Hetland's rather lengthy definition of what he refers to as the project construction where he focuses on

- *Project tasks as unique, final and multidisciplinary*
- *Project tasks being executed and managed by temporary and virtual organizations established for the project purpose to protect the stakeholder's best interest in the project*
- *Project stakeholders are acting as focused principals and agents being intentionally, but partly rational*

A more concise view of what makes a project is given in "ISO 10006: 2003, Guidelines for Quality Management in Projects" defining a project as a

*"Unique process consisting of a set of co-ordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including constraints of time, cost and resources."* (International Organization for Standardization, 2003)

The Project Management Institute offers an alternative to ISO 10006 with their "Project Management Body of Knowledge" (PMBOK) where project is simply defined as

*"A temporary endeavor undertaken to create a unique product or service."*  
(Project Management Institute, 2008)

Of the three definitions given above, Hetland's is perhaps leaning too much over on the philosophical side in addition to being rather lengthy and cumbersome. Narrowing in on ISO and PMI, the most obvious differences between them is ISO's view of project as a process and its focus on constraints. PMI also includes "unique" in its definition implying that a project has to be one of a kind.

Relating back to infrastructure projects in the oil and gas industry, both PMI and ISO have elements in their definition that builds up to the characteristics that the industry projects are known for. This report will therefore utilize a combination of the two definitions in order to best reflect upon these characteristics.

#### **2.4.2 Project as a part of the overall business development**

A major oil field (Johan Sverdrup) was discovered in the North Sea in 2011, where Statoil has been assigned the role as operator for the coming field development. Using this field development as an example, where does the project start and where does it actually end?

Some will undoubtedly refer to the entire life cycle of Johan Sverdrup from exploration to decommissioning as a project, while others might only think of the actual construction phase as

the project. The take back from this is that it depends on the point of view and ones definition of a project.

With the project definition utilized for this thesis, and the focus put on risk management and its value in improving the delivery of infrastructure projects in terms of cost and schedule. “The project” should be seen as the first part of the overall business development stretching from early concept screening until the constructed object is handed over from the project organization to the operational organization. An illustration of where the project sits in the business development is shown in Figure 2-1.

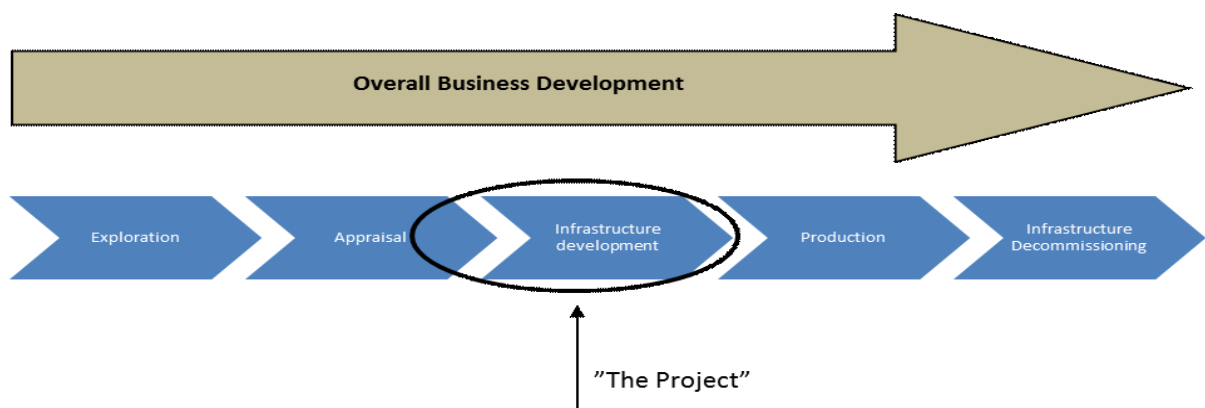


Figure 2-1: Project as a part of the overall business development

## 2.5 Project phases

A project consists of different sub-phases that constitute what we define as the project. Even though it does not always look like it, the concept of project phases is normally present to some degree in all type of projects. In many cases when projects are experiencing major cost overruns or schedule delays, how the project is structured from A to Z in phases is often given the blame and pointed towards as one of the reasons for the negative outcome. Therefore, structuring projects into different phases can be seen as a way of managing the risks related to a project.

### 2.5.1 Common project phases

Serving as a simple illustration of phases, one can split a project into three parts consisting of an identify phase, a planning phase and an execution phase as shown in Figure 2-2.



Figure 2-2: Simple project phase diagram

In this example the Identify phase includes the creative parts of a project, where the need for something or an idea is turned into a more or less tangible conception of what one wants to achieve with the project. Entering into the planning phase, the focus is now put on how to complete the project, while the final execute phase is all about realizing the plan and completing the project.

Are variants of this structure present in all projects? In its basic simplicity, there is always some level of progress from an idea to the final result. The result does not just appear out of nothing. However, the different phases does not need to be specifically explicit or formal, and it might sometimes be difficult to separate them, while in other cases they are quite defined and separated by project milestones requiring approval to proceed into the next phase.

Keeping the examples to construction projects, one can look at smaller home improvement projects as typically having low degree of structure and consisting of phases that merge into each other without too many decision gates. Still, there will necessarily always be some sort of evolution from the basic idea of doing something, into a concept of how the result should look like, and then actually doing the construction work. What is often missing is the crucial planning phase.

On the other side of the scale in terms of structuring projects, one can look at the Norwegian road administration and how they together with the government develop and fund new projects. As a sarcastic comment it has often been said that:

*“For a normal road in Norway, it takes an equivalent of an entire working lifetime from the idea of a road is hatched until it is completed, and by the time it is ready for use, there is no longer the need for it.”*

The road administration has five project phases which all fits into either the identify or the planning phase as mentioned earlier, where each phase might stretch over several years depending on the political climate at the time and the number of different alternatives and consequence studies undertaken. Even with all these phases completed, the project still has to go through a tender process and a detail-engineering phase before construction can commence.

In addition to the lengthy process leading up to the start of construction, bigger projects tend to progress unnecessarily slow due to how the project is financed over the National Budget from year to year, not allowing the road administration or the contractor to plan and build all parcels in one go.

## 2.5.2 Project phases as owners risk management

What is achieved by explicitly and formally structuring a project into different phases, where each phase requires some level of interaction and approval from the project owners in order to proceed to the next phase?

By going through different phases, the project is forced to mature and develop according to the formalized structure, which in many cases is equivalent of conducting more studies in advance, sorting out different alternatives and basically making many of the mistakes on paper instead of in the detail engineering or construction phase.

There is often a decision that has to be made by the project owners after each project phase whether to proceed or not. This implies that the project is only funded for one phase at a time, giving the owners residual control and ability to postpone the final “go or no go” decision to a later point in time, and to base their decision on what is hopefully a more well worked foundation.

A common illustration of the points above is given in Figure 2-3 where one can see that in the early phases of a project, the maneuverability to influence the project and make changes is high while at the same time the accrued cost is relatively low. As the project moves toward the execution phase the ability to influence the project becomes smaller while the cost is increasing towards the final sum.

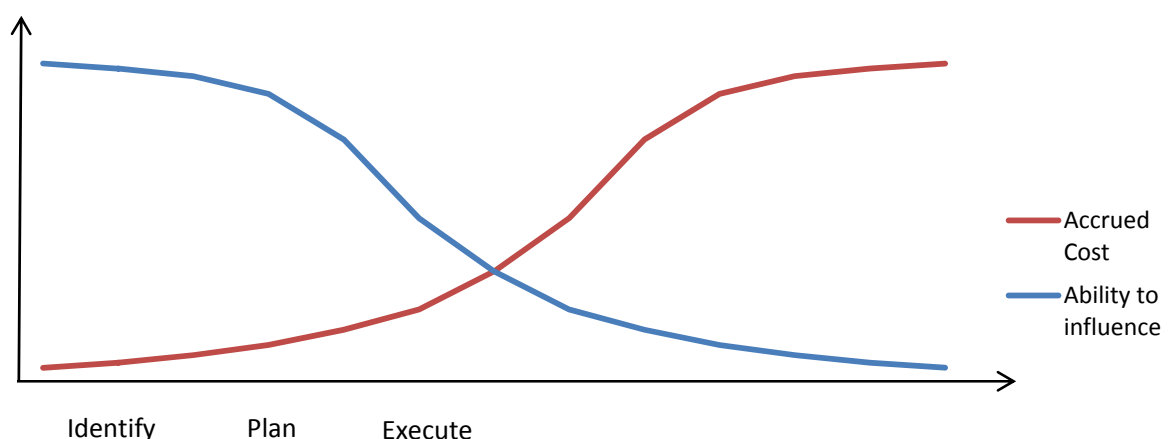


Figure 2-3: Accrued costs vs. the ability to influence the project

A real paradox exists when it comes to project maturity, and this can be illustrated in a similar way as above. As shown in Figure 2-4, the ability to make changes to a project declines all the way towards the end of the project while the associated cost of actually making a change increases dramatically throughout the project. The paradox is that the most important decision related to the outcome of the project is often taken in the earliest phases when information quality is at its lowest and there are not a whole lot of resources allocated to work the different issues.

Based on the arguments above, structuring a project into phases is in fact a risk management exercise in balancing the resources used to mature the project over time while owners retain residual control of major decisions to ensure that the right projects is undertaken.

As illustrated with the examples of home improvement projects and the Norwegian road administration, the resources spent in the early phases needs to be balanced with the additional value it provides for the overall project. A conclusion to draw of this is that the law of diminishing returns seems to be quite valid when it comes to planning, many projects are suffering from too little planning, while others are suffering from too much.

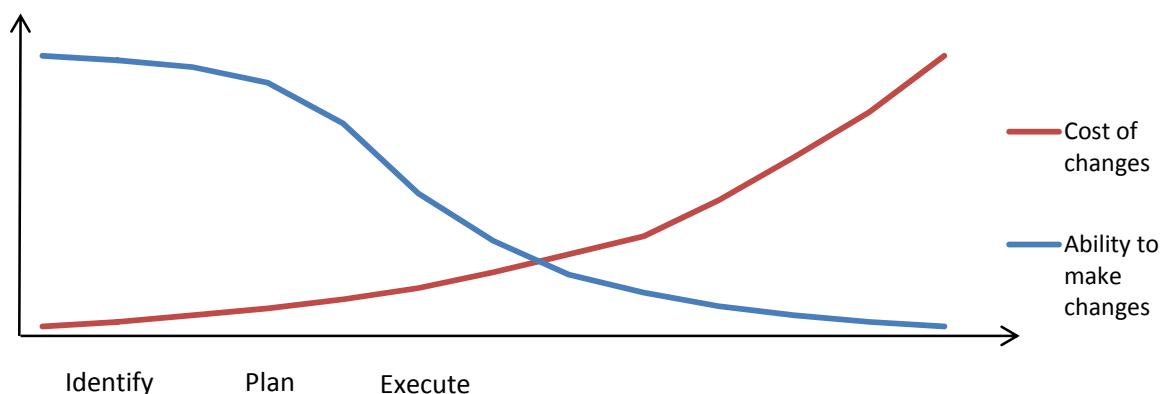


Figure 2-4: Cost of making changes vs. the ability to make changes

## 2.6 Deterministic project assessment

In the early phases of a construction project one is focused on developing the right concept leading to a design basis and eventually setting the scope for later phases. A crucial part of deciding on a concept for a commercial development is the economic assessment of the development. Big corporations tend to have standardized economic models to support decision-making, where the common approach is to calculate the net present value of the developments cash flow over its lifespan. Net present value assessment is however not necessarily straightforward, neither the concept of it nor the data used in the calculation.

## 2.6.1 Net present value in petroleum business development

Key to any net present value calculation (NPV) lays in establishing the cash flows. Using a typical petroleum exploration and production development as an example, there are several different elements that constitute the developments cash flows as shown in Figure 2-5. The illustration is simplified and excludes obvious elements such as tax and inflation.

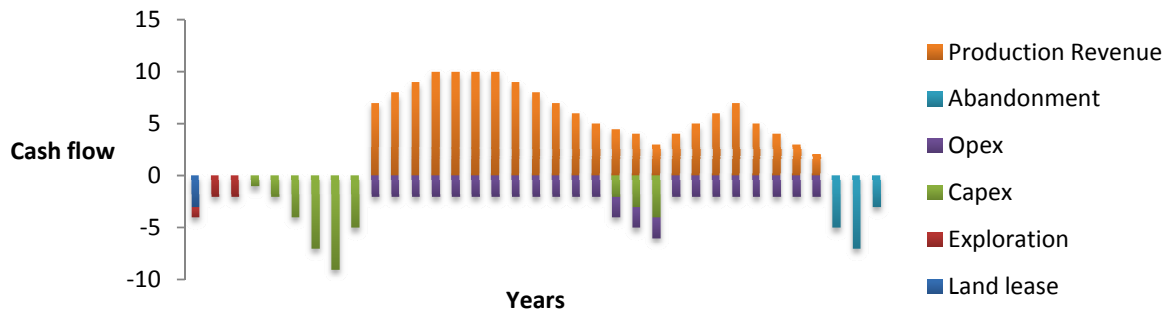


Figure 2-5: Exploration & Production Development Cash Flow

For developments in the early phases, most of the cash flow elements going into the NPV analysis are unknowns that have to be modeled and estimated in advance of making a decision. Some elements are partly controllable, while others, e.g. oil price is well beyond the control of any single company. For the purpose of this thesis, focus is put on the first Capex part of the developments life span according to the project definition. Key elements are then the cost of the project itself, the timing of the costs and finally the time of completion.

As a small detour on NPV before continuing, there are some interesting paradoxes using the NPV method for evaluating development opportunities that might be worth some thoughts.

Using Figure 2-5 as a reference point for the developments cash flow after the exploration activities is completed, should the costs encountered up until now be incorporated in the NPV calculation or not? In terms of economic theory, they should be regarded as sunk cost and therefore irrelevant when it comes to decision-making (Pindyck, et al., 2005). On the other hand, always disregarding sunk cost will contribute to paint a picture of the overall development that is too optimistic.

A more serious issue when it comes to NPV is the problem of incorporating the value of future flexibility into the calculation. NPV works fine with “low” risk development e.g. replacement of an old power generator on a production platform. The problem related to flexibility becomes apparent when looking at more complex developments, especially those with long life spans combined with technology dependent growth potential (Myers, 1984). As an addition to the NPV assessment, it has been proposed to use a method based on real option theory to evaluate petroleum developments on the NCS where flexibility related to prolonged asset lifespan and step change technology already has proven its value (Aven, 2010)

## 2.6.2 Project duration

From concept selection and until the project is finished, one of the key questions for the project manager to be able to answer is “When will the project be completed and delivered to the owners?”

Related to the E&P business development cash flow example shown in Figure 2-5, completion of the project and start of production has potentially a huge impact on the developments net present value. In other words, if the project organization needs a long time to execute the project or encounters a prolonged delay, the timing of the project capex versus the production revenue might tilt the economics of the development to the negative side. This crucial implication will in most cases drive commitment and follow-up from the project owner’s as well as the project manager and his/her team since they are well aware of that their future roles and opportunities in the organization depend on their ability to complete the project as promised. But, how does the project actually set a completion date in which they later on are measured against?

To answer the question above, one need to start with understanding the project objective, what is the project actually trying to achieve? With the objective settled and a coarse concept available, one should be able to define an overall scope of work needed to complete the project and some sub milestones indicating that the different pieces of scope has been completed.

The overall scope of work can then in turn be split into smaller work packages e.g. according to the NORSOK WBS/PBS system. The next step thereafter will be to develop the resolution of the plan by splitting each WBS element into different activities that needs to be finished before the overall work package is completed.

With the appropriate resolution on what actually needs to be accomplished, one can start to link all the different tasks together in creating a schedule network with logic driving the dependencies between all the different activities and milestones.

Finally with all the logic in place, durations need to be estimated and provided for each activity in order to define the critical path from start of project execution until handover to the project owners. The length of the critical path will then indicate when the project should be completed. The simplified process lined out above is illustrated in Figure 2-6 and Figure 2-7.

In addition to providing a finish date for the project, the project plan and schedule provides information that feeds into the cost estimate, the timing of costs and resource allocation over time.



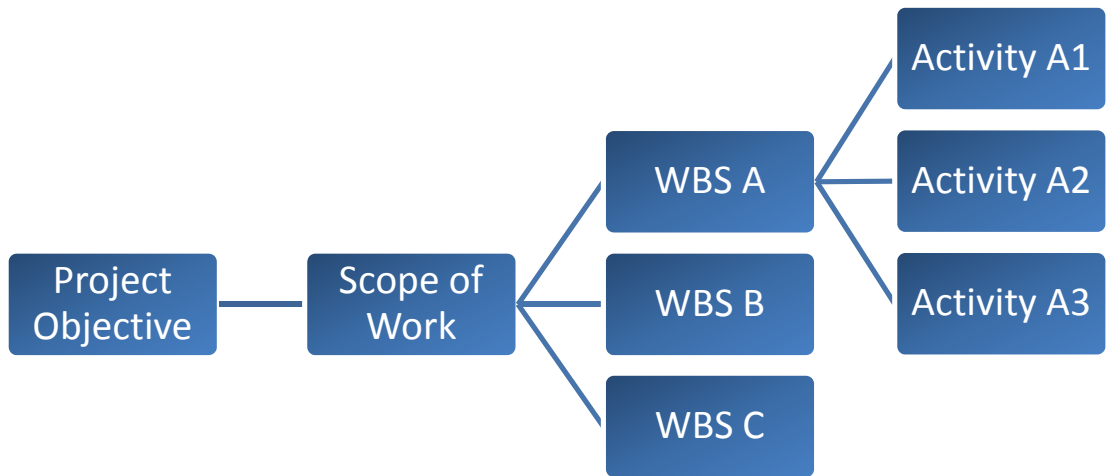


Figure 2-6: From project objective to the activity level

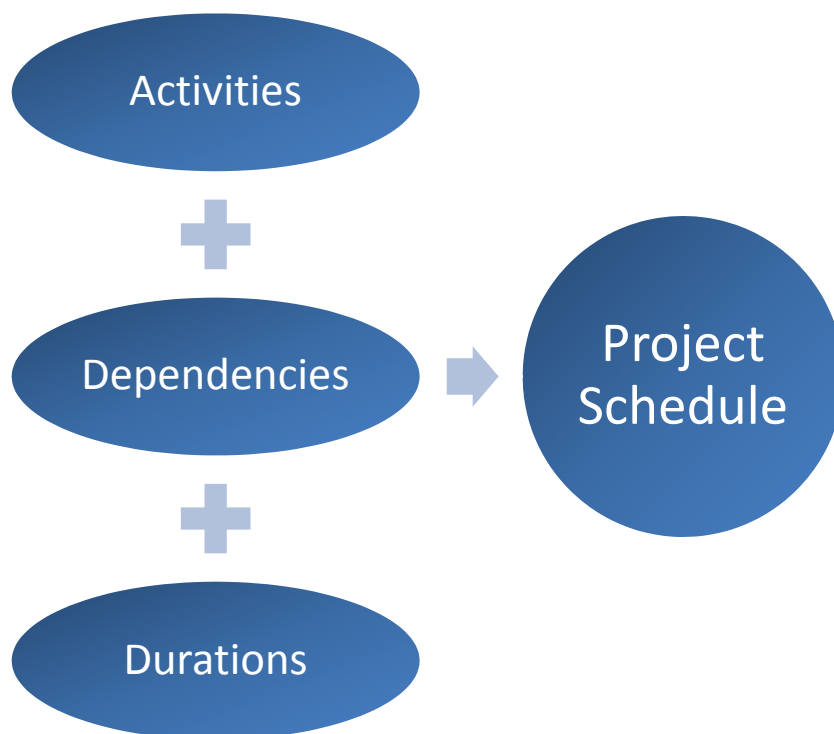


Figure 2-7: Basic elements in creating a project schedule

### 2.6.3 Project cost

Another key question that the project manager at any time needs to be able to answer is “What will the project cost to complete, and when will the money be spent?”

It should be obvious that the cost of the project will affect the developments economics and therefore be of high interest for both project owner and project manager. In addition, the timing plays a role in the economics as sketched out in the previous chapter. The timing of when the money is spent is also of interest in terms of allocating capital to the project, since all companies and governments in reality are capital constrained (Brealey, et al., 2006). To answer the question above, one need to develop a cost estimate that provides the total cost of the project in addition to a spend profile spreading the cost elements out in time.

Depending on the project phase, the level of information available, the resources put into creating the estimate and the level of details required, the final cost estimate can vary from one single number to several thousand line items that is aggregated to the overall cost estimate.

Some guidance on cost estimating is provided in “Applied Cost Engineering” (Clark, et al., 1997) splitting the cost estimate for the different project phases into estimate categories and thereby reflecting the information level and resource availability normally present at the different phases.

Clark & Lorenzoni labels their estimate categories as *screening estimates*, *budget estimates* and *definitive estimates* where the *definitive estimate* has the highest estimate accuracy.

One of the simplest estimating methods available is prorating, which is a comparison of a key parameter for a new project and the same parameter for some other projects that has been completed and where the final cost is known. The method requires some relevant historic data to be able to set the prorating factor, but when that is done, the simplistic cost estimate can be calculated in a matter of seconds.

On the other side of the scale of estimating complexity, one finds the definitive or detail estimate where the different WBS elements and activities needed to complete them is taken fully into account. For an oil platform project the starting point for the detailed approach is normally a 3D model and the master equipment list, which in turn can be split into equipment types, bulk weight for the different disciplines and structural support steel. The total project cost can then be calculated for the different cost elements by combining information of the physical structure being built with labor efficiency rates, labor cost rates and procurement cost rates as shown in Table 2-1. The utilized rates can be a result of previous experience, assumptions, market quotes or contracted numbers. The detailed approach can require month’s long efforts from estimating professionals depending on the resolution required and the available data. As mentioned in chapter 2.5.2, there is also an issue of diminishing return for cost estimating when it comes to chasing after the last percentages worth of details.

Cost Element	Estimating method	Comments
Procurement	Equipment quote $T * \text{NOK}/T$	For major equipment For bulk disciplines and structural steel  NOK /T is the bulk procurement cost rate
Construction	$T*(\text{MHR}/T)*(\text{NOK}/\text{MHR})$	MHR/T is the labor efficiency rate NOK /MHR is the labor cost rate.  These two rates vary highly from contractor to contractor and are normally negatively correlated.
Engineering and contractor management	$T*(\text{MHR}/T)*(\text{NOK} /\text{MHR})$	MHR/T is the labor efficiency rate NOK /MHR is the labor cost rate.  These two rates vary highly from contractor to contractor and are normally negatively correlated.
Owners Management	$\text{MHR}*(\text{NOK} /\text{MHR})$	NOK /MHR is the owners labor cost rate.  MHR is normally taken from man power plans showing the number of people and their allocated work load throughout the project
Marine Operations	$\text{Days}*(\text{NOK} /\text{day})$	Days are taken from the project plan Cost/day is the vessel day rate
Hook-up & Commissioning	$T*(\text{MHR}/T)*(\text{NOK} /\text{MHR})$	MHR/T is the labor efficiency rate NOK /MHR is the labor cost rate.  These two rates vary highly from contractor to contractor and are normally negatively correlated.
General Cost	% of other cost elements	Typically insurance, 3 <sup>rd</sup> party inspections etc
T= Tonne MHR = Man Hours		

Table 2-1: Cost estimate example

## 2.7 Advanced project assessment methods

Economic assessment, project schedule and cost estimate was briefly touched upon in chapter 2.6, and in all fairness, the superficial introduction to the three topics does not do them justice in terms of their overall importance in a project. However, for this thesis, the focus is put on project risk, where probabilistic treatment of the deterministic cost estimate and project schedule is in the center. A first approach to this is given underneath where more advanced concepts of project assessment are introduced.

### 2.7.1 CPM

As mentioned in chapter 2.6.2, one can determine the projects duration and completion by calculating the critical path of the project activities. The critical path of the project will then be defined as the sequence of linked activities from project start and until completion that cannot be delayed without delaying the overall project. As a result of this, activities that are not on the critical path is said to have float in them, meaning that the start-up and/or duration of the non-critical activity can be delayed according to the free float without delaying the overall project.

There is a specific analysis method called the “Critical Path Method” (CPM) which was developed by DuPont in early 1960’s outlining how the actual calculation of the critical path should be done (Hetland, 2003). The CPM method requires the three basic components shown in Figure 2-7, i.e.:

1. Project activities
2. Dependencies between the different activities.
3. Duration of the different activities

The benefit of the critical path method should be clear, by knowing which activities that cannot be delayed without delaying the project, the project manager can focus his effort towards the most crucial elements in the project. Together with the knowledge of which activities that has free float in them, the project manager can make value based trade-off decisions on transferring resources from one activity to another or choose to acquire more resources if needed to meet the project objectives.

The critical path method is quite easy in concept, but the algorithm required to compute the critical path and float is rather lengthy and time consuming as manual labor is regarded for any schedule with more than approx. 10 activities. Fortunately, with all the advanced software available on the market today, the entire critical path method is running in the background of the software and providing real time updates on critical path and float, and as a result reducing the critical path method to something that is taken for granted. Typical professional scheduling software includes Microsoft Project, Safran and Primavera.

## 2.7.2 CPM example

The activities, their duration and dependencies is given in Table 2-2 as the necessary inputs for the CPM method.

#	Activity	Duration (months)	Predecessor	Successor
S	Project Start	-	-	1,2
1	Engineering	15	S	3
2	Procurement Long Lead Items	20	S	4
3	Procurement	7	1	4
4	Construction	10	2,3	5
5	Installation	5	4	E
E	Project Finish	-	5	-

Table 2-2: Critical Path Method example data

Based on the dependencies between the different activities, the following schedule network is established as shown in Figure 2-8. It is easy to see that this network has two alternative routes from start to finish. By adding the durations for each activity in each of the branches, the critical path will be represented by the branch with the longest total duration. In this example, the lower branch has a total duration of 35 months, while the upper branch has a duration of 37 months making it the critical path through the network. Activity 2 is then the only activity in this example that is not on the critical path, making it easy to see that it has a total of two months worth of free float i.e. the start-up and/or the duration of activity 2 can be delayed a total of two months without delaying the overall project.

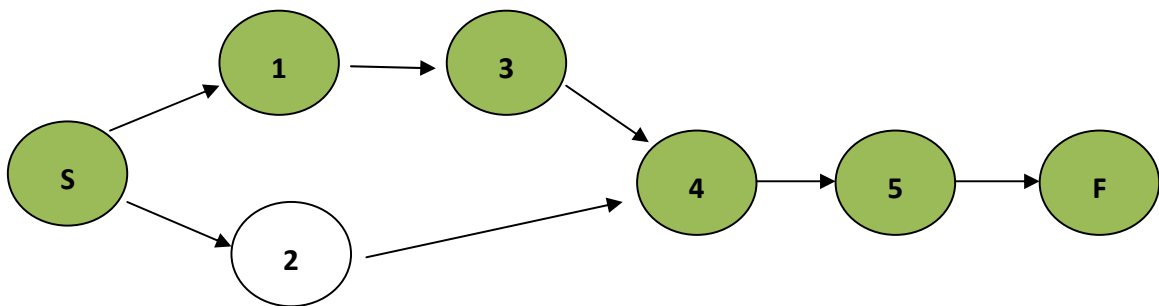


Figure 2-8: Critical Method example schedule network, critical path in green.

### 2.7.3 PERT

One can debate how advanced the critical path method is, even though its over 50 years since it was first introduced, it is still the dominating concept for project scheduling. However in the previous chapters, the schedule and activity durations were treated as deterministic values, which is a coarse simplification of reality. No one really knows how long time an activity will take, and there might be some unforeseen external events affecting the activity. In other words, a natural step forward at this time would be to try to incorporate the risks related to the duration of the individual activities and the total project.

At the same point in time as CPM was developed by DuPont, a close relative named “Program Evaluation and Review Technique” (PERT) was developed by the US Navy to improve their project management capabilities when developing nuclear submarines. PERT was with its three-point activity duration estimate the first step towards a full-scale probabilistic schedule assessment (Hetland, 2003).

Instead of just assigning each activity with one deterministic duration, with PERT, the analyzer has to provide his/her assessment of the smallest possible duration, the longest possible duration and the most likely duration according to his/her knowledge about each specific activity. Based on the three given input values, the expected time is calculated for each activity using the PERT formula. The expected duration for each activity is then used in the same way as shown in the CPM example to determine the critical path and free float.

In reality, the expected durations obtained by using PERT are just a simple semi-probabilistic extension to the previous deterministic CPM model. It gives the notion of incorporating some of the risks related to project execution, and depending on the input, it has the possibility to change the assessed critical path as will be shown in the next chapter.

The PERT formula for expected durations:  $E(T) = (S + 4M + L) / 6$

E(T) = Expected activity duration

S = Smallest possible duration

M = Most likely duration

L = Longest possible duration

Even though it is quite rare to do so, by using the same technique as for schedule assessment, PERT can in theory very well be used to incorporate risk into the project cost estimate. But as pointed out above, PERT for cost estimates is probably quite rare, and even today with big corporations, one can probably find that the risks related to cost estimates is in many cases incorporated just as a generic percentage uplift of the base cost estimate.

## 2.7.4 PERT example

Using the same example data as in chapter 2.7.2, Table 2-3 has now been extended to include all inputs required for PERT evaluation of the schedule. The new data shows that there are some risks related to all activities, where it seems like procurement of long lead items is the biggest source of concerns, having the longest duration as double that of the most likely duration.

#	Activity	Smallest	Most Likely	Longest	Expected	Predecessor	Successor
S	Project Start	-	-	-	-	-	1,2
1	Engineering	12	15	20	15,33	S	3
2	Procurement Long Lead Items	19	20	40	23,17	S	4
3	Procurement	6	7	9	7,17	1	4
4	Construction	9	10	15	10,67	2,3	5
5	Installation	4	5	6	5	4	F
F	Project Finish	-	-	-	-	5	-

Table 2-3: PERT example data

Using the same approach and the same schedule network as in chapter 2.7.2, the upper branch of the network has now an expected duration of 38.17 months, while the lower branch has an expected duration of 38.84 months making it the critical path. Remember that in the deterministic example in chapter 2.7.2, the upper branch was the critical path through the network. In addition, the two activities 1 and 3 now have a total float of 0.67 months. The fact that two activities share schedule float is quite interesting, float cannot necessarily be allocated to activity 3 ahead of project start, what if activity 1 lags behind and uses up the entire float? The question is a bit tedious and philosophical, while the answer is refreshingly brutal, total system float cannot be allocated in advance, the first one to use it, gets it.

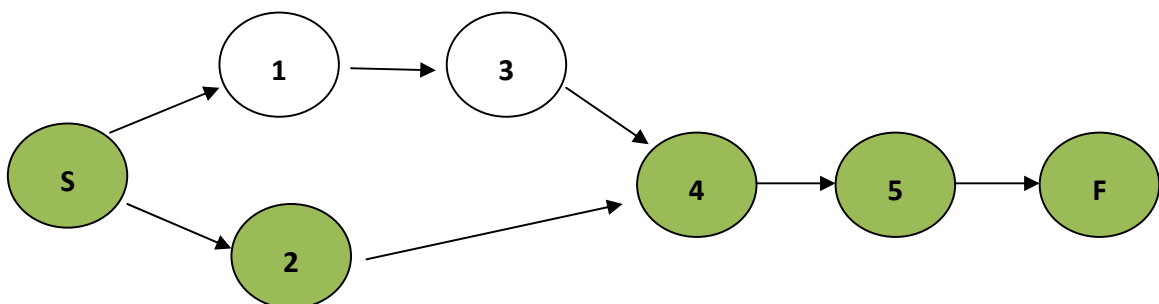


Figure 2-9: PERT example schedule network, critical path in green

What becomes clear by studying the example above is that the PERT model is just a first step towards a full-blown risk based schedule. There are no dynamics in PERT. There is still just one critical path through the schedule network, while in reality you can expect that both branches can become critical depending on the associated risk events and their outcome. Another issue to take into account is the use of expected values, referring back to chapter 2.2, where expected values as representation of risk were deemed as an inadequate approach.

### 2.7.5 Monte Carlo simulations

CPM and PERT added some basic insight of and analytical capabilities to the project assessment. But as pointed out in the previous chapters, it does not really incorporate risks related to the project in accordance with this thesis interpretation of risk, in addition to being static in its behavior. In search of a full-scale probabilistic approach, it is time to look into Monte Carlo Simulations and continue to build on the previous examples shown for CPM and PERT.

Monte Carlo simulation as it is known today has a wide variety of applications in everything from physics, engineering, games, finance, and mathematics etc. The basic concept of Monte Carlo simulation was first developed by John von Neumann, Stanislaw Ulam and Nicholas Metropolis in the 1940's in an attempt to solve practical radiation problems related to the Manhattan project, whose purpose it was to develop the first nuclear bomb, preempting Nazi-Germany and the Soviet Union (Wikipedia, 2012).

The concept of Monte Carlo simulation includes three basic steps, which can be summed up to define, draw, and aggregate.

1. **Define.** Each element in a model that should be treated probabilistic needs to be defined with a probability distribution and the appropriate parameters in such a way that the used distributions constitute a reasonable representation of the potential outcomes for each element.
2. **Draw.** In one single iteration, all the probabilistic elements in the model are replaced with a deterministic number that is a result of a random draw of the associated distribution. This number is then used in the model and effect the final result of the single iteration.
3. **Aggregate.** The same model is now run with several thousand iterations, where the iterations are sorted according to the size of the final result for each single iteration. With the iterations sorted, one can apply simple statistical methods and techniques to extract the desired simulation results, for instance the P50 value, representing the value that the model predicts that there is an equal 50 % chance of getting in under or above.



Monte Carlo simulations has some common features with PERT as mentioned previously, but by utilizing a probability distribution for each single element instead of an expected value, and running the model several thousands of iterations, the Monte Carlo simulation is able to provide wide ranges of outcomes representing all potential combination of the different probabilistic elements included in the model. The result generated from a Monte Carlo simulation is therefore more in line with how risk is defined in this thesis.

Some readers might at this point want to comment that Monte Carlo simulations appears to be a tool for estimating total probabilities of complex systems by making an almost infinite number of trials, and hence referring back to the previous debate between classical versus bayesian probability theory.

There is some element of truth in the statement above. Monte Carlo and the law of large numbers are to some extent related. However, this does not mean that one cannot stick to the bayesian theory while at the same time conducting Monte Carlo simulations. First, the inputs used to construct the probability distribution will still be based on the analyst’s perception about the probabilistic elements and the future outcome of these, which clearly is in accordance with the bayesian framework. Secondly, the major difference between classical and bayesian theory is how probabilities and analysis results are understood and communicated. The methodology used to create ones degree of belief is in fact rather irrelevant in terms of probability theory. The methodology used in the analysis speaks more to the quality and credibility of the results than anything else.

As pointed out for PERT, the Monte Carlo simulation method showed in the following chapter could very well be used to incorporate risks in cost estimates.

### 2.7.6 Monte Carlo simulation example

To continue with the same example as shown in chapters 2.7.2 and 2.7.4, the schedule network has now been constructed using Primavera Risk Analysis. The activities have the same dependencies between them, and the same durations as used earlier. In terms of probability distribution, the three-point estimate is assigned as a triangular distribution and not PERT. The results are therefore not 100 % comparable with what was shown earlier. The take back from this example is still valid though in terms of capturing the wide range of potential outcomes.

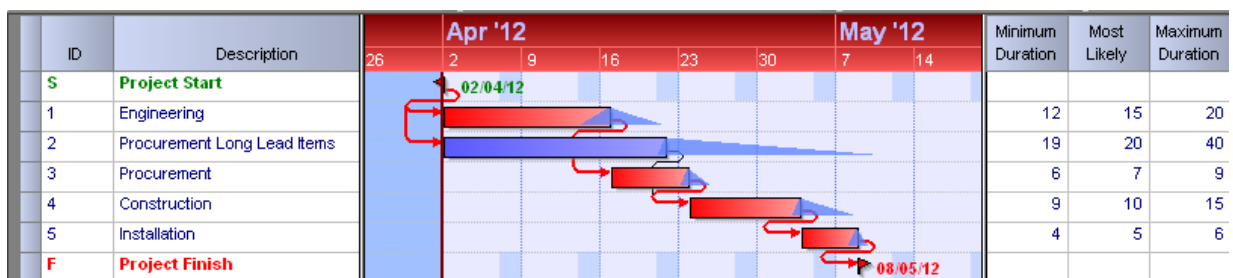


Figure 2-10: Primavera Risk Analysis Monte Carlo Simulation setup

With the model set up as illustrated in Figure 2-10, the Monte Carlo simulation is conducted by running 100 000 iterations. In every iteration, a single value for each of the five activities is drawn from the associated distribution range and used to determine task duration whilst maintaining logic between tasks. The critical path and its length may therefore vary from one iteration to the next. Each of these 100 000 project simulations are thereafter stacked in increasing order from the shortest to the longest duration accompanied with basic statistical parameters recorded for the overall simulation as shown in Figure 2-11.

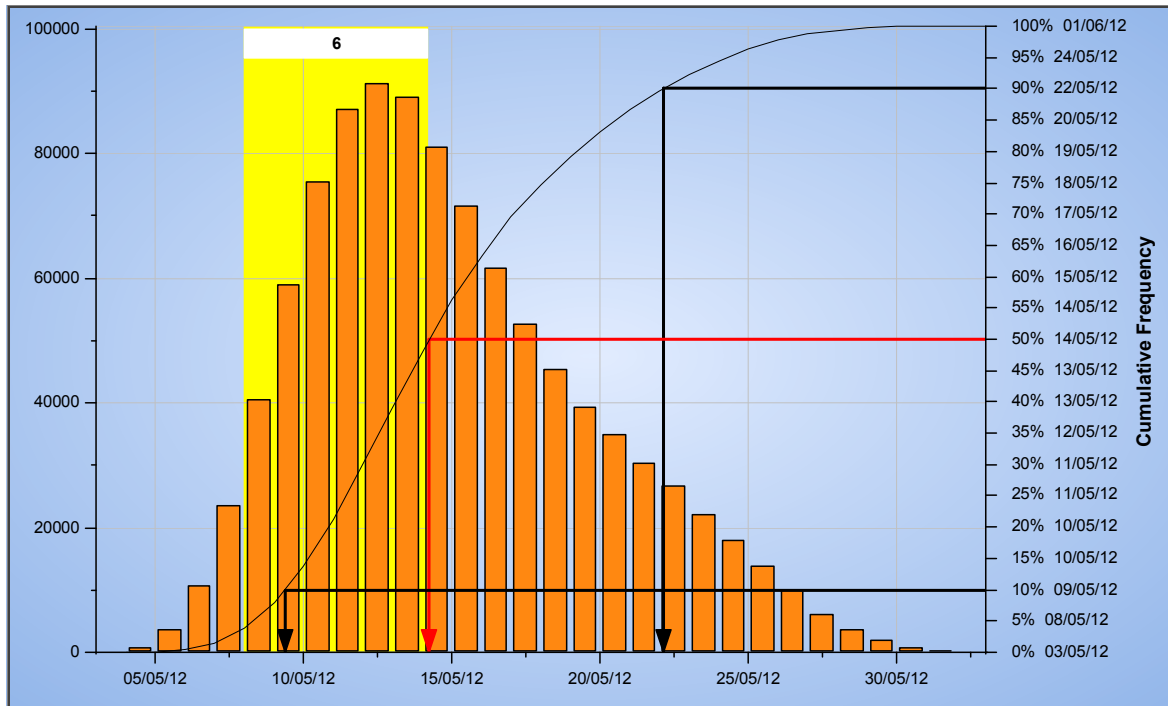


Figure 2-11: Monte Carlo Simulation Results Graph

As one can see in Figure 2-11 and Table 2-4, there is a wide spread in the simulation results. As risk analysis of the project schedule and if one chooses to believe in the model, it is important that one not only communicate the mean or the P50 number. Crucial insight is gained from communicating the range of potential durations, either it is the P10-P90 range, or the minimum - maximum range.

Result Parameter	Duration (days/months/years etc)
Deterministic	37
Minimum	32
Maximum	61
Mean	44
P10	38
P50	43
P90	51

Table 2-4: Monte Carlo Simulation Results Table

### 2.7.7 Mean or P50?

Which duration value from the Monte Carlo simulation shown in chapter 2.7.6 should be chosen as the projects target duration and used in the economic assessment of the development?

The mean and the P50 duration seems like the obvious candidates to chose from, but there are some issues related to both of them that are worth looking at. Starting with the easiest example, were the schedule risks are modeled in such a way that the final distribution of all the simulations is perfectly symmetrical as shown in Figure 2-12. In this case it does not matter which values is chosen, the mean value is the same as the P50 value.

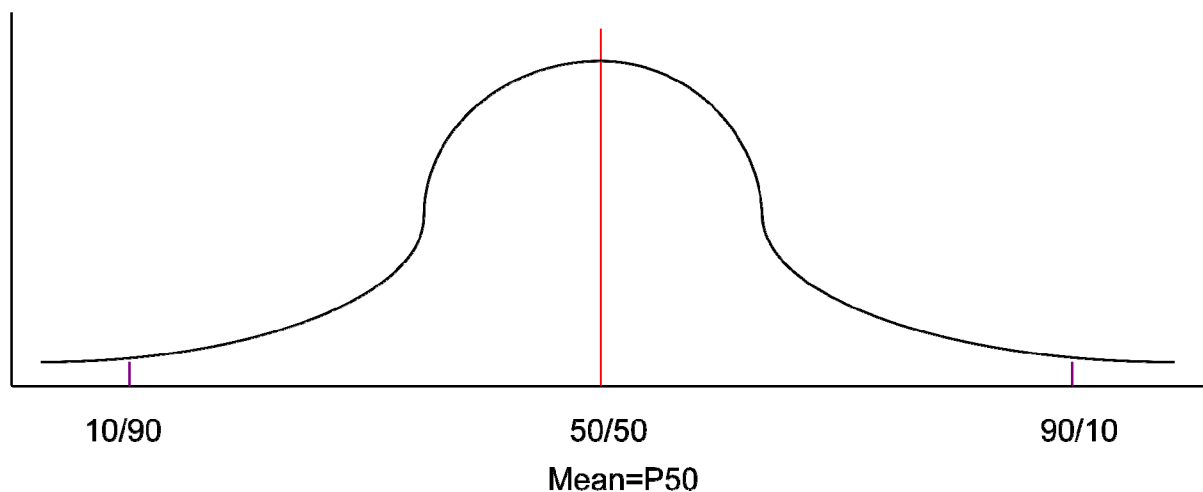


Figure 2-12: Symmetrical distribution

The symmetrical schedule or cost risk model is quite rare, analyst and project managers tend to focus more on the potential threats to the project, and not exert the same level of energy trying to incorporate the potential opportunities. In addition, there is no upper limit on either a projects duration or cost, whilst there obviously is a lower limit and therefore contributes towards skewing the distribution to the right, giving it a long tale as shown in Figure 2-13. With such a distribution, the mean and the P50 will not be the same. Since the mean value is an average of all iterations, it will be affected by the extreme outliers, whilst the P50 value as the middle observation will tend to ignore the potential extreme results.

In statistical terms, the mean value is the only unbiased estimator, whilst the P50 value will systematically underestimate when the distribution is skewed to the right as shown in Figure 2-13. That is the theory at least, but does that exclude the P50? The short answer is no, the mean value might be the one to take into account if conducting the exact same project an infinite number of times or as part of a huge portfolio with similar project as discussed in chapter 2.2. But for any single project it is not that obvious. The typical outliers are represented

by very high impact and very low probability type of events, and as a result of that, if one of these were to hit the project, it would in some cases be so severe that neither the P50, P99 nor the mean value would be sufficient to save the project. Based on the previous point, if one does choose to go for the P50 value, that is in reality equivalent with saying that all the extreme risks related to this particular project are disregarded in terms of the probabilistic assessment.

Referring back to the introduction and the concerns rose about the Yme redevelopment project, which currently is looking at a final cost that is three times higher than premised. It is obvious that the potential catastrophes of a project should be considered, but for any single project, the mean value does not make much sense.

A potential compromise could then be that the project owners need to use the mean value in their economic decision models that feeds into the PDO and is communicated to the government. The project manager on the other hand should be targeted to meet the P50 value, which could be seen as a stretch target, implying that the project is required to navigate clear of all the big catastrophes and game changers in order to reach its objective.

Regardless of which measure one ends up with, it should be pointed out that insight is gained by reporting the full range of outcomes instead of just one number.

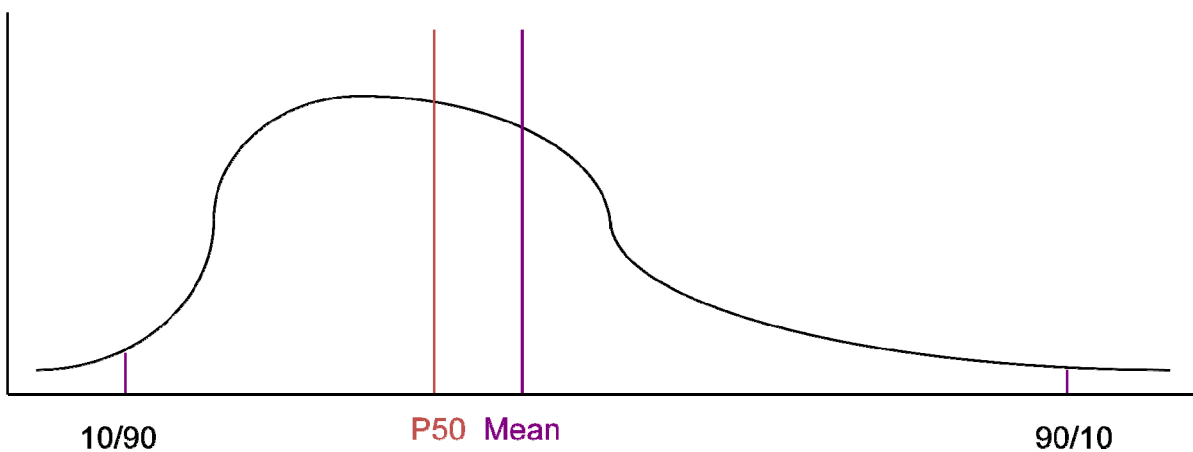


Figure 2-13: Skewed distribution

## 2.8 Project risk management

*"The essential of risk management is to improve project performance via systematic identification, appraisal and management of project related risks." (Chapman, et al., 2000)*

Project risk can be understood by combining the more generic definition of risk given in chapter 2.1 and key parts of the project definition relating to the project objectives, more precisely towards the objective of creating a unique product in a constrained environment.

Thus leading up to project risk being defined as:

*"The combination of potential future events and their associated uncertainty that has the potential to affect the project in its effort to reach its objective".*

The definition requires risks to be related to project objectives, and by that making the definition broad enough to be useful for the project team, the project manager, the project owners, the government and other stakeholders. The key is which objectives one chooses to take into account. For the previous example of an oil platform development, the team responsible for operating the platform for 40 years will typically relate their objectives towards having a platform with a high operating efficiency, low maintenance levels and high operability levels. The project as defined in this thesis, will on the other hand be focused on delivering the platform on time, on budget and without any safety related incidents.

The important insight to be had from this, is that more often than not, the reason why project stakeholders experience poor communication when it comes to risks, is not necessarily caused by a lack in knowledge of the project or risk in general. It is more an issue of going into the same meeting with different objectives, agendas and missing capabilities to look at the project risks from a total life cycle value perspective.

### 2.8.1 Sources of project risks

When an oil platform is put in production there is typically a small collection of risks that is on everyone's radar e.g. hydrocarbon leaks, blowouts, vessel collision, extreme weather and structural integrity issues, helicopter crashes etc. It makes sense to be worried about them, even though the probability of such an event occurring is quite small, typically less than  $10^{-4}$ , the potential consequence if it were to occur is so high that it needs to be given top priority at all times.

For projects however, the story is a bit different. There are typically not too many black swans affecting projects. Not saying that they do not exist, just not to the same degree as mentioned above. Risks in project risk analysis are assigned probabilities normally in the range of 1% to 40%. A typical risk that falls outside this probability range is the risk of losing a platform topside in the ocean during lifting operations. Even though the risk is valid and important, it would be hard to argue that this should be part of the project schedule or cost risk assessment.

However, if one is not too concerned about the catastrophic type of events, what type of risks should a project include in their schedule and cost risk analysis?

A way to shed some light on the question above could come from diverging from the normal approach of look directly for risk events affecting a project, and instead try to understand a standard set of sources where risks originate. A common view on how to split and approach sources of project risks goes by the name of “the six W’s”, referring back to the six main sources of project risks. Surprisingly enough, the inventors actually admit to forcing at least two of the sources into the general “W” naming convention (Chapman, et al., 2000).

The underlying sources of project risks can be approached by the six W questions summarized in Table 2-5 (Chapman, et al., 2000).

The six W’s	The questions	The logic translation of the W
Who	Who are the parties ultimately involved?	Parties
Why	What does the parties want to achieve?	Motives
What	What is it the parties are interested in?	Design
Whichway	How is it to be done?	Activities
Wherewithal	What resources are required?	Resources
When	When does it have to be done?	Timetable

Table 2-5: The Six W’s

Chapman and Ward then try to illustrate the different sources of risks by creating a project definition process overview, connecting the different elements and their relations to each other, and by doing so they perhaps make it more complicated than it needs to be.

However, most readers and especially those with any kind of previous experience working on a project should have no problem relating the W’s back to rather general common project risk as contracting issues, procurement issues, late design changes, lack of key personnel, logistics problems, coordination issues, communication problems etc.

### 2.8.2 Generic risk management process

How should risk be managed? A simple question, unfortunately without a simple answer. Except from acknowledging that a structured and well thought out process is a preferred alternative to an on the fly or a chaos approach, professionals do tend to disagree when it comes to deciding on how the exact process should be, wanting to provide or stick to their own developed process. A contribution and a step towards consensus are however offered by the International Organization for Standardization (International Organization for Standardization, 2009).

As illustrated in Figure 2-14, ISOs risk management process focuses on five main elements shown in the center of the figure, with additional emphasis on continual monitoring and communication.

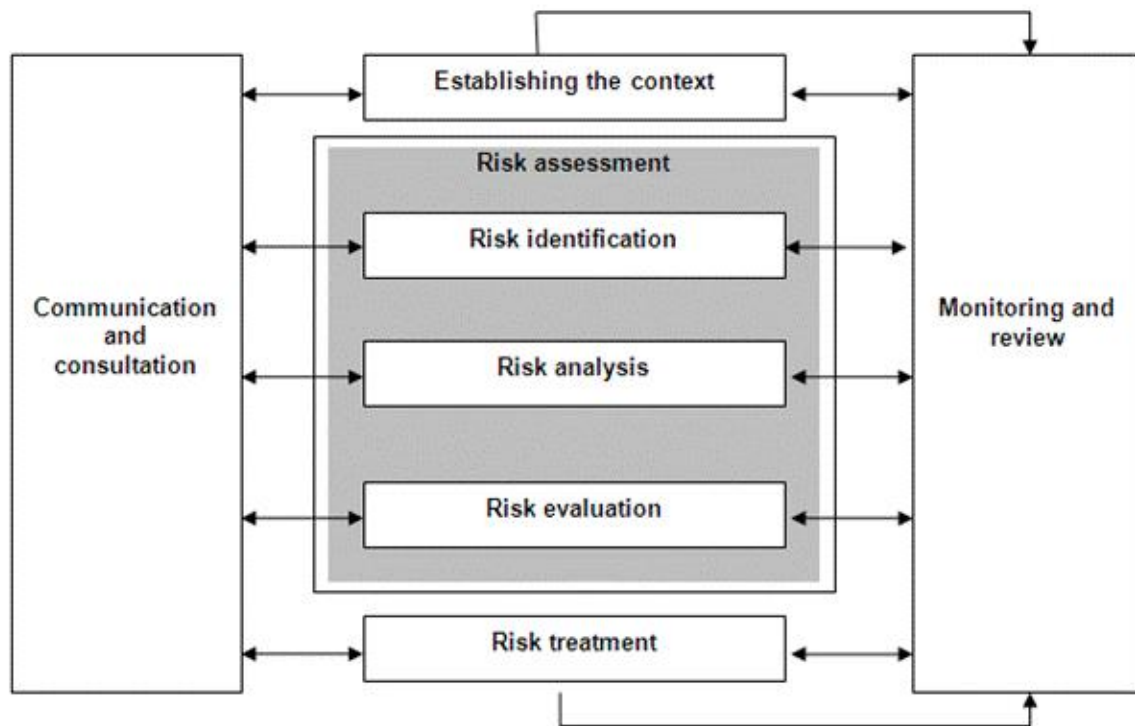


Figure 2-14: ISO Risk Management process

Starting from the top, the first element is about setting the context for the rest of the process. This element has been discussed widely relating back to project risk, where risk has to be seen in relation to the different project phases and project objectives that the relevant stakeholders ultimately are responsible for. Ref chapters 2.4.2, 2.5.2 and 2.8

With the context set, the next natural step is to start the risk assessment part of the process by identifying the relevant risks, before continuing with analysis of the identified risks. The risk identification part has not been specifically covered up to this point. However, relating it to project risks, the most common approach is to conduct brainstorming workshops with a broad project team to try to capture the risk picture. Some quantitative analysis methods was discussed in chapter 2.7, where these methods often go hand in hand with a more qualitative approach e.g. by using a simple risk matrix.

Risk evaluation is the last step within risk assessment, which is basically weighing what the risk analysis is telling against the organizations risk acceptance criteria or risk appetite. Based on this evaluation, a decision on how the different risks should be managed has to be made.

It is important to point out that even though the context, the identification, the analysis and the following risk treatment element can, and often is, carried out by people in lower parts of the organization hierarchy, the risk evaluation and setup of risk acceptance criteria should always involve those who are ultimately responsible for the project outcome.

Risk treatment is the last central element, which represent the execution part of the decision made in the risk evaluation element. There are different risk treatment strategies to take, where one strategy is to accept the risk and do nothing, while others can include sharing the risk, eliminating it, reduce the likelihood and/or the consequence etc.

As a general comment on the five main elements in ISO's process, the risk identification and risk analysis elements seems to be the most mature ones, and the ones able to capture the most amount of focus in risk management processes. On the other hand, risk evaluation and especially risk treatment is struggling to gather the same amount of enthusiasm.

ISO's risk management process is for most organizations and risk management professionals a standardized and recognized framework, and a basis to develop from if in quest for something more advanced. In more trivial cases, a simplification of the ISO's standard, focusing in on just the identification, analysis and treatment elements is often also a justifiable approach.

### **2.8.3 PRAM**

A more detailed and complex framework for risk management focusing in on project risk has been developed by the Association of Project Management (APM). Going by the name "Project risk analysis and management" (PRAM), it was designed based on APM's wide body of project experience and with the intention of creating a generic risk management process that could be tailored to the specific project, with the option of simplifying the approach wherever possible. (Chapman, 1997)

Tailored to project risk management and with the flexibility to adapt the process to a specific project, PRAM tries to accomplish many objectives in one go. Resulting in it being a quite heavy and a bit abstract process to start the customization from. Some help is offered along the way in form of case studies e.g. "Ian's tale: Aligning buyer and supplier motivation" (Chapman, et al., 2002), but even this attempt on a practical approach is balancing close to the abstract border.

PRAM as a process includes nine phases, where each phase has its specific purpose and an accompanied set of deliverables. As illustrated in Figure 2-15 and Figure 2-16 the PRAM approach and its phases is partly parallel but also iterative, allowing the risk management process to change the basis of the project and accordingly trigger a new cycle of the process. The way PRAM is structured with its parallel activities and iterations between its phases, PRAM has been referred to as a risk management process that itself should be conducted as a project (Chapman, et al., 2002).



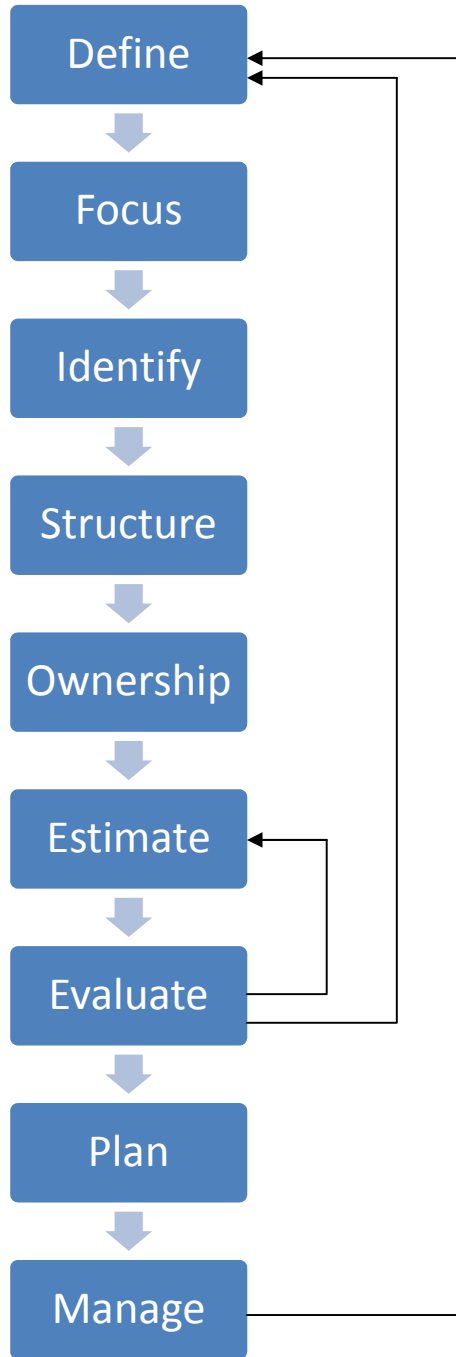


Figure 2-15: PRAM process flow

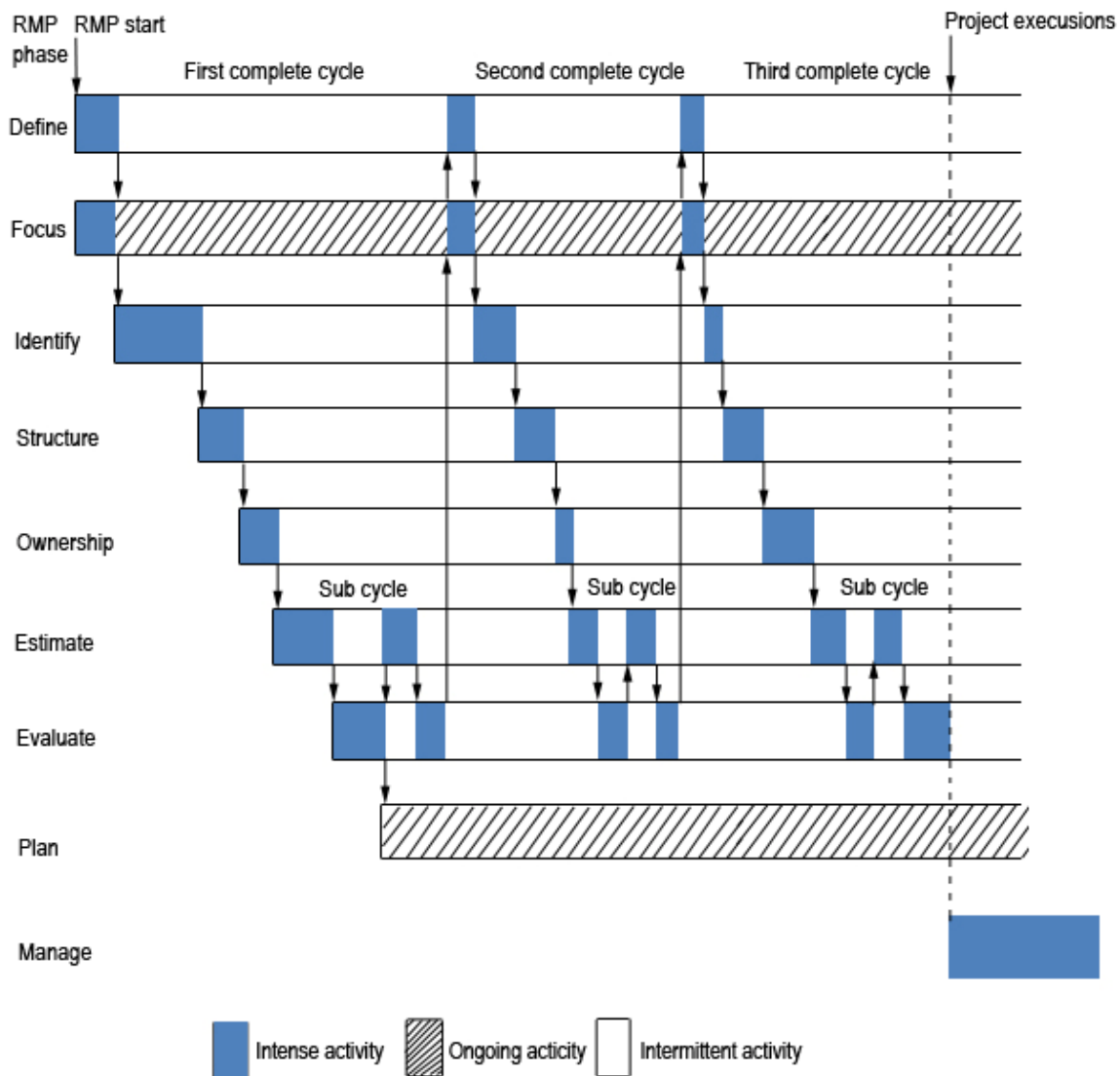


Figure 2-16: PRAM process, example of parallel and iterated phases

Some more insight into the different PRAM phases and the purposes of them is provided in Table 2-6 (Chapman, et al., 2002). Without going any further into the specific details of PRAM, it should be mentioned that with its structure and detail level, PRAM offers some additional suggestions and insight on how to tailor a risk management process for a specific project that could be used in conjunction with the more generic ISO process shown in chapter 2.8.2 to design a risk management process suitable for any use. However, for the purpose of this thesis, a simplified version of ISO's process will be utilized when analyzing ConocoPhillips approach to risk management in their capital projects organization.

Phase	Purposes
Define the Project	Consolidate relevant existing information about the project. Fill in any gaps uncovered in the consolidation process
Focus the project	Scope and provide a strategic plan for the RMP. Plan the RMP at an operational level
Identify the issues	Identify where risk might arise. Identify what we might do about this risk, in proactive and reactive responses terms. Identify what might go wrong with our responses
Structure the issues	Test simplifying assumptions. Provide more complex structure when appropriate
Clarify ownership	Client / contractor allocation of ownership and management of risks and responses. Allocations of client risks to named individuals. Approval of contractor allocations
Estimate sources of variability	Identify areas of clear significant uncertainty. Identify areas of possible significant uncertainty
Evaluate overall implications	Synthesis and evaluation of the results of the estimation phase
Plan for implementation	Preparing base plans ready for implementation and associated risk management contingency plans
Manage Implementation	Monitoring. Control. Responding to crises. Ongoing development of action plans for immediate implementation.

**Table 2-6: PRAM Phases and its Purposes**

### 3 ConocoPhillips

ConocoPhillips as a company seems to be under a constant change. It has a history of frequent mergers and acquisitions, but is currently<sup>1</sup> finalizing a split of the company into two separate publicly traded companies, where the split is expected to be executed first of May 2012. However, since most of this report is written before that point in time, and the knowledge gathered is a reflection of the past and not necessarily valid for the post split company, this chapter will for the most parts reflect the pre split ConocoPhillips. As with chapter 2, this chapter is intended to create a common background of knowledge, and might as a result not be applicable for all readers.

#### 3.1 General introduction

ConocoPhillips is regarded as one of the six big international integrated energy companies with ExxonMobil, Chevron, Royal Dutch Shell, BP and Total in its peer group. The company has its base in Houston, Texas and is currently running operations in more than 30 countries all over the globe. The global workforce is close to 30 000 employees and with a market value of approx. 100-110 Billion USD, it is hovering somewhere between the 20-30 biggest US companies. As an integrated company, ConocoPhillips is present in the entire hydrocarbon value chain, all the way from exploration to the delivery of processed and refined products to the customers, where the portfolio of products include, petrol, lube oil, natural gas, plastic and chemicals etc. An illustration of such a value chain is shown Figure 3-1.

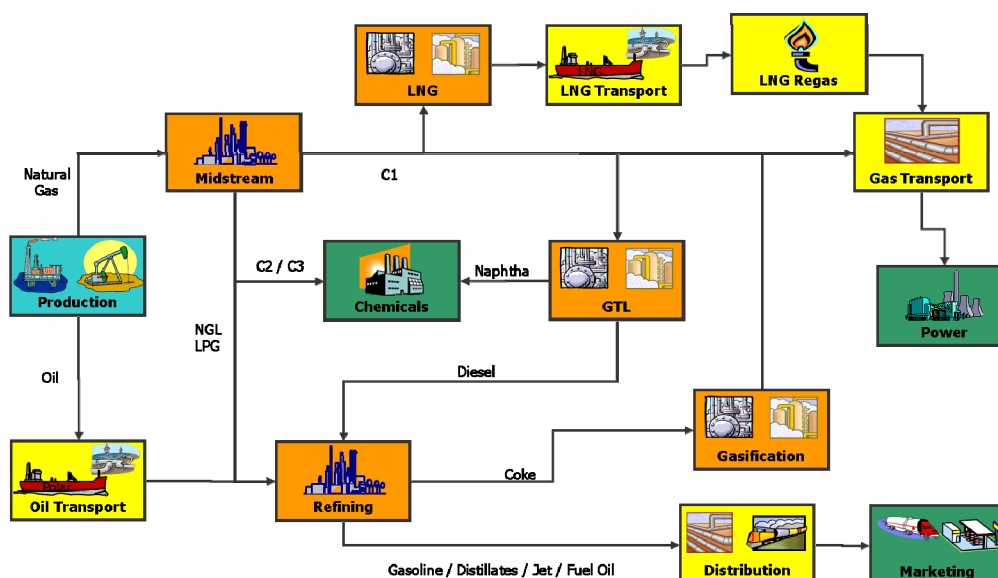


Figure 3-1: Hydrocarbon Value chain Example (Source: ConocoPhillips)

<sup>1</sup> March –April 2012

ConocoPhillips is currently producing 1.75 MM BOED, where approximately 80% of the production is stemming from OECD countries. The portfolio includes heavy oil represented with SAGD<sup>2</sup> production in Canada, via shale gas revolution in lower parts of the US to LNG developments in the Middle East and Australia. In an effort to maintain and grow the annual production volume, the company has an exploration and appraisal portfolio reflecting its current production portfolio. The global spread is illustrated in Figure 3-2 and Figure 3-3

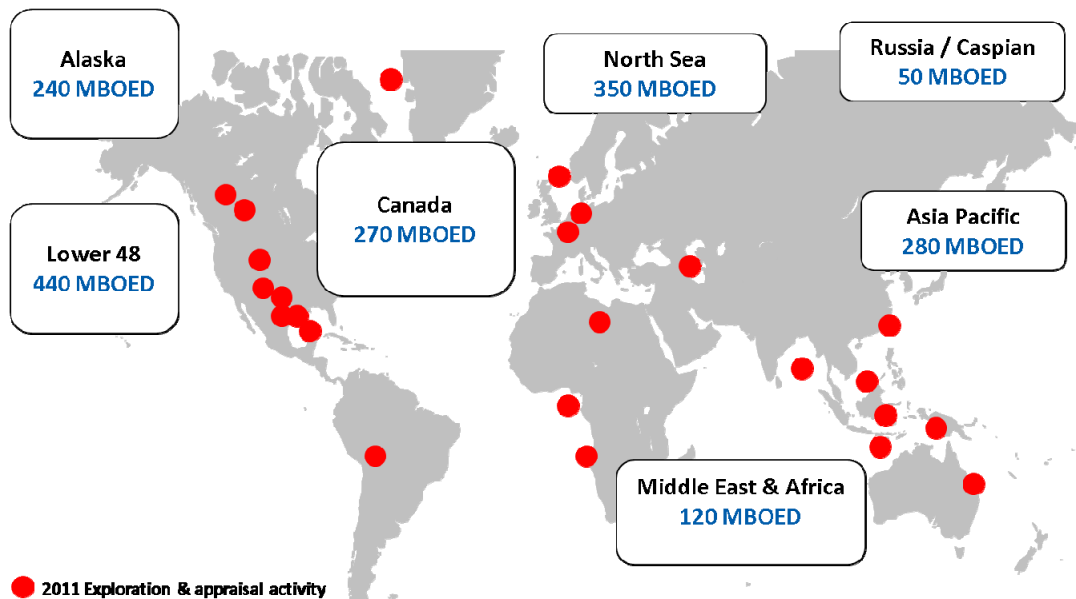


Figure 3-2: ConocoPhillips Production Summary (Source: ConocoPhillips 2011)

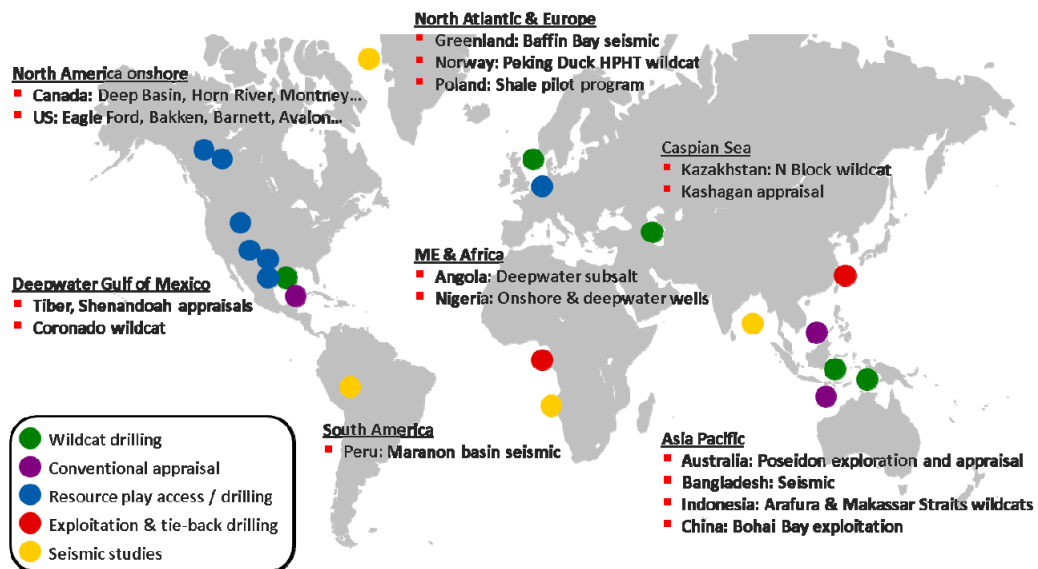


Figure 3-3: ConocoPhillips Exploration & Appraisal Portfolio (Source: ConocoPhillips 2011)

<sup>2</sup> Steam Assisted Gravity Drainage

### 3.2 History of ConocoPhillips

ConocoPhillips as it is known today has roots going back to the late 1800's and early 1900's where the two companies Conoco Inc and Phillips Petroleum were born. During the 1900's both companies grew and became the foundation and backbone for their separate communities. Conoco settling down in Ponca City, Oklahoma, while Phillips was located in Bartlesville, Oklahoma. It is perhaps an understatement to say that Phillips was located in Bartlesville, when almost every building above two stories in this prairie town is still bearing some sign of Phillips Petroleum.

During the 1950s and 60s both companies decided to expand their horizon from the US, starting exploring in Africa, all the way around the west European coastline and finally entering the North Sea. Phillips Petroleum found their gold in form of Ekofisk, marking the start of the industrial revolution that transformed Norway into an oil-producing nation, and providing the foundation for the welfare based society that we know today.

From the 1980's until today, the petroleum industry has been marked by a series of mergers and acquisitions, ConocoPhillips being no exception. Conoco became a fully own subsidiary of DuPont in 1981 after avoiding a series of unwanted takeover attempts. The marriage with DuPont lasted until 1997 when the two companies were separated again. Phillips on the other hand, together with most of the oil companies at that time, was suffering from an unhealthy balance sheet due to poor investment decisions managed to fight off the hostile takeover attempts, amongst those one led by the famous corporate raider at the time, Thomas Boone Pickens Jr.

From the year 2000 and onwards a series of rapid acquisitions and the merger between Conoco and Phillips Petroleum in 2002 led the way for ConocoPhillips as it is known today, as the sixth largest publicly traded oil company in the world. An illustration of the companies involved in the different recent transactions is shown in Figure 3-4.

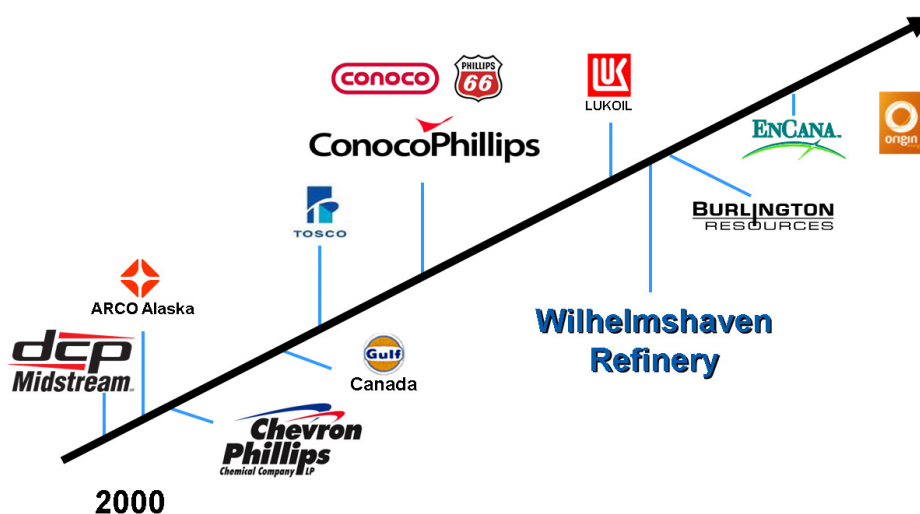


Figure 3-4: ConocoPhillips, Mergers and acquisitions (Source: ConocoPhillips 2011)

### 3.3 Ekofisk

As mentioned above. Phillips Petroleum played a significant role in kick starting the Norwegian oil era. Phillips was the company that initially approached the Norwegian government back in 1962, requesting permission to explore for hydrocarbons in the North Sea. Most of the big international companies at the time found an interest for the previously unexplored area, and with Exxon in the lead the first well was drilled in 1966.

With a lot of dry holes, and only small and commercially unviable discoveries, the optimism faded towards 1969. Phillips wanted to pull out of the region, but had committed to a drilling program in which they had one more well left to drill. Unsuccessful in negotiating their way out of the contract with the government and the rig owner, Phillips decided to drill what since has been known as “the last well on block 2/4”. As taken out of a Hollywood movie, Phillips Petroleum struck gold with their last gamble and discovered what was to be the Ekofisk Field.

Production of Ekofisk started already in 1971 with the temporary jack-up platform Gulftide, and since then the landscape in the Greater Ekofisk area has been under a constant change with more than 25 different structures installed, in which some in the last couple of years also has been removed. The history of Ekofisk includes a list of engineering achievements as the Ekofisk Tank construction in 1973 and the field wide jack-up of subsiding platforms in 1987.

The contribution from the Ekofisk area to the Norwegian society in the period from 1969-2010 has been estimated in at 1800 Billion NOK, and the field is still producing. But the value creation has come at a high cost, more than 160 people have lost their lives over the years working or during transport in conjunction with ConocoPhillips operations in Norway, where the Alexander Kielland capsizing in 1980 alone claimed 123 lives. (Norwegian Petroleum Museum)

Even though the Ekofisk field has been producing for over 40 years, there are still vast amounts of hydrocarbons left in the ground. ConocoPhillips is at the time preparing for the next 40 years of production by removing old infrastructure and installing new platforms, subsea templates and wells at a total cost of approx. 100 Billion NOK.<sup>3</sup> The current forecast of the final recovery factor for Ekofisk is approx. 52 %, a solid step upwards from the original 17 % forecasted back when then field was discovered. The increased recovery factor is a result of knowledge gained over 40 years, world class petroleum academic research region and significant technological developments. Another way to look at it is to say that ConocoPhillips is currently forecasting to leave 48 % of the Ekofisk resources in the ground. Comparing that with Figure 3-5<sup>4</sup> (NPD, 2011), it becomes obvious that there is a lot of future potential value to capture from Ekofisk. In that perspective the previous discussion in chapter 2.6.1 regarding NPV and flexibility in field developments should be of new interest and worth a reminder.

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<sup>3</sup> Estimated number provided by public commentators. Exact estimate is regarded as confidential information.

<sup>4</sup> The report from NPD does not include any of the discoveries made during 2011.

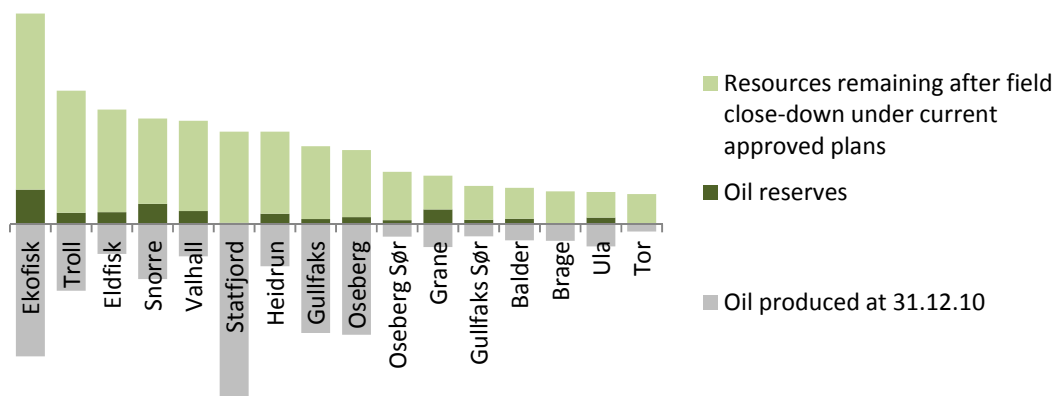


Figure 3-5: NPDP Field resources overview

### 3.4 Corporate organization structure

ConocoPhillips organization structure can be laid out in a couple of different ways. A common approach for any company is to split the organization between what is regarded as the operational departments and corporate staff. The organization chart provided in Figure 3-6 utilized this approach, where the red background color is representing the different staff functions, while the orange background color is representing the corporate operational departments. It should be noted that this layout does not exactly replicate all the different departments and reporting lines, but serves as an illustration of the main structure.

Represented by green background color is the various business units (BU) around the world reporting in through E&P International, while business units on the American continent is reporting in through E&P Americas<sup>5</sup>.

What starts to make the organization layout complex, is the fact that within each of the business units the members of the BU leadership teams responsible for a given area within their respective BU, does also have some “stippled reporting” to their relevant corporate group. This will be illustrated further in the next chapters about the Project Development & Procurement organization and Norway Capital Projects.

<sup>5</sup> The Lower 48 (US) business unit consists of three smaller regional units.



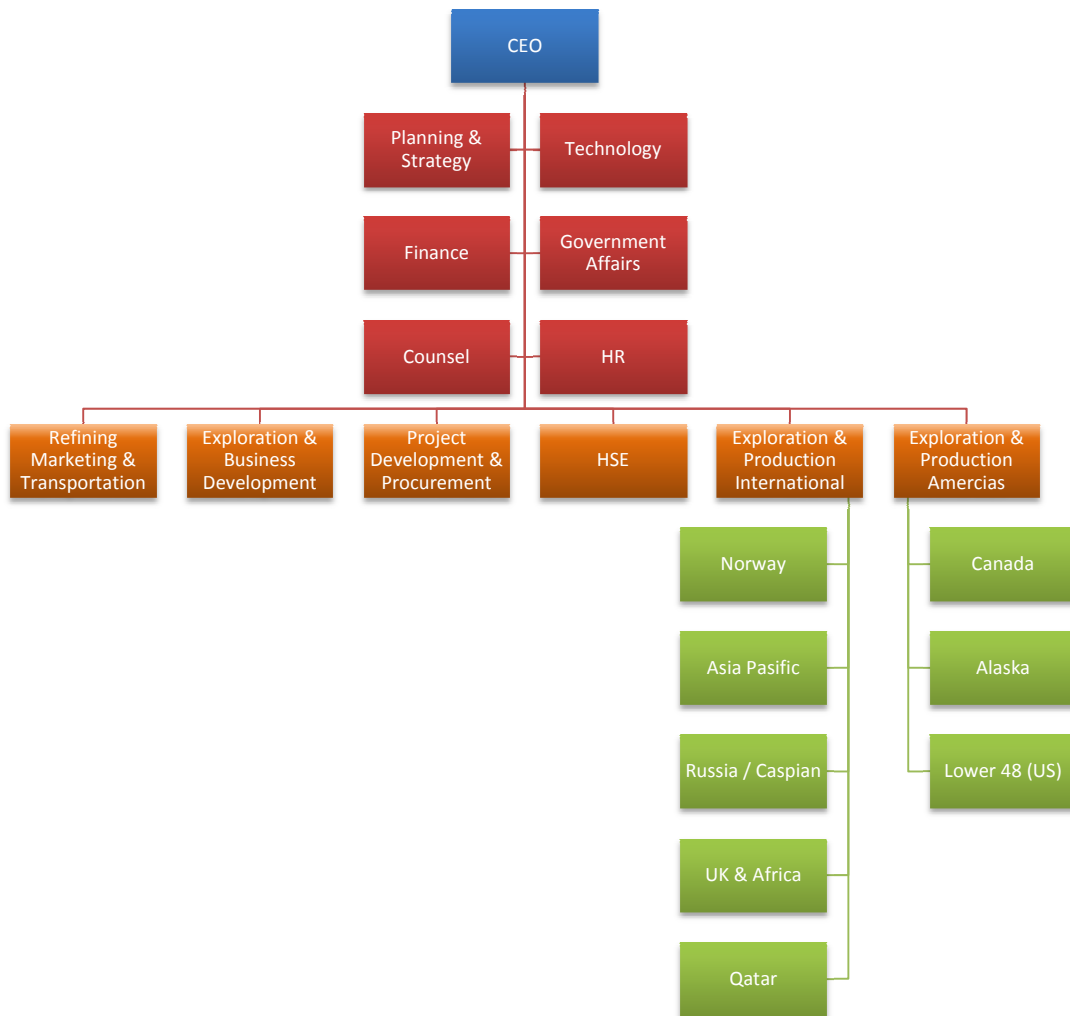


Figure 3-6: ConocoPhillips Organization Structure

### 3.5 Project Development & Procurement

The Project Development & Procurement group (PD&P) as it is known today, was created by the company in 2006. PD&P’s purpose is to support the company’s major projects all over the world, from the development stage until the infrastructure is handed over to the operating unit. The emphasis on major projects, means that PD&P is primarily focused on bigger projects with a total capital expenditure over a certain amount.

PD&P has developed and continue to maintain the capital project management system (CPMS) in which all projects around the globe that falls in under PD&P’s area are required to follow. In addition to that, PD&P is the highest functional body within ConocoPhillips responsible for project reviews before and after final project sanction.

### 3.5.1 Organisation structure

With the same approach as with the corporate organization structure, The PD&P organization can be illustrated by dividing the organization into staff groups represented by red background color and operational units represented by orange background color.

The development of CPMS and all the formal and informal project reviews are conducted by engagement teams from the staff groups, where the project services group plays a leading role. Project services is PD&P's center of functional excellence of project management with sub groups on project controls, project risks, cost estimating, project management, QA/QC, engineering and construction services. Experts within these groups are also called upon when business units around the world without the necessary local competence require long or short-term assistance with project development.

The development engineering group, that is based out of Houston is a small team of specialists with a wide background of experience that are responsible for evaluation of business development opportunities around the world, conducting high level screening of potential engineering concepts and their economic profitability. Most of the work conducted by this group is in relation with new or inexperienced business units.

Referring to the comment made earlier about reporting lines, in green background in Figure 3-7, two of the project organizations sitting in a business unit are shown with a dashed reporting line to E&P Projects Europe & Africa

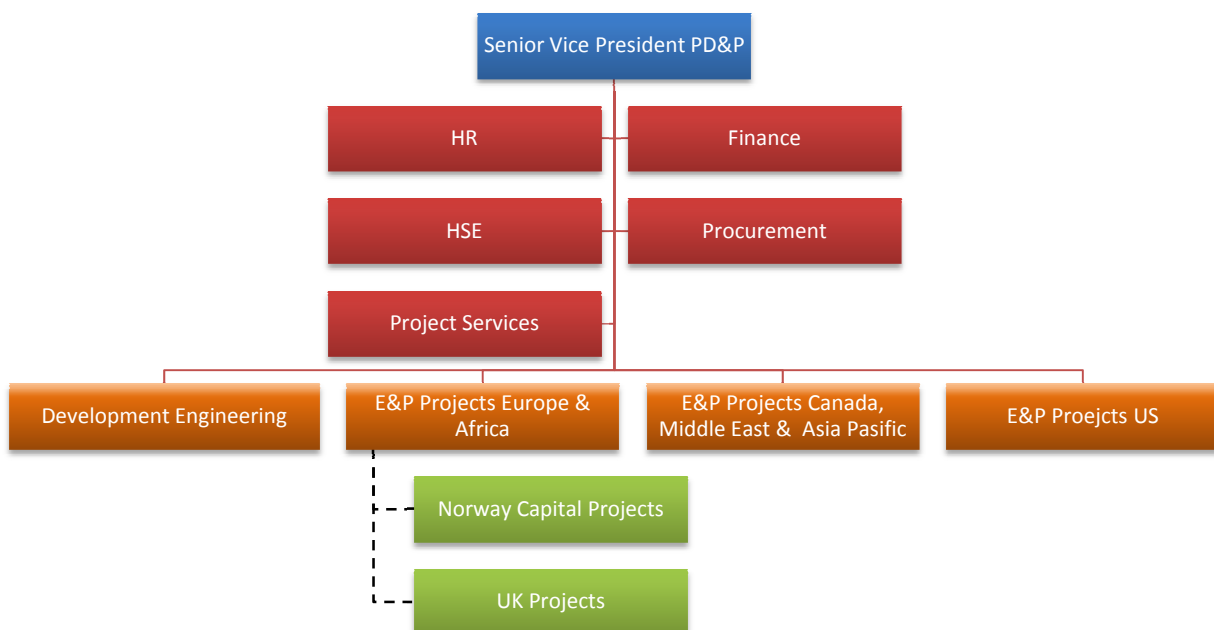


Figure 3-7: Project Development & Procurement Organization

### 3.5.2 Global portfolio of projects

The company as a whole has during the last years been hovering around an annual capital spending program of around 11-13 Billion USD and is forecasting a continued ramp up in infrastructure investments going towards 2015. As illustrated in Figure 3-8, there are 30 E&P projects around the world under the PD&P umbrella that is expected to start-up within 2015 and contribute with a production of approx 500 MBOED. Further ahead in time there is 26 additional projects up for evaluation in early phases.

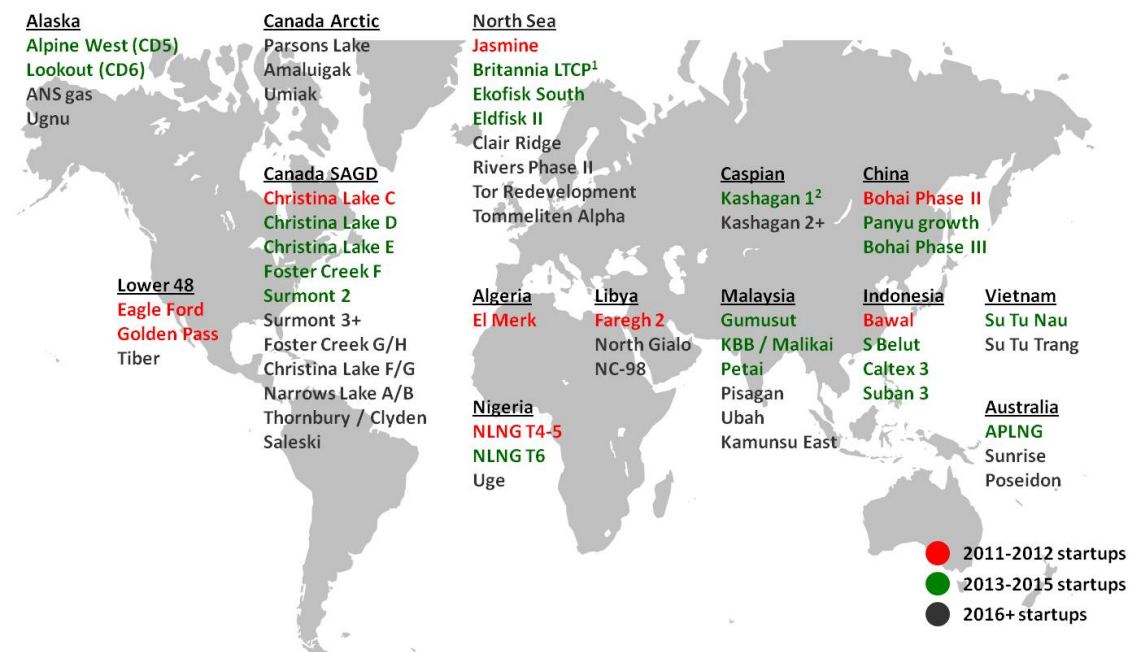


Figure 3-8: Portfolio of PD&P E&P Projects (Source: ConocoPhillips 2011)

### 3.6 Norway Capital Projects

Norway Capital Projects (NCP) is the main organizational group within the Norwegian business unit that is responsible for planning and execution of new development projects and major modification projects. NCP also plays a role in terms of providing services to internal review and follow-up on projects conducted by the company's partners on the Norwegian continental shelf. NCP has a big portfolio of major operated and partner operated projects, with project teams located all over the world.

The total number of employees and consultants working for NCP is expected to increase from approx. 350 from the beginning of 2011 until it peaks at approximately 700 people during 2013. The massive ramp up in staff and activities involves a whole series of challenges in its own, but

also some opportunities. During some intense years of planning and project execution, a lot of expertise is gathered and experience is developed. As a way of benefitting from this body of knowledge when the overall intensity of the project portfolio eventually slows down, an initial dialogue has been established to investigate the opportunities related to transforming NCP into a center of functional excellence for project management that can take on a similar roles as the PD&P Project Services group, servicing and reviewing projects in other business units around the world.

### 3.6.1 Organization structure

As mentioned in previous chapters, there are many “double” reporting lines with the current organization form. NCP is formally reporting together with 13 other departments directly to the managing director of ConocoPhillips Norway. In addition, as showed in Figure 3-8 and Figure 3-9, NCP also reports to PD&P as the central project organization in Houston, which ultimately will be responsible when it comes to promotions and career development for most of the people working in NCP.

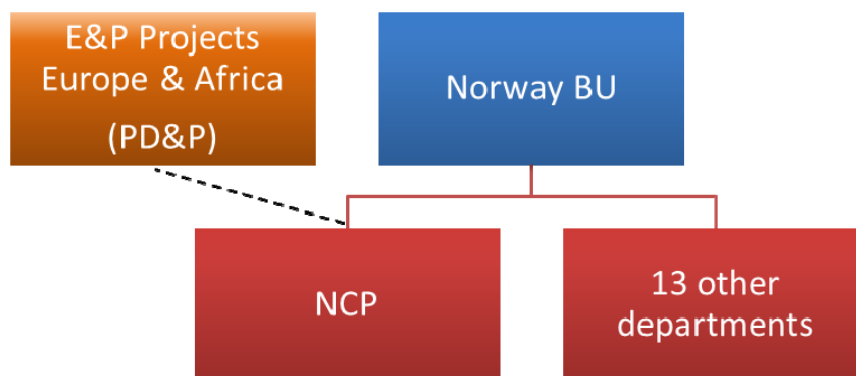


Figure 3-9: NCPs double line of reporting

Focusing more in on NCP as an organization unit, there is a much clearer matrix structure to represent the individual projects and the functional organizations that are providing support to the project teams e.g. contracts and procurement, cost estimating, planning, project control, IT integration and systems engineering. NCPs organization structure is illustrated in Figure 3-10.

A comparison of the functional groups within NCP and PD&P staff groups, and particularly subgroups within PD&Ps Projects Services group, shows that there is a lot of mirroring of the organizations going on. Mirroring is probably a result of various factors e.g. trying to satisfy the requirements set by the Houston organization in the capital projects management system, the presence of international representatives in the NCP leadership team and their direct reporting to Houston, but perhaps also a result of the fact that the business unit is quite mature, having existed since the late 1960s and the flexibility and opportunities provided with simultaneous execution of a big portfolio of projects.

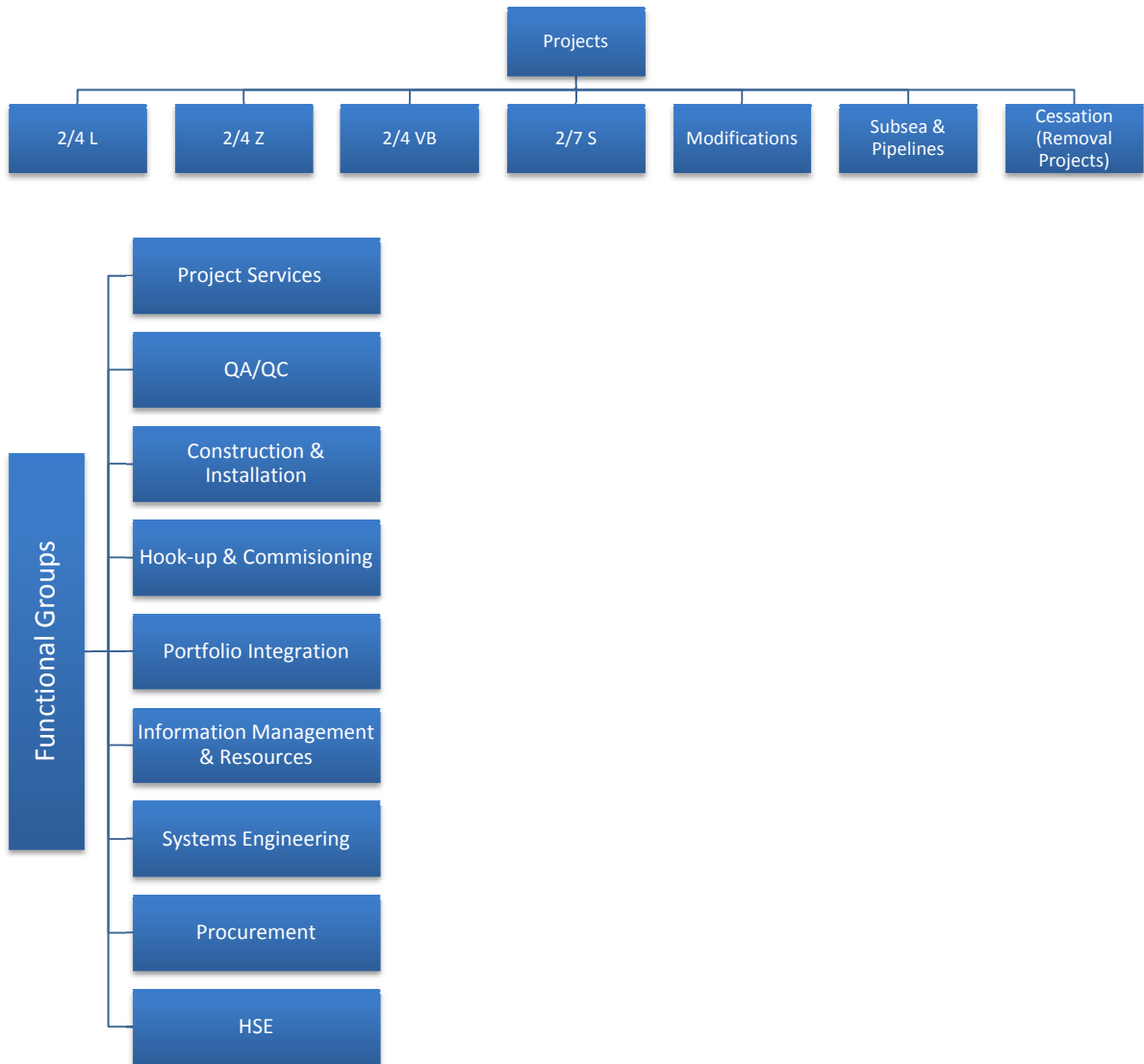


Figure 3-10: NCP Matrix organization structure

### 3.6.2 Portfolio of projects

There are four main projects currently in the execution phase being managed by NCP. In the field map seen in Figure 3-11, the new structures being installed in the period 2013-2015 is illustrated in blue.

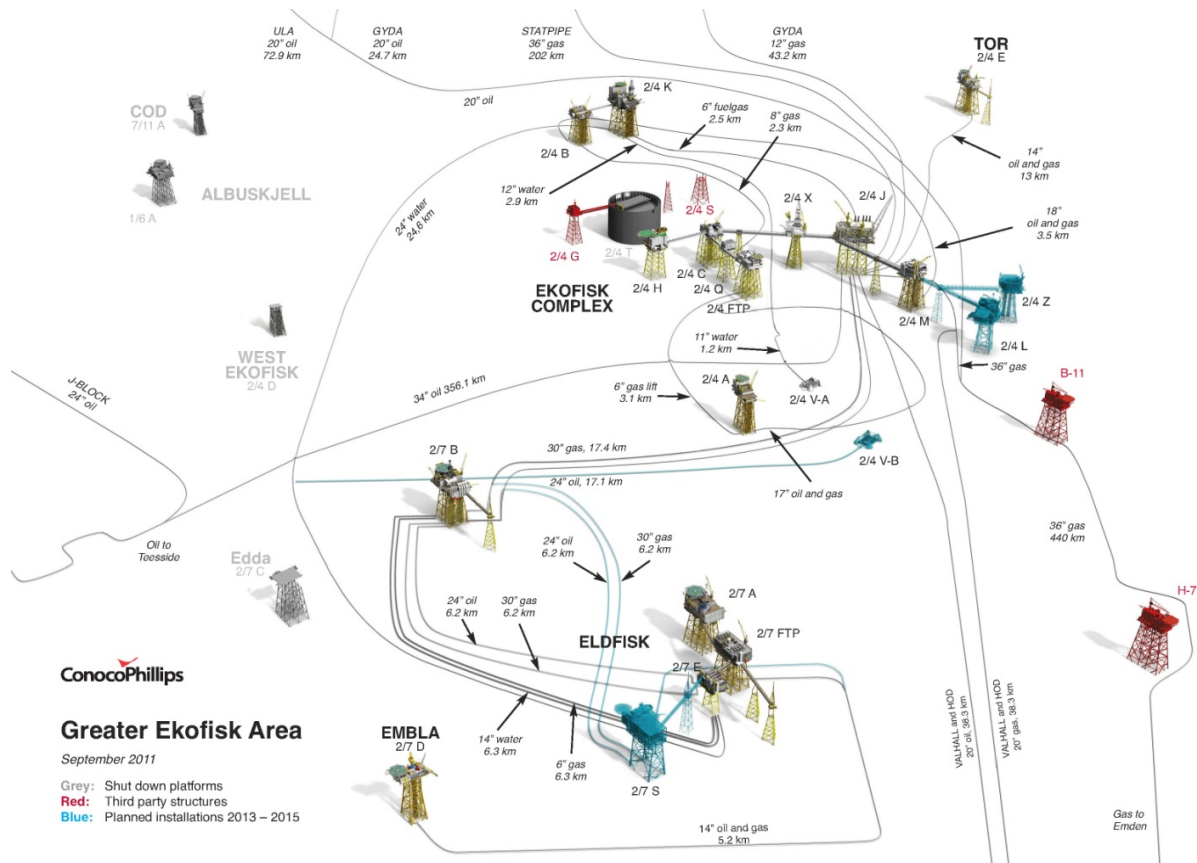


Figure 3-11: Greater Ekofisk Area Field Map

2/4 Z is a new wellhead platform with 36 drilling slots that will be connected by bridge to the main Ekofisk complex. The jacket substructure is being built in Spain and the installation is scheduled during 2012. The topside modules will be pre-fabricated in Poland before final fabrication and assembly will be conducted in Egersund. Topside installation is planned during the summer of 2013.

2/4 L is a new accommodation platform with 552 single cabins connected by bridge to the existing Ekofisk complex. The platform will also become the new central for telecommunications, helicopter and marine vessel control, and a hub for extended integrated operations (IO) with onshore IO-center. The jacket substructure is built in Verdal and is scheduled for installation during 2012. The topside living quarter modules will be pre-fabricated

in Finland before the assembly with the remaining topside takes place in Singapore. The topside installation is planned during the summer of 2013.

2/4 VB is a subsea template with 8 drilling slots for water injection that will be installed in 2013. Water injection has since Ekofisk 2/4 K was installed in 1986 been the main reservoir drive mechanism to enable continued production on Ekofisk. The new 2/4 VB is the second subsea water injection template, and together with its predecessor it will be operated from onshore by the help of integrated operation technology.

The Eldfisk II project includes a new platform 2/7 S, new export pipelines for oil and gas to the Ekofisk complex, and a significant modification scope on the existing Eldfisk complex. 2/7 S will become the new Eldfisk field center, including 40 drilling slots, living quarter with 130 beds and processing facilities. The jacket substructure is under construction in Spain, and is planned to be installed during 2013, while the topside will have modules coming in from Poland and Finland before final fabrication and assembly in Stord. The topside is planned for installation in 2014.

In addition to the new infrastructure being installation, NCP is currently executing an extensive cessation campaign to remove installations that has been shut-in over the last 30 years.

### **3.7 ConocoPhillips split into two companies**

As mentioned briefly in the introduction to chapter 3, ConocoPhillips is currently planning to split the company into two separate publicly traded companies. The split that is expected to be executed on the 1<sup>st</sup> of May 2012 will be made around the current integrated value chain.

The current upstream value chain including exploration and production activities will continue in what will be the “new” ConocoPhillips, while most of the midstream activities as natural gas processing, NGL fractionating and chemicals will to together with the downstream value chain including, transportation, refining and marketing form the spin-off company, which will take the name of “Phillips 66”. The Norwegian business unit will continue its operation as of today, with only smaller organizational changes.

The main reasoning provided for splitting the company across its value chain is the inherent difference in how the different business segments work. While the offshore exploration and production segment can be classified as a “risky” business, due to the high stakes and low probabilities of making commercially viable discoveries and the accompanied high reward on discoveries. This does not hold through for the downstream segment. With a global refining over-capacity, the profit margins are very small. It is all about buying crude oil with the most optimal specifications for the specific refinery and then try to squeeze as much high value products out of each barrel processed. By executing the split, the current board of directors hope to create two focused companies, where the value of the separate elements is higher than that of the combined company. Going forward from 1<sup>st</sup> of May, the financial market will decide if they were right or not.

## 4 Projects the ConocoPhillips way

With the previous chapters introducing ConocoPhillips as a company, and the introduction and to some extent the discussion of project management fundamentals, it is now time to look at how ConocoPhillips structure and manage their projects. The intention of this chapter is not to go into every single detail of the ConocoPhillips way, but provide the readers with a high-level overview. For some readers this might be a bit redundant, while hopefully useful for others

### 4.1 A governing framework

In a big corporation, there will always be a need to balance between giving the employees the necessary freedom of action to do their jobs in an effective and creative manner, versus the senior executive management and board of directors desire to retain control and oversight of the company and how and where capital investments dollars is spent etc. This balance is normally achieved by putting limitations to what each employee can undertake by himself and by creating procedures and standards for specific tasks, but also general behavior. (Jacobsen, et al., 2007)

Although it might appear cumbersome for individual employees, it is unavoidable with companies of ConocoPhillips' size, and especially for projects with total capital expenditure in the range of several billion USD. In fact, anything else than a structured system should be seen as irresponsible.

ConocoPhillips is no exception to the rule when it comes to corporate governance, where the capital projects organization and major projects in general have three overall bodies of governing framework that sets expectations, structure, and deliverables that affect the project and the people working on it on a day-to-day basis. The governing framework for capital projects viewed in a top down approach is illustrated in Figure 4-1, and will be discussed further in the next subchapters.

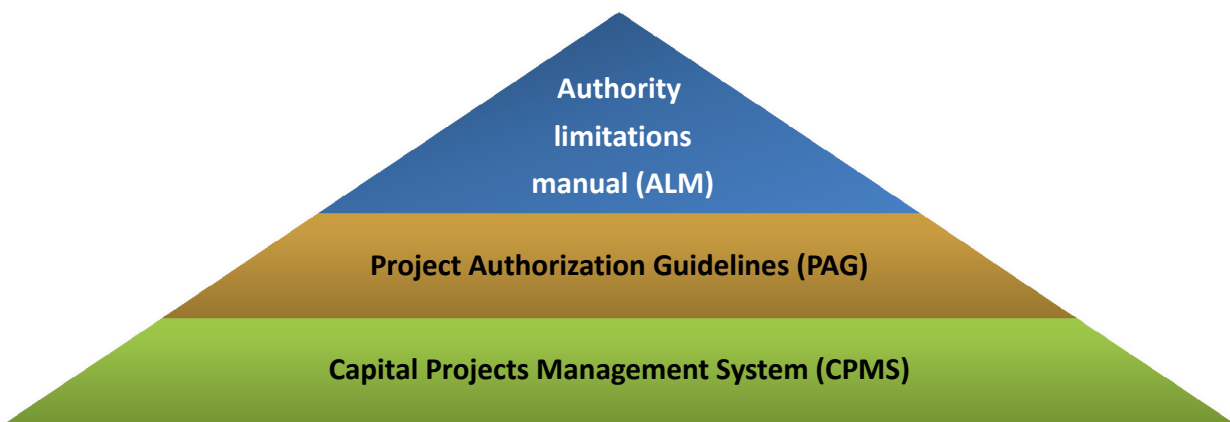


Figure 4-1: Governing framework for projects



## 4.2 Authority Limitations Manual

The corporate authority limitations manual is the highest governing framework that expresses what the different levels of executives in the company is allowed to commit to on behalf of the company, where the amounts also vary depending on the type of expense or capital investments in question.

For projects, depending on the total investment cost of the project, ConocoPhillips' share of the total cost and whether or not the project is operated and executed by one of the license partners, there are typically four layers of limited authority and one unlimited layer of authority in from of the board of directors as shown in Figure 4-2.<sup>6</sup> Projects that fall under PD&P's area of responsibility, relating back to chapter 3.5, will in most cases require final investment approval from Houston.

As noticeable in Figure 4-2, there is no approval authority for major capital expenditures within NCP or even PD&P. The thought behind this is that NCP and PD&P could be viewed as a separate entity that is hired to plan and execute the project, where the asset owners or the production side of the business is the project owner/customer that is paying the bill and retains the residual right to approve the expenditure.



Figure 4-2: Investment authority hierarchy

<sup>6</sup> Numbers are not shown as they are regarded to be company confidential.

### 4.3 Project Authorization Guidelines

The second layer of governing framework is what is called the “Project Authorization Guidelines” (PAG). As with the Authority Limitations Manual, the PAG is a document owned and maintained by the corporate strategy & planning unit, i.e. it is a governing framework for projects set by the corporate staff function, and not by PD&P.

The project authorization guidelines merges the authority limitations manual with a structured project phase process as discussed in chapter 2.5. The result is a consistent framework including directions on how the project should be structured over time with approval gates and the need for authorization. The PAG details what type of reviews that needs to be conducted at the different project phases for different sizes of project and the expected high-level deliverables for each phase and accompanied reviews etc. An overview of all the main elements governed by the project authorization guidelines is shown in Table 4-1.

PAG Element	Main Content
Authorization Framework	Links the PAG to the authority limitations manual
Project Phases Framework	Structures the project over time and details the status and expected project maturity over its life time
Project Funding	Detailing structure for the funding process depending on the type of funding request
Approval Documents	Information regarding the main documentation required for project approval including the “CEO approval letter”, “Form 2320” and the “Justification and Premise Document” (JPD)
Review and Approval process	Outlining the different types of review depending on the type of project, size and the authority level required to approve the project.
Performance Monitoring	Requirement to major projects to update economic assessments based on current status and compare with status at the time of project sanction. This is mainly done in relation with the yearly budget process.
Economic Evaluation	Outlining of principles and extent of economic assessment required, where the economic point of view as discussed in chapter 2.6.1 is taken into account.
HSE And Sustainable Development	Requirements to HSE , stakeholder, community relations, climate change and sustainable development assessment required

Table 4-1: Project Authorization Guidelines Governing Framework

## 4.4 Capital Project Management System

On the third level of the governing framework one finds the Capital Project Management System (CPMS), which defines policies, standards and procedures that are connected to the various project phases outlined in the project authorization guidelines. The CPMS provides the link between the project's day to day work, into the project phase process, the PAG and eventually the governing authority limitations manual. While the ALM and the PAG is owned by the corporate planning and strategy unit, CPMS is developed, owned and maintained by PD&P.

While CPMS applies to all major capital projects, the full-blown version of it and PD&P's involvement is only required when the previously mentioned threshold is reached. Accountability for using CPMS is then a function of project cost as illustrated in Table 4-2. There seems that there is a balance to be had between using CPMS where it can provide value, versus available resources in both PD&P and the various business units for smaller projects.

	Accountability for using CPMS		
<b>Project Services Engagement</b>	<b>BU</b>	<b>BU</b>	<b>PD&amp;P</b>
<b>Available</b>	<b>X</b>		
<b>Recommended</b>		<b>X</b>	
<b>Mandatory</b>			<b>X</b>
<b>TIC net to Company</b>	<b>&lt; \$BB MM</b>	<b>\$BB MM-\$ AA MM</b>	<b>&gt; \$AA MM</b>

Table 4-2: Accountability for using CPMS(Source: ConocoPhillips)

CPMS combine the three main elements as illustrated by the CPMS cube in Figure 4-3, where the cube itself is located on PD&P intranet site, and all elements shown in the cube are clickable.

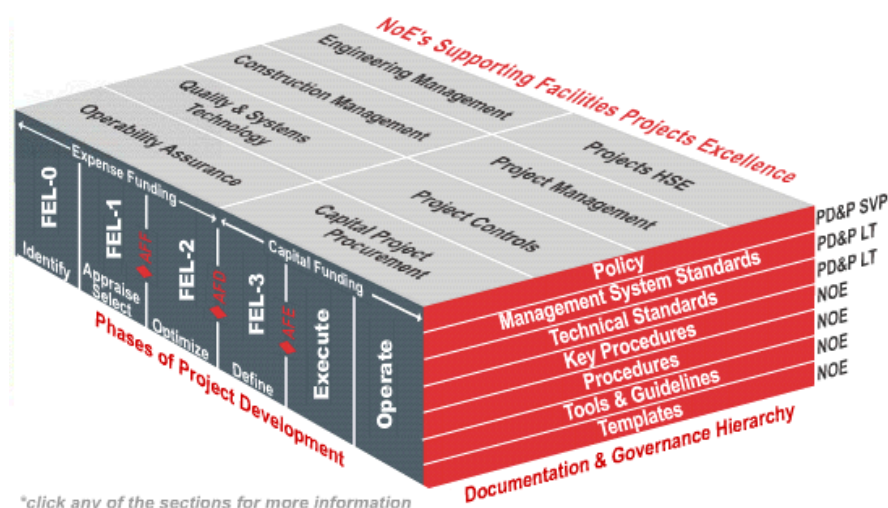


Figure 4-3: CPMS cube (Source: ConocoPhillips)

The phases of project development as illustrated in the cube are an exact match of the phase process that is outlined in the PAG. By clicking on a specific phase one is led to a list providing an overview of what in general is expected to be achieved during the relevant phase.

In red background color in front of the cube is a hierarchy of documents governing the project, from policies at the top to the tools, guidelines and templates at the bottom. Further explanation of the document hierarchy is provided in Figure 4-4.



**Figure 4-4: CPMS Document Hierarchy**

The top side of the CPMS cube illustrate the different Networks of Excellence (NOE's) that are informal groups of professionals within a discipline that communicate through a member based website community to share best practices, learn from each other, ask questions and seek help to solve problems across the global ConocoPhillips universe. As CPMS is regarded, each document within the lower end of the document hierarchy is owned and maintained by the specific NOE's. Requests to change and update CPMS documents is then often a result of discussions and trouble shooting in the various NOE's

#### 4.4.1 PD&Ps main goals

By following the “ConocoPhillips Way” of executing projects utilizing the capital projects management system, PD&P aims to achieve their four main goals of being safe, transparent, predictable and competitive as illustrated in Figure 4-5 . These goals are intended to benefit all the workers on the floor, the project team, PD&P, the project owners and external stakeholders. Table 4-3 includes interpretation of the four goals, which also becomes useful in the final discussion part of this report.



Figure 4-5: PD&P main goals (Source: ConocoPhillips)

Goal	Interpretation of goals
Safe	Execute the project and deliver assets that are safe to operate without any harm to either people or the environment
Transparent	Communicate project status, risks and issues openly and frequently
Predictable	Deliver projects accordingly or beyond the promises set for cost, time and quality at project sanction
Competitive	Deliver projects that in a safety, cost, schedule and quality perspective outperforms the company’s industry peers.

Table 4-3: Interpretation of PD&P goals

## 4.5 Stage gate process

As mentioned in relation to the PAG and CPMS in addition to the general introduction in chapter 2.5, ConocoPhillips utilize a structured project phase process called the "Front End Loading" (FEL) stage gate process.

The goal of the FEL process is to lay a solid foundation for the project by arranging for robust planning and design early in a project's lifecycle when the ability to influence changes is relatively high and the cost to make those changes is relatively low. As a result of this, it is expected that the FEL process will add cost and time to the early portion of a project, but costs are typically minor compared to the cost and effort required to make changes later on. In that sense the FEL stage gate process could be viewed as insurance against making mistakes, some sort of due diligence or as previously mentioned a risk management process in the project owners perspective.

The FEL process consists of 6 stages, and three major gates requiring management approval to continue further on as illustrated in Figure 4-6, where the final investment decision is taken at the AFE<sup>7</sup> gate.

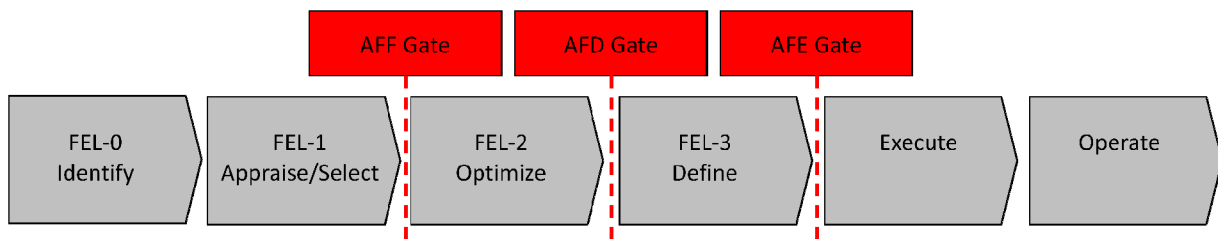


Figure 4-6: ConocoPhillips FEL stage gate process (Source: ConocoPhillips)

### 4.5.1 FEL-0 Identify

The key objectives related to the FEL-0 stage is to identify the business opportunities that arises somewhere in the world or is inherent in current assets. Upon identifying opportunities, different high level development alternatives should be investigated in an effort to assess the value and associated risk with the different alternatives. The decision to continue into the next stage is normally based on a high level cost estimate with premises for economic modeling ranging in the accuracy level of -20 % + 50%. The previously mentioned development engineering unit of PD&P is often referred to as the FEL-0 group, specializing in going around the world and evaluation new business opportunities.

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<sup>7</sup> AFF = Authority for FEED , FEED = Front End Engineering and Design  
AFD = Authority for Development  
AFE = Authority for Expenditure

#### **4.5.2 FEL-1 Appraise and select**

Getting through the FEL-0 stage with a set of different development alternatives, the objective in the appraise part of the stage is to continue working the different alternatives by conducting some high level engineering work, further the risk assessment, refine the cost estimate and update the alternatives economic model. Based on the prolonged screening in the appraise part of the stage, the team should in the select part of the stage identify at least one development concept, preferably more and prepare its deliverables to be able to select a single economic viable concept. At the end of this stage and going for an AFF approval, a cost estimate and a project schedule need to be in place along with a project execution plan (PEP) and a project objectives letter (POL). The accuracy range of the cost estimate is expected to be decreased to -20 + 40 % when reaching the AFF gate.

#### **4.5.3 FEL-2 Optimize**

Entering into FEL-2, the objective is to refine and optimize the selected single concept from FEL-1, including selection of in-concept alternatives, development of project scope and identification of long lead items. Extended engineering activities are undertaken, especially for main process facilities. The PEP needs to be updated, the cost estimate is matured to a accuracy range of -15 % to +25 %, while the projects execution schedule has increased its detail level. Risk Register and risk assessments from the FEL-1 phase should also be maintained and updated. At the end of FEL-2 the project is required to go through the AFD approval gate.

#### **4.5.4 FEL-3 Define**

Haven gotten through the Optimize stage there is only the home stretch left before final project approval waiting at the AFE Gate. To reach AFE state the project team needs to perform preliminary detail engineering and finalize the project execution plan. Long lead items identified in FEL-2 should be ordered, while the cost estimate and project schedule needs to be developed further to support full project funding and approval. Going for an AFE approval, it is expected that the cost estimate accuracy range is within -10% + 15 %, while the schedule should be matured to a level 3 execution schedule. As in FEL-2, the risk register and the risk assessment needs to be updated before going for the AFE approval.

#### **4.5.5 Execution & operate**

After getting through the AFE gate, the project can continue with full-scale detail engineering, initiate procurement and construction, before the final transport, installation and commissioning phase can commence. On completion of commissioning, the project object is handed over to the project owner / operating department where as the project organization is

demobilized, closeout reports and lessons learned are written before the project charge account is finally closed marking the end of the project.

#### 4.6 Project engagement process and reviews

As mentioned previously, the PAG includes a set of detailed requirements for the type of project reviews that are required at the different stages. In an effort to facilitate the entire approval process and the projects interaction with PD&P in each stage, there has been developed a project engagement process, with dedicated personnel responsible for planning the engagement and helping the project team through the various sets of engagement requirements.

Without going to much into the details of all the various types of reviews and technicalities around them, there are two main types of reviews applicable for a major project under PD&P's area of responsibility, known as the integrated review and the corporate review. A revised version of the FEL stage gate process with the reviews included is shown in Figure 4-7.

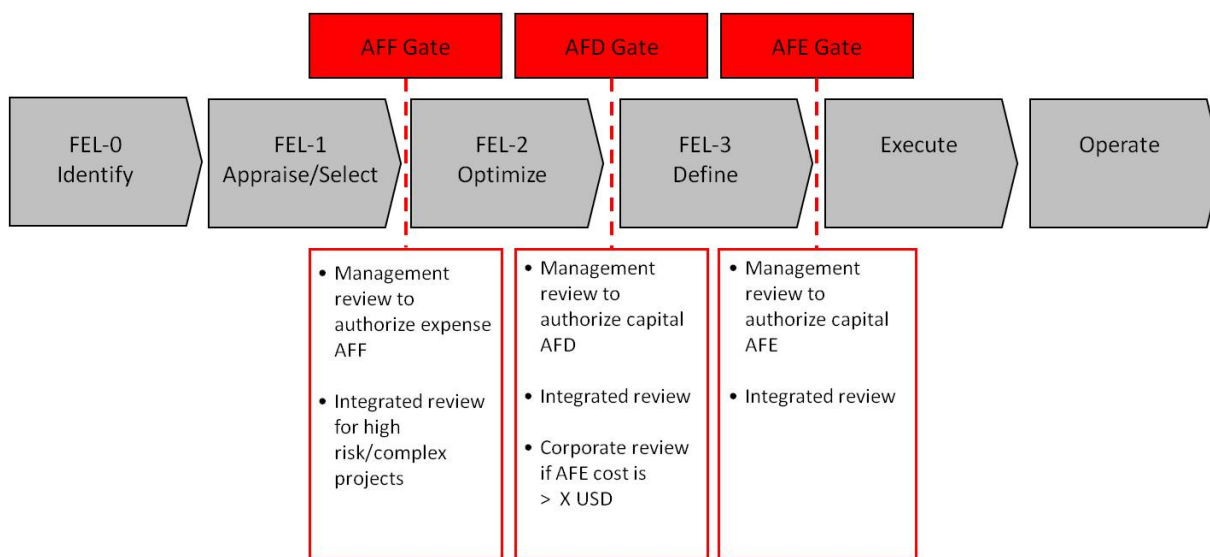


Figure 4-7: FEL and Review process (Source: ConocoPhillips)

While the integrated review focuses on technical maturity, HSE, procurement, cost, schedule and project risk, the corporate review is focusing more on the strategic fit of the project within the company, project governance, commercial aspects and the overall investment appraisal.



## 4.7 Project manager versus the project integration manager

All the projects that are currently being executed by the Norwegian business unit have been equipped with two managers sharing the project responsibilities between them.

There is the traditional project manager (PM) that is focusing narrowly in on the project objectives, including scope, schedule and cost. In addition, the PM is responsible for overseeing the contractors, staff and manage the project management team, reporting to PD&P management in Houston as well as providing input to the engagement plan and supporting the project reviews.

As the PM's counterpart, one finds the project integration manager (PIM). Whereas the PM is focusing only on the project objectives, the PIM is responsible for keeping a broad focus and manage the overall business objectives. The extent of the PIMs responsibilities covers:

- External stakeholder management
- Maintaining the interface to the business unit senior management
- Managing the broad specter of business objectives e.g. life cycle cost
- Managing all the interfaces between the project as led by the PM with the all the business unit functions that is external to the project organization while still important to the long-term success and fulfillment of the business objectives. The key functions are HSE, commercial, finance, tax, legal, subsurface, drilling and production

The relationship between the PIM and the PM and their reporting lines are illustrated in Figure 4-8.

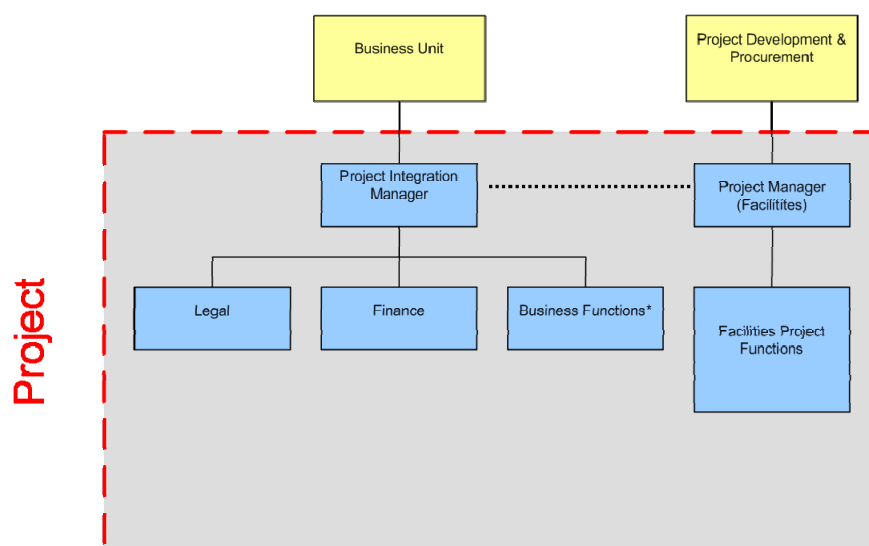


Figure 4-8: PM versus PM (Source: ConocoPhillips)

## 5 Project Risk Management in ConocoPhillips

Continuing onwards from the high level project management introduction in chapter 4, it is time to look a bit deeper into project risk management in ConocoPhillips, starting by outlining the different documentation related to risk management in CPMS and the deliverables required for each project phase before going more into details on the risk management process itself.

### 5.1 Risk management in CPMS

Risk management in CPMS is mainly covered by the three documents:

- Risk Management Standard CPMS-PMT-MS-002
- Risk Implementation Procedure CPMS-PMT-PR-013
- Project Risk Management Guide CPMS-PMT-GU-001

In addition to the PD&P CPMS documents, NCP has issued a supplement to the CPMS-PMT-MS-002 Risk Management Standard, with doc.no. NCP-PP-F-00004.

#### 5.1.1 Risk management standard CPMS-PMT-MS-002

The risk management standard is the highest-ranking relevant document in CPMS, outlining the minimum requirements for ConocoPhillips Project Management Teams (PMT) in terms of implementing risk management into the project.

As a standard should be, it is quite short and compact, only two and a half pages outlining in bullet points the requirements for a project to:

- Create a project specific risk management plan
- Conduct risk identification
- Conduct a qualitative risk assessment
- Conduct a quantitative risk assessment
- Establish risk mitigation plans
- Document their work in keeping a project risk register up-to-date and creating a Contingency Breakdown Report (CBR) for the project gates AFF/AFD & AFE based on the result of the quantitative assessment

#### Observations

While the standard for the most part is quite concise and to the point, it sometimes wanders off track of what should be included in a standard, e.g. setting guidance on how many digits results should be presented in the previous mentioned CBR, and outlining several specific requirements for the quantitative risk assessment.

## **Recommendations**

It seems like there is some opportunities to clean out some of the details mentioned above which might be more suitable in a procedure or a guideline. On the other hand, the standard could benefit from including a generic high-level risk management process, which currently only is touched upon in the risk management guide as the tier-3 level risk management document. The risk management process should in that case take part in structuring the content of the standard.

### **5.1.2 Risk implementation procedure CPMS-PMT-PR-013**

As for the standard, the risk implementation procedure is short, concise and on a high level with main topics on:

- How to populate and update the risk register
- How to conduct project level review of the risk register
- How to conduct functional level review of the risk register
- Mitigation plans
- Contingency plans
- Risk communication
- Record Retention

## **Observations**

As the tier-2 document under the risk management standard, this document is to some extent suffering from falling between two chairs. It picks up the thread started in the standard on bullet points as risk identification, risk register and mitigation plans, but then only adds some additional generic items to the list. In addition, there is still not outlined a risk management process, and the implementation part of the document is mostly covering issues related to the keeping and communication of the risk register information

## **Recommendations**

The way the procedure is currently laid out, and due to missing details, it is hard to see how it can be used. Of a practical nature, a potential solution could be to phase out the document while making sure that the information is covered in the tier-3 guideline document or in the standard as high-level requirements. An alternative solution could be to merge the project risk management guide with the implementation procedure to create a more encompassing risk management procedure.

### **5.1.3 Project risk management guide CPMS-PMT-GU-001**

The project risk management guide, which was last revised back in 2009, starts with the same generic sections as in the standard and the procedure, but goes more into details on areas as responsibilities and general validity. After the generic introduction, the guide outlines an ongoing risk management process that is recommended implemented, and continues thereafter by going through each step of the process outlining objectives, deliverables, participants and content of each process step, making it a very useful document.

#### **Observations**

The last step in the ongoing risk management process is “communicate” with some sub-information related to mitigation plans and CBR results.

#### **Recommendations**

On the observation point mentioned above, compared to the ISO risk management process outlined in chapter 2.8.2 there are some discrepancies and potential improvements to be had, this point is expanded upon in chapter 5.4. In addition, it should be noted that the recommendations from chapter 5.1.2 needs to be seen in connection with the treatment of the guide. As a final remark, serving as perhaps the most useful CPMS document on risk management, it should be revised more frequently.

### **5.1.4 Supplement to risk management standard NCP-PP-F-00004**

The only NCP specific document on project risk management has been classified as a supplement to the general standard, while in reality, the supplement is in fact more of a premade project risk management plan in which a NCP project can pick up and substitute the generic naming with project specific details.

The document contains:

- Definition of Risk
- In-depth information of areas of responsibility interfaces etc.
- Detailed information about risk reviews
- Detailed introduction to the entire risk management process with separate and encompassing subchapters outlining each phase

#### **Observations**

There is some inconsistency in the treatment of risk as a term related to negative versus positive outcomes in the definition part of the document. There are also some definitions that are not utilized later on in the document, and the elements included in the risk review chapter seem a bit out of place. The last step in the risk management process is named “Implement” and includes mitigation actions and communication of CBR.

## Recommendations

Being a project risk management plan that is generalized, this document should not be classified as a supplement to the standard, instead and with some minor changes, the document should be re-issued as a NCPMS key procedure. This re-issued key procedure should be in full compliance with the CPMS Risk Management Standard and in addition take in all relevant elements from the CPMS Risk Implementation Procedure and the CPMS Risk Management Guide. By doing so, the new key procedure would be the only document on project risk management that the Norwegian business unit would have to be in compliance with.

The document itself could benefit from sorting out the inconsistency issues described above, while the chapter on risk review could very well be incorporated into the process walkthrough. The risk management process itself should be reviewed, with some potential upside in adapting a version of the ISO 31000 risk management process. As with the risk management guide, this document was last revised in 2009 and deserves an update.

## 5.2 Project execution plan & risk management

The project execution plan (PEP) is one of the key deliverables for the project manager at the various stage gates, serving as a high-level document that explains how a project will be executed, managed, contracted and controlled. CPMS includes a "Project Execution Plan Key Procedure CPMS-PMT-PR-006" that outlines what should be included in the execution plan, with a section set aside for Risk Management. This sections reference back to the risk management standard CPMS-PMT-MS-002 as the governing document for project risk management while reinforcing that the risk management plan shall include:

- The strategy for identifying, quantifying, and mitigating project risks.
- The key risks facing the project (top 10 risks and opportunities).
- Contingencies and mitigation plans adopted for the key risks.
- Plan for communicating risks.

For projects in Norway, using the NCP-PP-F-00004 Supplement to the Risk Management Standard as a template for the risk management plan should ensure full compliance with the requirements set to the project execution plan.

### 5.3 Risk management key deliverables

The risk management standard and the NCP supplement outlines which activities should be undertaken and the intended outcome of these activities. CPMS also include a “Project Phase Deliverables Workbook CPMS-PMT-PR-032” that sums up all the high-level deliverables for all discipline/functions in each project phase.

The main risk management deliverables can in accordance with the above-mentioned documents be condensed into Table 5-1. The elements will be discussed further in coming chapters.

Deliverables	Description	FEL 0	FEL 1	FEL 2	FEL 3	Execute
Risk Register	Listings of risks with: <ul style="list-style-type: none"> <li>- Qualitative probability and impact assessments</li> <li>- Probability and impact from quantitative assessments</li> <li>- Identified mitigation actions with impact assessment</li> <li>- Action plans, accountability and status</li> </ul>		X	X	X	X
Cost Risk Model	Probabilistic Project Cost Model with: <ul style="list-style-type: none"> <li>- Base Estimate</li> <li>- Cost estimate variance</li> <li>- Cost risk events</li> <li>- Schedule variance</li> <li>- Schedule risk events</li> </ul>		X	X	X	X
Schedule Risk Model	Probabilistic Project Schedule Model with: <ul style="list-style-type: none"> <li>- Schedule variance</li> <li>- Schedule risk events</li> </ul>			X	X	X
Contingency Breakdown Report	Standardize document for reporting of cost and schedule contingency, with details on major risks, and model element contributions to the contingency. The document shows the buildup from base estimate to final P50 estimate of the project. Key delivery to Integrated review and as input to economics assessment and stage gate approval		X	X	X	X

Table 5-1: Risk Management Deliverables

## 5.4 ConocoPhillips risk management process

The NCP supplement to the risk management standard outlines a high-level risk management process that includes the four main elements plan, identify, assess and implement, where the process is supposed to be iterative throughout the project lifetime. A simplified illustration of the risk management process is shown in Figure 5-1.

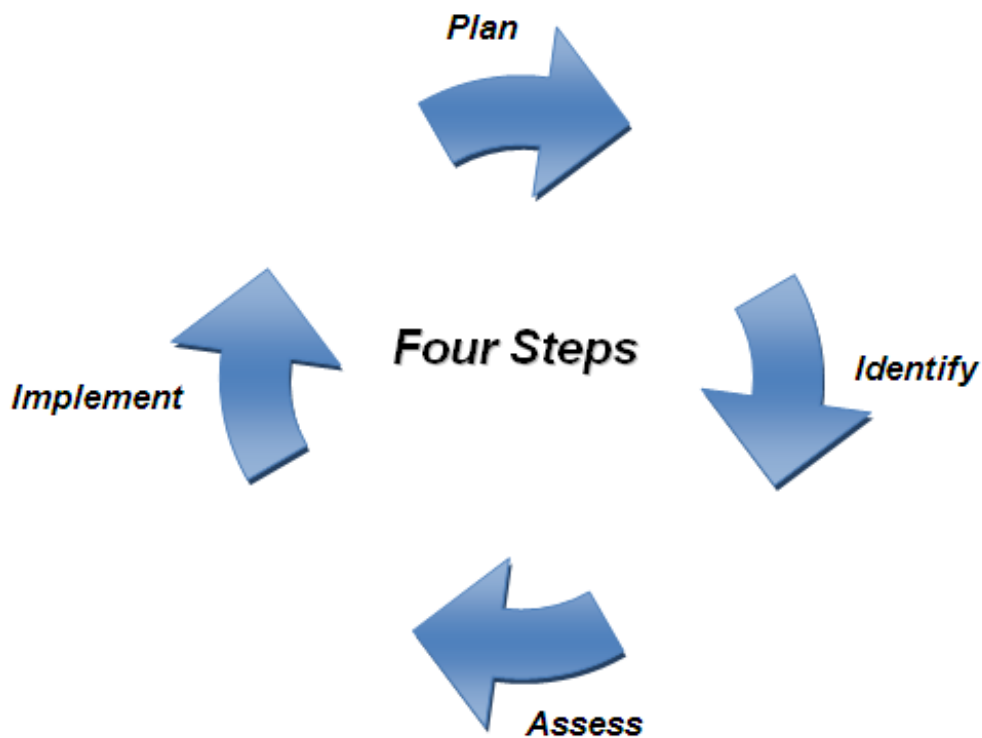


Figure 5-1: Risk Management Process

### 5.4.1 Plan

The first step in the process is to establish and validate the risk management plan for the project. This involves outlining an overall strategy and risk management approach including documenting roles and responsibilities for the various activities and depending on the project value and complexity; planning of which risk management activities to undertake and when to do so. The risk management plan needs to be reviewed at least at each project stage.

Going back to the discussion about definition of project risk in chapter 2.8.1, the planning phase also needs to define project risks in such a way that the boundaries for the coming process steps are clear and understood by all stakeholders.

### **5.4.2 Identify**

The second step in the process is about identifying risk and contributes towards creating and maintaining the project risk register, which is one of the risk management deliverables in the FEL stage gate process.

The (by far) most common identification technique is through facilitated workshops, where the broad project team is gathered to try to collect as many point of views as possible. The NCP supplement also points towards the risk advisor / risk coordinator conducting interviews with key project stakeholders in order to go more into depth on a specific risk than the broad workshop forum would allow for. Lessons learned from other projects, internal and external ones are also pointed towards as a potential valuable source of information.

The final supplement suggestion is to use assumption analysis of all the planning assumptions made by the project team, and that the outcome of such an analysis would have the potential to significantly strengthen the risk identification step. This consideration is probably very wise, but the extent in which it is actually carried out is probably rather limited.

All risk information needs to be entered into the project risk register, which is the key repository of risk information. The risk register is a “database” of all the risks that have been identified on the project with details of their cause, effect and consequence; the assessments made of likelihood and impact; as well as mitigation actions and any other pertinent details. The risk register is held on an Excel based tool and is controlled by the risk coordinator, but available to all project staff.

### **5.4.3 Assess**

The assess step, is to be understood as carrying out what PD&P refers to as quantitative risk analysis (QRA), where the main drivers behind the analysis are to enable better prediction of project cost and duration, in addition to serve as a decision tool when evaluating options.

A QRA is required before each approval gate, where the outputs from the analysis are fed into the contingency breakdown report (CBR) which is a key delivery to the PD&P Integrated reviews. In Norway, a QRA is normally also performed every sixth months during execution in relation with the current cost estimate update (CCE). QRA results are also fed directly into the projects economic model, which is part of the decision basis for the relevant authority.

As defined by PD&P, a QRA is basically separate Monte-Carlo simulations of the project schedule and cost estimate where the identified risks are included, and the base duration/cost



elements is assigned a probability distribution to reflect the inherent risks present in the estimates.

The separate Monte Carlo simulations of schedule and cost, means that the schedule model is run first, where the main results thereafter are fed into the cost model to enable slippage in the project schedule to drive costs. Due to the crudeness in the link between the schedule and the cost model, the PD&P approach could be classified as a semi integrated cost schedule model.

NCP however, seems to have taken the modeling part a bit further than the rest of the PD&P universe, by running only one fully integrated risk model where cost and schedule is linked together seamlessly with full interaction for each single iteration of the Monte Carlo simulation.

#### **5.4.4 Implement**

Implement is the last step in the iterative risk management process, where focus is put on risk treatment or mitigation as it is referred to in ConocoPhillips. The real value of risk management lays in how the organization chooses to act on information gathered through the identification steps and the analysis result to help them achieve or exceed their objectives.

The risk management standard supplement includes generic risk treatment strategies as; eliminate the risk, reduce likelihood of the event, reduce impact of the event, share the risk, accept the risk etc.

For all risk treatment strategies, there is a requirement to capture and document the following data in the project risk register:

- Description of the action(s) identified
- How the action will help treat the risk
- Who the action owner is
- Target date for completion of the action
- How much the action will cost
- The post-action assessment of the risk
- Details of any secondary risks that result from the action itself

As a general comment to the risk management process; even though the process is iterative, it should be noted that while still in the early phases of the project, focus should predominantly be put on risk identification and analysis, while shifting more towards risk treatment and implementation of the treatment strategies in the late phases.

## 5.5 Roles & responsibilities

There are many different people involved in the risk management process and various activities e.g. for the current major projects managed by NCP the number of participants vary between 30-60 individuals on each project. The following descriptions of the different key roles are abstracts taken from the NCP supplement to the risk management standard. A high level illustration of all the interfaces is provided in Figure 5-2.

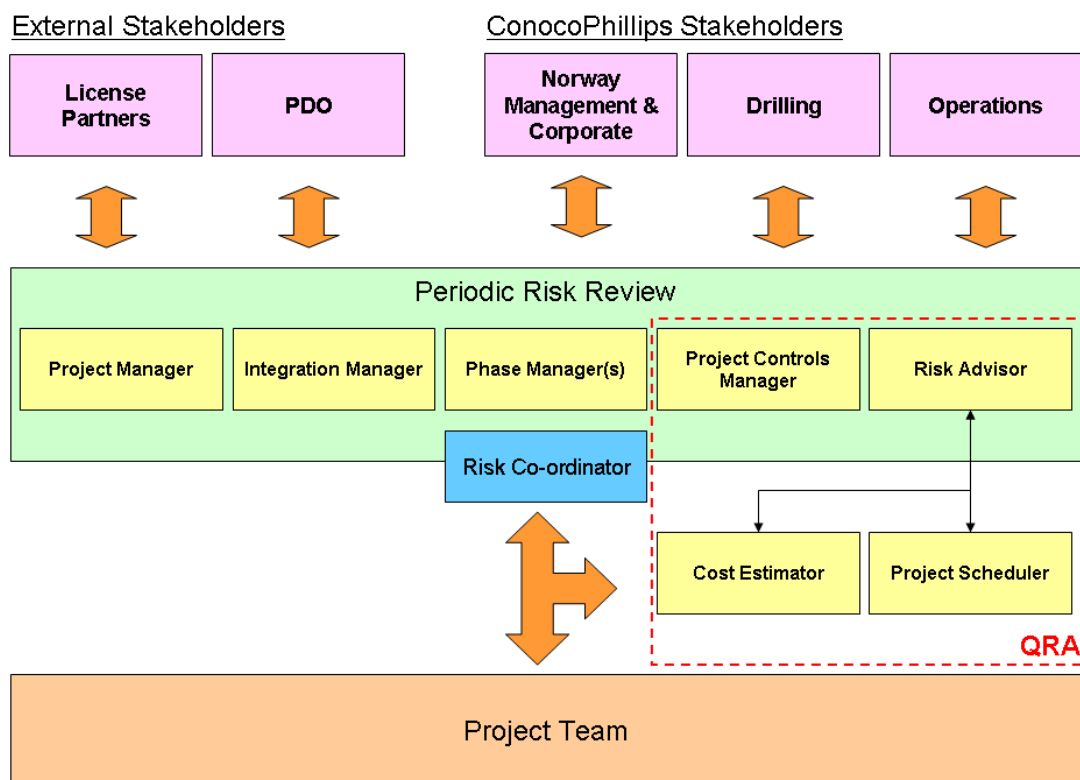


Figure 5-2: Project Risk Roles & Interfaces (Source: ConocoPhillips)

### 5.5.1 Project manager

The project manager is ultimately responsible for the project objectives and all the mandatory deliverables during the projects lifetime, with risk management being no exception. This includes:

- Responsible for compliance with the risk management plan and standard
- Support the development of a risk management culture within the project, such that risks can be raised and discussed openly

- Determine the level of resource effort that should be applied at each phase of the project
- Ensure that the project team pro-actively manage risks in accordance with agreed strategies
- Ensure that the appropriate internal and external stakeholders are involved in the identification and assessment of risk and that risk outcomes are effectively communicated

### **5.5.2 Project team members**

Risk management is the responsibility of all project team members. Team members shall:

- Attend risk workshops/interview sessions
- Pro-actively identify risks and inform the risk co-ordinator of newly identified risks
- Carry out specific actions that they are assigned
- Be familiar with key risks to the project and the risk register with emphasis on risks within their own areas of expertise and those they need to interface with

### **5.5.3 Risk advisor**

The risk advisor is normally a shared resource that is part of the functional side of the NCP matrix organization working in the NCP Risking group, where the group leader reports directly to the NCP Project Services Manager. The group of risk advisors is then split between all the projects in the portfolio, where their main responsibilities include:

- Facilitating the identification of risks to the project through risk workshops & interview sessions
- Conducting Quantitative Risk Analysis (QRA) in preparation for either an upcoming approval gate, Current Cost Estimate (CCE) or as otherwise directed
- Provide suitable analyses of risk model results to enable risk treatment decisions to be made
- To facilitate the capture of risk treatment actions identified by the project team

### **5.5.4 Risk co-ordinator**

The risk co-ordinator can either be the same person as the risk advisor coming from the NCP risking group, or it could be a member of the project team that takes on the risk coordinator role either as his/hers fulltime job or in addition to other areas of responsibilities, where the risk co-ordinator role includes:

- Ensure project risks is reviewed by the risk owner on a regular basis
- Track progress against risk treatment actions

- Update the risk register to reflect the most recent progress and comments following risk reviews
- To chair the periodic risk reviews (usually Monthly)

### 5.5.5 NCP risking group & portfolio integration

As mentioned above, the NCP risking group is part of the functional matrix organization where the group leader is reporting to the Project Services Manager. In addition, there is a portfolio integration group, where the group leader and most of the employees previously has either worked in and/or, been leading the NCP Risking group. An organization chart is provided in Figure 5-3.

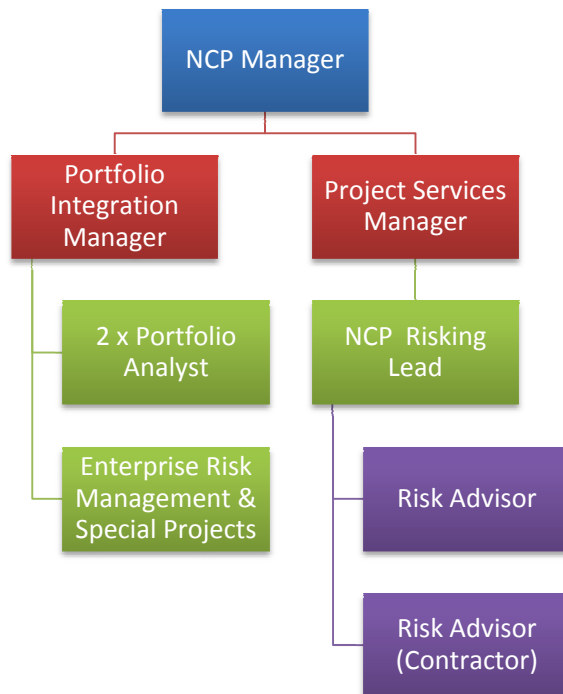


Figure 5-3: Extended Project Risk Management Personnel

All the individuals working in these two groups have the experience and capabilities of providing services as either risk advisor and/or risk coordinator to a project. Even though there is a lot of knowledge and experience, it is only the NCP risking lead and the two risk advisors that are dedicated resources set aside to facilitate the risk management process for all the projects, operated as well as partner operated.

## 5.6 Risk analysis results and contingency

In the previous chapters, reference has been made to the risk analysis results, more specifically of the results being used to populate the CBR and as input to the economic model.

While going more into the details on risk modeling in chapter 6, for now, the main purpose of the cost risk analysis is to provide the contingency amount that will go into the overall project-funding request. While the cost estimator creates a deterministic base cost estimate, the risk analysis is intended to take risks related to the cost estimate, the schedule, contractors, vendors, organization etc, and translate these risks into a monetary amount that should be added on top of the deterministic cost estimate to ensure that the project is adequately funded. Escalation is finally added to both the contingency and the deterministic cost estimate to reflect the timing of the expenses. These three elements then constitute the P50 cost of the project.

The same methodology is valid when it comes to the project schedule risk analysis, but the P50 build up is limited to the deterministic project plan and the contingency contribution. Illustrations of total cost build up and P50, versus contingency and deterministic values is shown in Figure 5-4 and Figure 5-5.

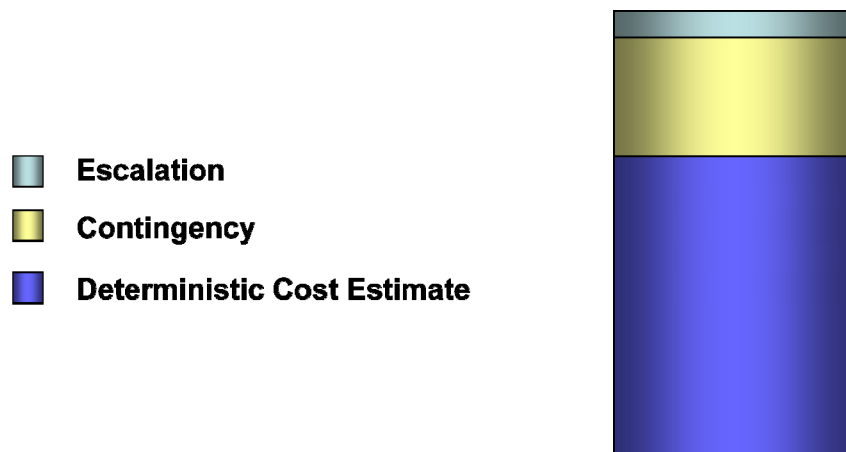


Figure 5-4: Contingency as part of the total cost

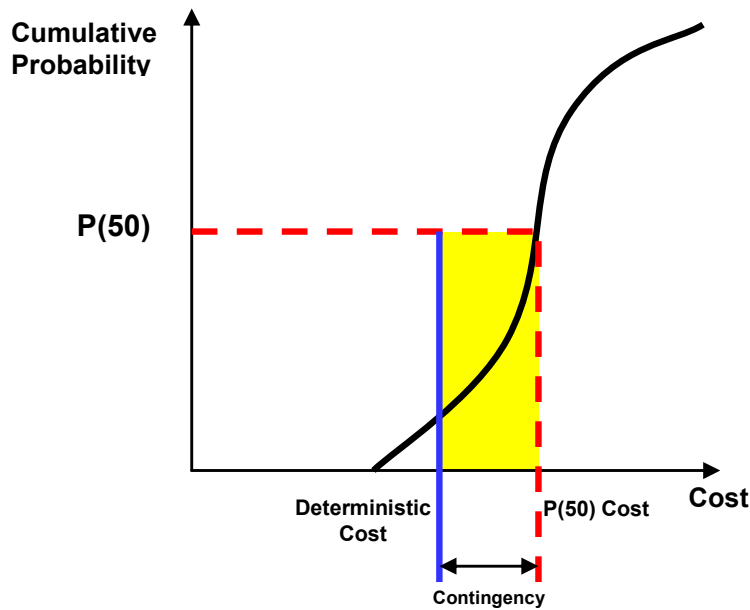


Figure 5-5: P50 & Contingency versus deterministic cost (Source: ConocoPhillips)

## 5.7 Contingency breakdown report

The contingency breakdown report (CBR) is one of the key risk management deliverables that is required as part of the integrated review. The CBR is a 3-5 page long document that is full of detailed information within the following headers:

- Project team involved in the QRA
- High level cost estimate & cost estimate variance from risk model
- Labor cost variance
- Cost risk events
- Schedule variance contribution to cost
- Schedule risk events contribution to cost
- Schedule risking result of project milestones
- Escalation and foreign exchange scenarios
- Excluded risks
- Overall summary of both schedule and cost assessment

By examining the four pages long “AFE CBR” of one of the current major projects, more than 1100 cost related numbers and project dates was counted in the document. In addition, there is a lot of comment fields, and supporting text.

## 6 Risk Analysis Model Review

The assessment part of the risk management process is predominately focused in on conducting a quantitative risk analysis (QRA) of the project schedule and cost estimate, where the main technique is to create and run a Monte-Carlo based model. As previously discussed, the results of the risk analysis are used to populate the CBR and feed into the economic model. This chapter will go more into the details of how the risk model is put together in order to give an impression of the complexity and work effort related to facilitating the QRA process, creating the model, interpret the results and translate them into the mandatory communication format.

### 6.1 Model overview & interfaces

It is worthwhile to establish an overview of the situation, to see the model from a bird's eye view, before zooming in on the details throughout the rest of the chapter. As illustrated in Figure 6-1, the cost estimate, the project schedule, and the risk register is the main input elements necessary to create the Monte Carlo model. The main results of the simulation in form of P10-P50-P90 values for both cost and major milestones are then extracted and used for the CBR, feeding the economic model and in an approval presentation package.

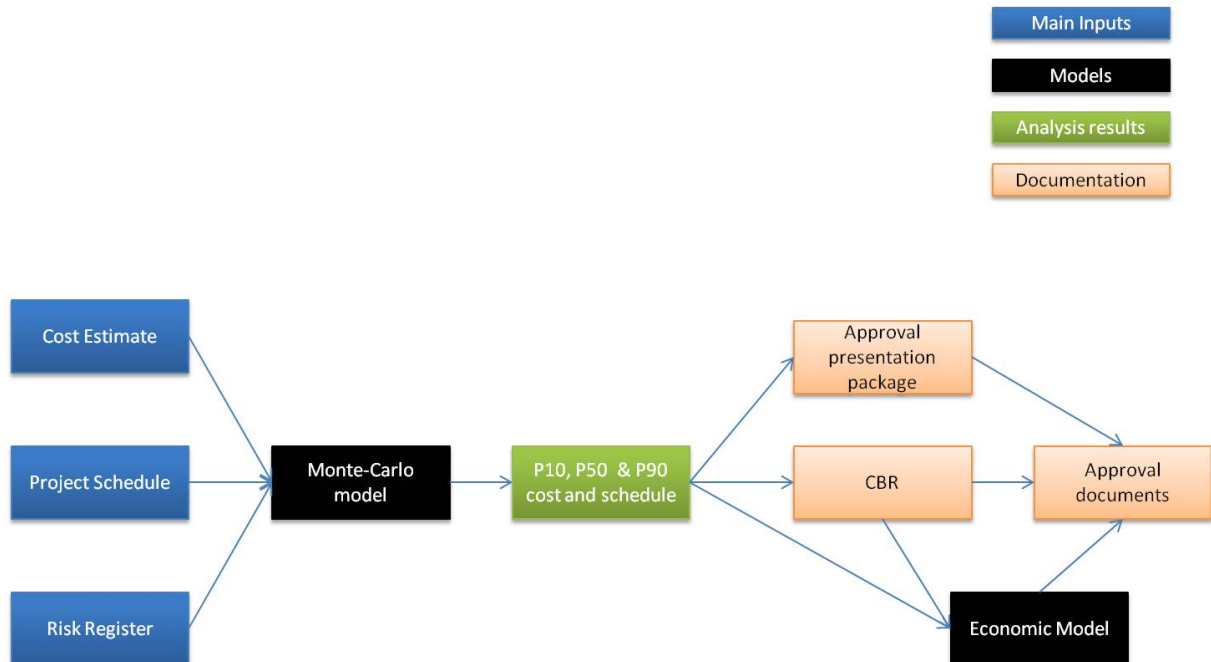


Figure 6-1: Model overview and Interfaces

## 6.2 Main inputs

The three main model inputs shown in Figure 6-1 will in the following subchapters be outlined in more detail.

### 6.2.1 High level project schedule

Using the AFE approval gate as an example, there is a generic requirement that the internal project schedule is matured to a level 3-4 schedule, meaning that in many cases the schedule is split down and showing different activities that fall into the various execution phases as:

- Engineering
- Procurement
- Onshore Fabrication
- Onshore Commissioning

Later phases tend to not be equally matured at the time of AFE, and might still be on the higher-level 2-3 schedule, this is typically valid for activities as transportation, installation and offshore commissioning.

Even though the internal schedule is kept on a high level compared to the schedule the contractors are providing, a level 3 AFE schedule might still include all from 100 to 1000 activities depending on the size of the project and scheduler preference. Running a Monte-Carlo simulation with a schedule consisting of 1000 activities is not a preferred option. It needs to be simple enough for the risk analyst and project team members to get their heads around it, they have to recognize and own it as otherwise they do not get the value. In addition, it is important that the risks from the risk register and the schedule are kept at the same level to be able to tie them together.

A normal project schedule therefore needs to be modified to some extent in order to be fit for risking, where the modification goes towards simplifying the schedule, removing unnecessary float and creating a pure logic.

Simplification of the schedule is done by aggregating some activities together to create an overall header activity or simply by removing the activity if it is deemed irrelevant for the risking purpose i.e. if it does not affect the completion time, and cannot drive costs.

Removal of unnecessary float and constraints is an important step in transforming the project schedule into a risking schedule. Float can initially be built into the schedule to provide the project with some initial buffer in case the work takes longer time than anticipated or in case of an event occurring and affecting the project. In any case, the float described above is just risk elements hitting the project. For risk analyses purposes, all sorts of unnecessary float needs to be taken out, until the remaining schedule is representing all the activities staked in sequence



and/or parallel as they could be carried out as the most optimized schedule from start of execution until handover is complete.

The removal of float means that some sort of constrained start-up date of an activity is removed and replaced with preferable a finish-to-start link. However, some activities need to be constrained to a specific date. For example, offshore heavy lift operations can only occur during the normal lifting season in the South North Sea i.e. from 1<sup>st</sup> of April until 30<sup>th</sup> of September.

A last point in creating a schedule suitable for risk analysis is to make sure that proper network links between different activities and milestones are established. In most cases this is equivalent with setting the schedule with predominantly finish to start links as discussed in the section above. Without providing any specific reasons to explain why, experience in running schedule models has revealed that the algorithms used in Monte Carlo simulation does not cope very well with activity links as start-to-start, start-to-finish and finish-to-finish.

### **6.2.2 High level cost estimate**

As with the project schedule, the main internal AFE cost estimate might have anywhere between hundred to several thousands of line items in it. Trying to integrate each individual cost element that is covered in the main cost estimate would be a nightmare in terms of the manual work process involved to link each cost element into the model, but also rather impractical in terms of actually running the model and interpreting the results.

As with the project schedule, the cost estimate needs to be specifically prepared in order to be suitable for risk analysis. In terms of reducing the number of cost elements to a manageable size, the various bits and pieces from the main cost estimate are typically aggregated up to the project execution phase level with cost elements buckets as:

- Owners Management
- Contractors Management & Engineering
- Procurement
- Onshore Fabrication
- Onshore Commissioning
- Transport & Installation (mostly marine and heavy lift vessel)
- Hook-up & commissioning
- General costs

The list of cost elements above would then typically be used for each of the main project objects. For example, with the current Eldfisk II model including project objects as listed below, the total number of cost elements included in the risking model could easily be up to a three-digit number when analyzing major projects.

- Topside
- Jacket
- Bridges
- Subsea & Pipelines
- Modification for x number of platforms

Since all elements of risk are supposed to be added as part of the risk analysis and contribute towards the contingency which is separated from the deterministic cost estimate, potential existence of built in allowance, typical weather allowance or other sources of buffer should be removed from the main cost estimate in order to create a “risk-free” deterministic cost estimate.

### **6.2.3 Integrating schedule and cost estimate**

With both the project schedule and the cost estimate modified for risk analysis, it is time to link them together in the model in such a way that schedule slippage can contribute to increase the total cost of the project.

Bear in mind that the network schedule is normally built using a scheduling tool like Safran, Microsoft Project or as in the case of ConocoPhillips by using Primavera. On the other side, the cost estimate is built in Excel using a standard template, which often is customized to the specific project in question.

The way these elements are integrated is by setting up what is called the “cost loading matrix”, where all the schedule activities are listed in rows, while all the cost elements are listed in columns to make up a matrix. With the matrix set up, all cost elements are distributed to the relevant activities as a percentage of the total cost element. This means that a cost element can be distributed with a percentage on many different activities or in the minimum case, just to one activity. Either way, the total distribution of the cost elements needs to be 100 %. An example matrix showing the principles described in this section is provided in Table 6-1.

The intention behind building an integrated model combining the cost estimate with the schedule is to allow schedule slippage directly to contribute towards the final P50 cost. This effect can be achieved by using the allocated cost elements and the scheduled duration of an activity to calculate a day-rate, which can be used as a burn rate in case of schedule slippage in the model. However, assigning a burn-rate is not necessarily relevant for all activities and cost elements. For instance, if the procurement activities takes longer time than planned, this does

not necessarily mean that the cost of the procured items itself is any higher. The same is valid for lump sum contracts, where a delay might not have any direct cost impacts to the project itself. This rather important distinction is taken care of by setting a separate parameter for each of the cost elements to either contribute to a burn rate or not.

The work related to modify both the project schedule and cost estimate before linking the two elements together is normally a joint effort between the scheduler, the cost estimator and the risk specialist.

		Cost estimate elements			
		Owners Management	Contractors management	Contractors Engineering	Procurement
Total cost (B USD)		15	15	20	30
Allocated %		100%	100%	100%	100%
Contributes to Burn-Rate		Yes	Yes	Yes	No
Schedule Activities					
Project Approval		40%	20%	5%	
Fabrication engineering module 1		5%	7.5%	20%	
Fabrication engineering module 2		5%	7.5%	20%	
Fabrication engineering module 3		5%	7.5%	20%	
Fabrication engineering bridge 1		5%	7.5%	15%	
Fabrication engineering bridge 2		2.5%	7.5%	10%	
Fabrication engineering bridge landing		2.5%	7.5%	10%	
Other....		35%	35%		100%

**Table 6-1: Cost loading matrix**

## 6.2.4 Risk register

The project risk register contains all the risks that the extended project team has identified throughout the various workshops, interviews etc. All risks in this register are supposed to be related with a cost and/or a schedule impact. However, this does not necessarily mean that one will not find any HSE risks identified in the register, since HSE events often have some implication on both schedule and cost.

A first step towards integrating the risk register into the schedule and cost model is to decide on which risks to include in the risk modeling. A risk register might contain several hundreds of risks, which as therefore, if all were to be included would significantly increase the complexity of the model and interpretation of the results. In addition, some risks that are identified might not be suitable for risk modeling at all, and will need to be excluded from the model. An example being the risk of pirates attacking and sinking the new Ekofisk accommodation topside when it is under transport from Singapore to Stavanger. Referring back to the discussion on

expected values and mean versus the P50, it does not make much sense to include such a risk in the cost & schedule model. The same reasoning also applies for typical acts of God and force majeure. It is important to point out that excluded risks are not forgotten risks. In case of the piracy risk, this could very well be one of the most important issues to actively manage for this project phase.

With a condensed sub-set of the risk register ready for inclusion, each risk will be linked directly to one or more of the schedule activities that is included in the risk model. The process of allocating risks to different activities is called risk mapping, and is normally a joint effort by the extended project team, where the exercise is led and facilitated by the risk specialist. At this stage, the integrated cost & schedule model and the condensed risk register are all combined into Pertmaster as the risk analysis software, enabling an effective click and select risk mapping process.

A screenshot of Pertmaster in risk mapping mode is shown in Figure 6-2, where the risk register list is in the left box, while the list of model activities to allocate a risk to is shown in the right box. The allocation is as mentioned above easily done by clicking on a risk and thereafter selecting the appropriate activity. If applicable, the same risk may be assigned to several activities

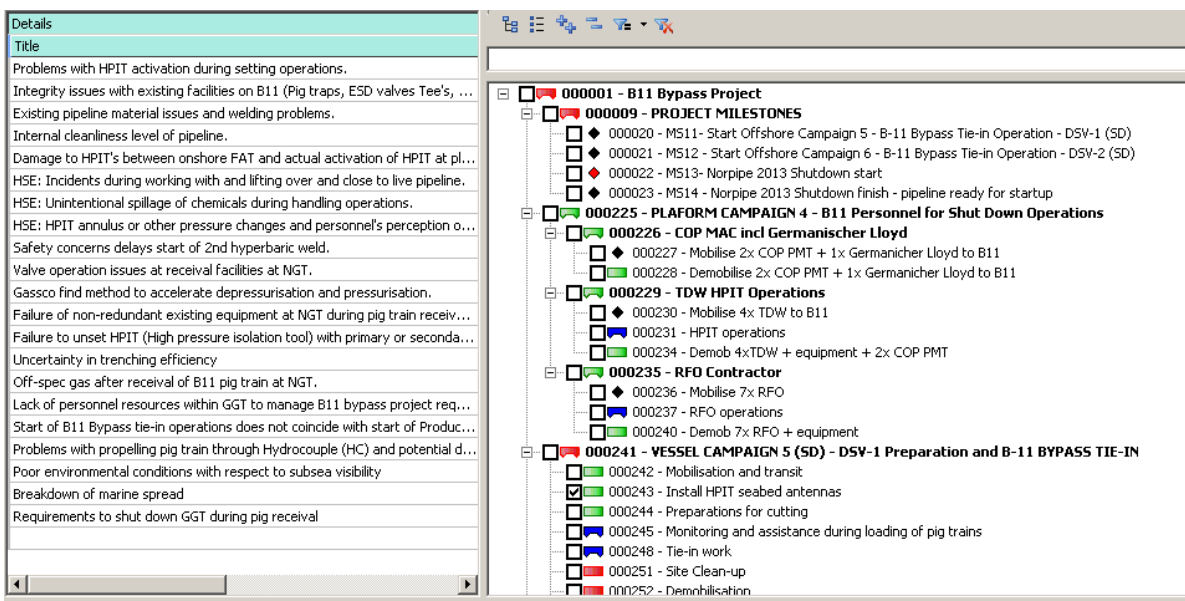


Figure 6-2: Risk mapping in Pertmaster

### **6.3 Probabilistic model parameters**

With the three main elements in the model accounted for, there are many parameters to set in order to transfer the model from an advanced deterministic model to a full-blown integrated probabilistic model. The entire list of parameters to assign is represented by:

- Schedule Variance
- Weather Calendar
- Carry-Over logic
- Cost Estimate Variance
- Labor Productivity
- Labor Rate
- Weight Variance
- Likelihood of the risk occurring
- Impact distribution if the risk occurs ( Cost & Schedule)
- Correlation of risk events
- Correlation of risk impacts
- Linking of risk events in series

#### **6.3.1 Schedule variance**

For each activity incorporated into the risk model there is an inherent risk that the activity might take longer or shorter time to complete than accounted for in the project schedule. As a result of this inherent risk, a range is normally put on the duration of each individual activity, where the common approach is to use a triangular distribution, where the planned duration is set as the most likely parameter, while the min and max value is either assigned as generic percentages of the most likely value, or as a result of a project team discussion.

#### **6.3.2 Weather calendar**

As previously mentioned, some activities are constrained to be carried out in a specific time of the year. To account for this type of limitations in e.g. heavy lifting operations, a probabilistic weather calendar can be added to the relevant activities. The weather calendar is then a parameter in which one of its purposes is to limit when the activity could be carried out. If for instance a heavy lift operation is being pushed out in time in one iteration of the model due to schedule variance, risk events etc. to such an extent that the heavy lift operation itself would be conducted outside the lifting window, the weather calendar would not allow for this to happen. The calendar would then move the activity to the beginning of the next lifting season causing the schedule to slip with approximately six months extra.

In addition to setting a constrained time period for which an activity can be carried out, the weather calendar can also be equipped with wave height criteria's where historical weather data from the Ekofisk field is built into the calendar. For heavy lift operations requiring a specific sea state condition for x number of hours to be able to conduct the lift, the weather calendar will act as a probabilistic variable in the risk model, and in each iteration determine whether or not any period of time is outside or within the given wave criteria. The occurrence of bad weather is reflecting the historical data month by month, meaning that the probability to have a none working day in April and September is much higher than what it is in June or July.

### **6.3.3 Carry-over logic**

Even if the project schedule slips to such an extent that it according to the original plan and schedule would miss the lifting window, there are still some potential for a topside being towed out and installed anyway, just to avoid sitting in the construction yard losing up to six months waiting on the next lifting season.

The downside of taking the topside offshore before it is completed is obvious, there is a lot of unfinished onshore commissioning work left to do. Instead of doing the work on land, it now has to be done offshore as carry-over work with the added time and cost that offshore work brings along. For instance, doing the work offshore could easily take four times the number of man-hours compared to doing it onshore, while the man-hour rate could easily be between 3-15 times higher than the rate of doing the work onshore, naturally depending on the location of both onshore and offshore commissioning.

The logic that is built into the risk model determines upon each iteration whether or not a specific milestone is reached, indicating that the topside is ready to be towed offshore before the last potential sail-away date from the construction yard in order to be lifted in the current season. With this, there are three potential scenarios that the model needs to be able to handle for each individual iteration as shown below.

- If the progress is insufficient to take the platform offshore, it will complete work onshore and aim to conduct the lift next year. No carry-over is required.
- If the platform has reached the milestone indicating it is ready to take offshore, but without completing the onshore commissioning work before the last sail-away date, the platform will be taken out to sea and a multiplier for the time and cost required to conduct the remaining work offshore will be added to the final P50 cost and completion date.
- If the project has finished onshore commissioning before the last sail-away date, the topside will be taken offshore and installed according to the plan without the need for any carry-over work.

### 6.3.4 Cost estimate variance

As with the schedule activities, there is an inherent risk<sup>8</sup> that the cost of each of the cost estimate elements that are included in the risk model is either going to be higher or lower than the deterministic value. To treat this probabilistically in the model, a range is assigned to each of the cost elements, normally by using the same triangular distribution and approach as previously described for the schedule variance. This assigned variance should represent the total cost estimate variance.

### 6.3.5 Additional cost estimate variances

In addition to the total cost estimate variance assigned for each cost element as indicated in the section above, there is an existing requirement to include three additional and separate variances in terms of labor productivity, labor rate and weight. All these three variances are normally handled as triangular distributions with a most likely, min and max percentage value of the deterministic cost element. Each of the three variances needs to be assigned to the relevant cost elements, where in theory; all three variances plus the total cost estimate variance can be stacked on top of each other with their maximum value in any given iteration. The total amount including variance contribution for each cost element is thereafter spread out on the different activities according to the cost-loading matrix as illustrated in Table 6-2.

Variance type	Variance Distribution			Iteration draw
	Min	Most Likely	Max	
Total Cost	90 %	100 %	115 %	115%
Labor Productivity	95 %	100 %	110 %	110%
Labor Rate	95 %	100 %	110 %	110%
Weight	95 %	100 %	110 %	110%
Total cost element uplift in iteration example				45%

Table 6-2: Cost Variance Example

The work effort required in setting all the variance ranges for both schedule and cost estimate is again a joint effort primarily done by the scheduler, cost estimator and the risk specialist.

<sup>8</sup> Valid for both schedule and cost variance. Strictly speaking, there is 100 % likelihood that the duration and cost will be different from the premised values if using a continuous probability distribution of all the potential outcomes as a reference case.

### 6.3.6 Likelihood and impact of discrete risks

All the discrete risk elements that have been included in the model and linked to the various activities has to be assigned with a general likelihood of the risk occurring, where the likelihood is valid for all the activities that the risk is linked to. In addition, a specific impact distribution needs to be chosen and parameters for this distribution needs to be assigned for each individual activity that the risk is linked to. The impact distribution and parameters are treated separately for cost and schedule.

For instance, a risk is assigned with a 50 % likelihood of occurring, and if it occurs, it will have a schedule impact drawn from a triangular distribution with a min, most likely and a max value. Whatever this schedule impact turns out to be, the duration impact will be added to the duration of the activity it is linked to, and if this activity has a burn-rate associated with it, the days added by the risk will have a cost impact. In addition to the schedule impact creating a cost impact, there might be a separate cost impact assigned for this risk and activity that will come on top of any other costs as a lump sum. An example is provided in Figure 6-3.

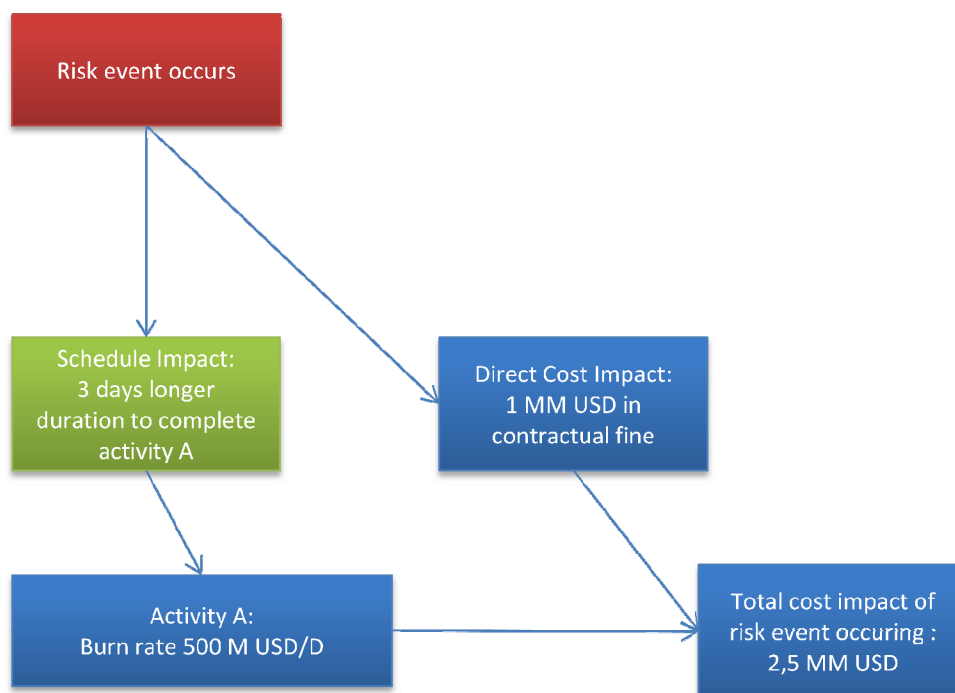


Figure 6-3: Risk event illustration



### **6.3.7 Advanced risk settings**

There are some additional advanced modeling options for discrete risks in terms of correlation and sequencing of risks in series.

If a risk is mapped to more than one activity, there is an option to create correlation between the risk event existence for the activities in question. Meaning that in any given iteration, if a risk event is triggered for one of the activities it is mapped to, the same risk will be triggered for the remaining activities as well.

It is also possible to create the same correlation effect as mentioned above for the impacts associated with the different activities for a specific risk in any given iteration. By correlating, the existence of a risk event for different activities and their impacts, one will normally produce more extreme results in the simulation, contributing towards creating a wider overall P10 – P90 range.

For an activity that has more than one risk mapped to it, there is an option to link the potential impacts of the different risks in series if more than one of the risks were to occur in any given iteration. For instance, if the two risks related to a heavy lift activity is late arrival of the lifting vessel and mechanical breakdown of the vessel during the lift. Both these risks might affect the lifting activity in a series and the impacts should in this case be added together. On the other hand, if the activity is sea fastening and load out of a steel jacket, and the associated risks are late arrival of transport barge and delayed completion of the jacket itself. The nature in which these risks are related to the activity in question, means that they should be viewed in parallel, and as a result of this, only the biggest impact should be taken into account in the iteration if both were to occur.

### 6.3.8 Model parameters summary

With all the parameters influencing each other, the available settings and opportunities offered by the software, it is hard to fully grasp and understand how the model works.

Figure 6-4 tries to offer a simplified example of a single model iteration, where there is only one cost element, one schedule activity, one risk and a weather calendar included.

In a real life NCP model, there could easily be 100 activities, 100 cost elements, 50 discrete risks with advanced settings, weather calendar on 15 activities, carry-over logic etc. included.

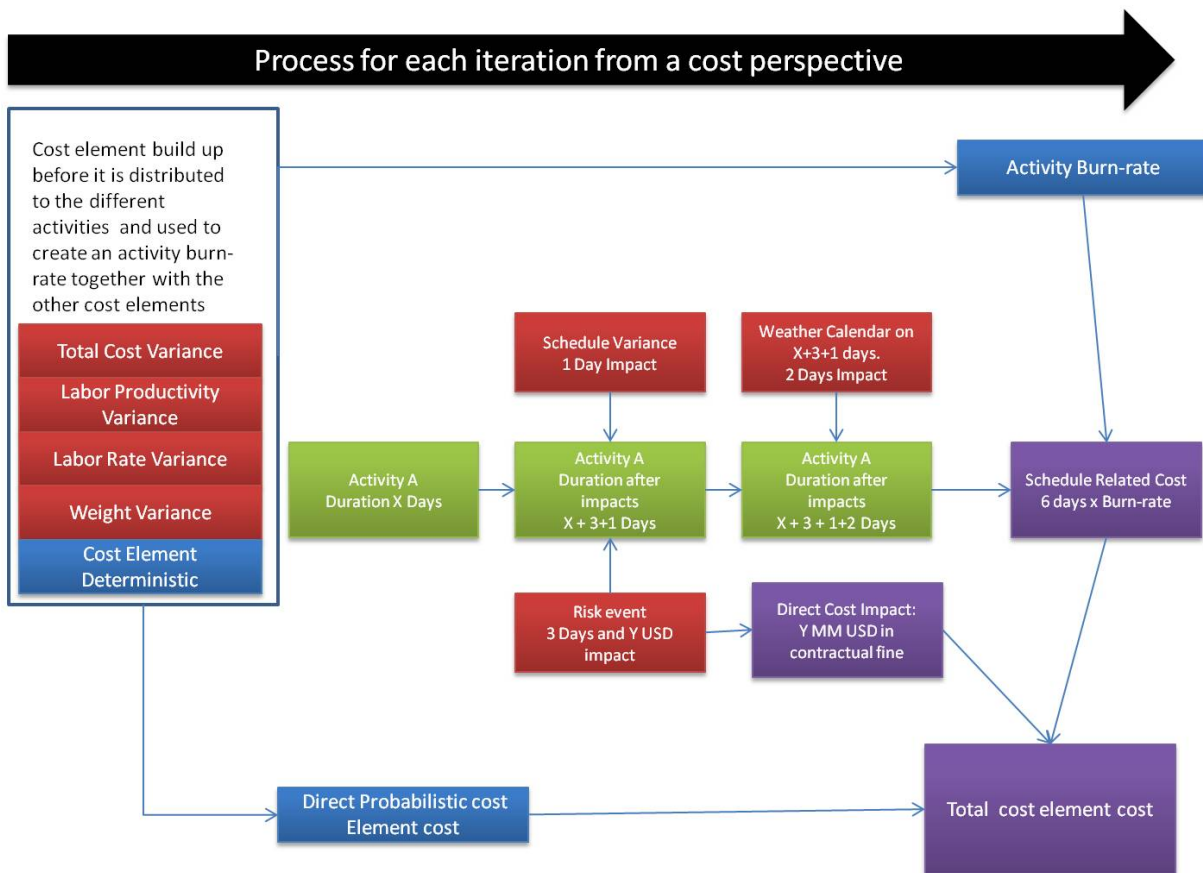


Figure 6-4: Cost Model Iteration Example

## **6.4 Model results**

With all the main inputs and the probabilistic parameters set in the model, it is time to configure, run and interpret the results of the simulation.

### **6.4.1 Simulation configuration**

NCP is using a simulation result analyzer that was specially developed by a former employee. The analyzer extracts a vast amount of information for each iteration of the simulation, stores it in separate files and when the simulation is completed, the data is processed by the means of a special algorithm. To be able to use the result analyzer, a range of settings on probabilistic results (typical P10, P50 & P90) has to be made.

Of other common settings, one can choose to run the simulation on a fixed seed or not. By choosing fixed seed, one should expect to get the exact same results in each simulation when running the same model several times. One could argue, and justifiably so that by taking this approach, some of the “randomness” in the simulation is taken out. On the other side, if the model is run with enough iterations, there will only be minor and insignificant changes to the overall result. In addition, sticking to the same seed makes it easier to assess the impacts of minor changes made to the inputs, since everything else stays the same.

The last step before starting the simulation is to decide on the number of iterations to run. Ideally, one would like to run an infinite amount of iterations, while in reality with a highly complex model where the presence of particularly weather calendars and the visual basic for applications (VBA) based simulation result analyzer is restraining the number of iterations it is feasible and practical to run with a personal computer in a time-constrained setting. And as mentioned above, with a high “enough” set of iterations, one will typically see that the overall simulation result tend to converge, and the marginal value of additional iterations decreases. For most NCP models, 5000 iterations seem to meet the desired balance between accuracy and speed. However, a major project model might still take six to twelve hours to run full analysis with details on risk element contribution.

### **6.4.2 Simulation run**

For each of the selected 5000 iterations, the software will “simulate” the project from start to finish by drawing from all the assigned probabilistic parameters and implement the values from these draws as fixed numbers as relevant for the different activity durations and cost elements. By taking the final sum of all cost elements including variance, pure cost risk impacts and cost impacts from schedule slippage one ends up with the final project cost for that specific iteration. For the schedule, the final duration for different activities including contributions from schedule variance, schedule risk and weather calendar is used together with the schedule network logic to determine the duration of the project for that specific iteration.

### 6.4.3 Simulation results

After running the model 5000 times, one is in reality left with 5000 digital executions of the project, where most, if not all of them, are slightly different from each other. One is also left with 5000 results of both the cost and the duration of the project. No single iteration is by itself representative of the project or the model as a whole, it just represents a single potential outcome of all the elements included in the simulation.

However, by sorting all the observed outcomes for a specific milestone or the total project cost in ascending order and interpreting each individual iteration to have a probability of occurrence of 1/5000 one can count ones way upward from the lowest result all the way through to the opposite end and extract the desired P-values in the process.

ConocoPhillips fund their projects at the P50 value, where the P50 value can be viewed as the risk weighted best estimate of project cost and duration. Subtracting the deterministic cost estimate that the cost estimator initially provided from the risked P50 value, one is left with a bucket that is referred to as the cost contingency.

The previously mentioned contingency breakdown report does as the name reveals, offer a breakdown of the total cost contingency amount into its minor components as:

- Cost Variance
- Labor Productivity
- Labor Rate
- Weight Variance
- Schedule Variance
- Schedule Risk
- Cost Risk
- Weather Calendar

As pointed out above, there is no simulation iteration in itself that is representative of the model or the project as a whole. Nevertheless, by utilizing the method described above one is able to use the iteration outcomes to generate a population that in turn can provide the desired P50 value. The question then becomes, how can one determine each of the risk elements contribution to the total contingency amount as the CBR requires? The problem is that the contingency amount is the difference between the overall median iteration result and the deterministic estimate, while the outcomes of the different probabilistic components in the median iteration might not be representative for the rest of the model at all. What if, every probabilistic cost element except one is drawn with the lowest possible cost, while the last one ends up being extremely high an balancing the overall cost in such a way that it ends up as the median observation?

In order to solve the problem of allocating contingency to the different probabilistic elements, the previously mentioned VBA based simulation result analyzer is required. The simulation result analyzer named “COP Analysis” uses custom built Excel VBA algorithms and a method in which its inventor calls “Factiles”. The method can be used to assign model element contribution to any P-value for any desired schedule milestone or project cost.

The basic concept behind factiles is to identify and isolate a continuous subset of all the iterations, where the mean value of the overall outcomes of the iterations included in the subset is equal to the p-value that one wants to assess the probabilistic element contribution for. With the subset identified, one can summarize the contributions for any given risk across all subset iterations and divide by the total number of iterations in the subset to get what in reality is a mean contribution of the risk in the subset and a P50 contribution of the risk in the overall simulation.

In mathematical terms, the concept can be transformed into criteria in which the subset needs to fulfill, and a formula that provides the element contribution to the desired P value.

The iteration subset needs to fulfill the following criteria for use of the factiles methodology:

$$P_{value} = \frac{\sum_{i=1}^j \sum_{k=1}^n Z_{ki}}{j}$$

While the mean impact of any model element in the subset can be determined by:

$$\bar{Z}_k = \frac{\sum_{i=1}^j Z_{ki}}{j}$$

Since applying the above criteria, summarizing the mean model element value for all model elements would be equal to the desired P-value. Hence, the mean impact of element k in the subset can be taken as a proxy for element k contribution to the P-value.

Where:

$P_{value}$	The overall P-value that one wants to assess the risk element contribution to
i	Iteration number in subset
j	Total number of continuous iterations in the subset
k	Model element number
n	Total number of model elements
$Z_{ki}$	Impact of element k in iteration i
$\bar{Z}_k$	Mean impact of element k in subset

## 6.5 Risk analysis tool suite

There are a lot of different tools and interfaces between them that is necessary to be able to create, run and interpret the integrated cost & schedule risk model. Especially critical is all the customized interfaces surrounding the Pertmaster model, where the customized interfaces include; Cost Loading Matrix, Carry-Over Macro, COP analysis and CBR factory. An illustration of the various tools and interfaces is provided in Figure 6-5.

The main challenge with the mentioned customized tools is that they are all built by a former risk specialist in ConocoPhillips using typical Excel VBA programming, with the limitations, flexibility constraints, support and inherent stability issues that in-house excel solutions brings along.

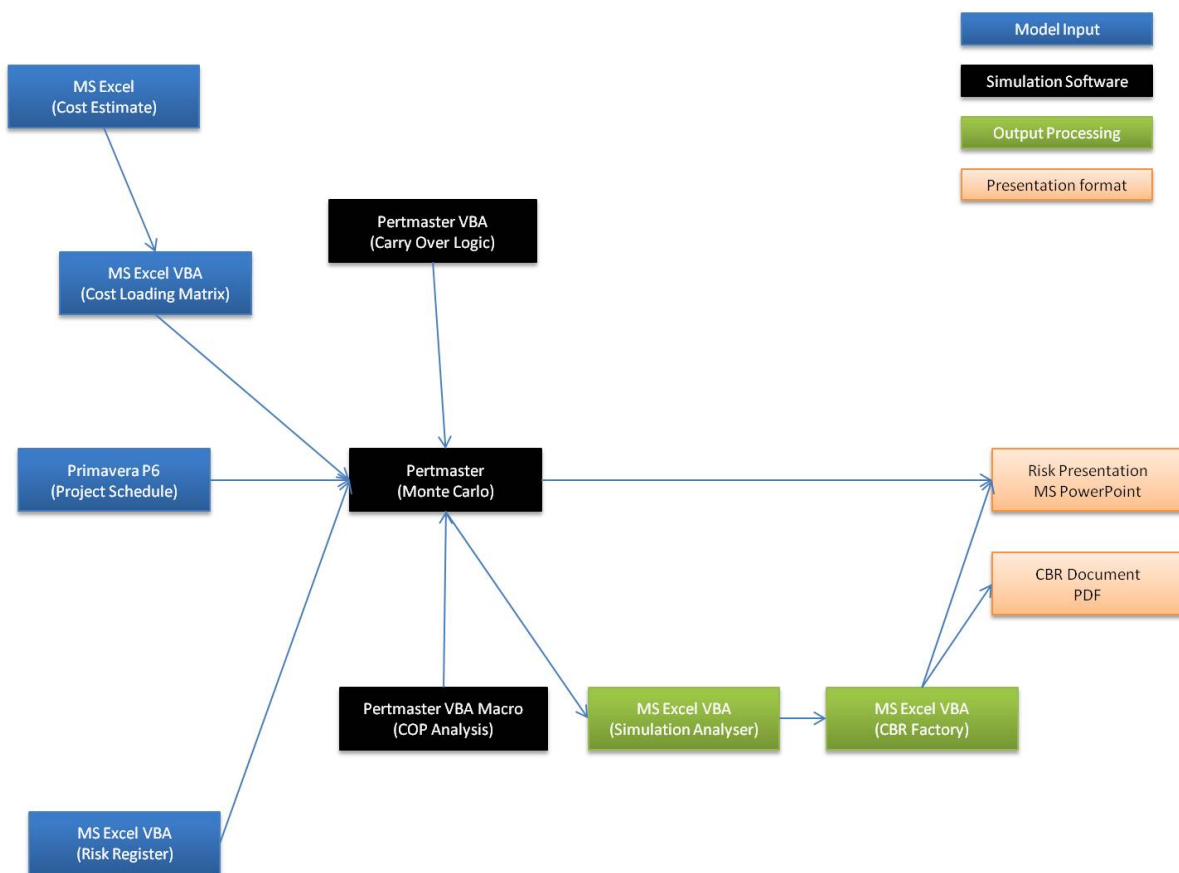


Figure 6-5: Risk analysis tool package

## **7 Discussion**

So far the thesis has been leading up to this point by introducing a common background of knowledge, setting the organizational context, outlining the big picture of how projects are managed in ConocoPhillips before narrowing the focus in on risk management, the process and especially the quantitative risk modeling. With all those points covered, it is time to bring them all together in the discussion part of the thesis, evaluating some of the many topics touched upon to this point.

### **7.1 Value adding contributions of risk management**

The key question for many people involved in risk management activities is; “What are the value adding contributions of risk management?”

With reference to a simplified ISO risk management process, focusing on risk identification, risk analysis, risk evaluation and risk treatment, the question can be answered in a semi-structured manner.

#### **7.1.1 Risk identification**

In terms of risk identification, the major value adding contribution should be seen in early phases of a project where a diverse team gets together in a workshop trying to identify all the potential threats and opportunities related to the different concepts. By doing something as simple as sitting around the same table and having a structured conversation the team as a whole can learn very much from each other. The workshop drives awareness of risk in general, but also highlights issues that might have a ripple effect to other unforeseen areas. At the very early stages of a project, a simple risk identification exercise can bring up potential issues and challenges that straight away enable the team to turn down a potential concept. Normally, the value of risk identification declines together with the ability to make changes as illustrated earlier in Figure 2-4. Accepting the notion that identification of risk generates the most amount of value in the early phases, one should expect to see a matching contribution of risk management resources at that time.

For ConocoPhillips, and referring back to Table 5-1 summarizing the risk management deliverables at the different stages, there seems to be a mismatch between the ideal situation as described above and the actual requirements. There are no requirements set forward to implement a structured risk management process or risk identification process at the FEL-0 stage, where the wide identification and initial screening of multiple concepts take place. It is at the FEL-0 stage that many of the major decisions that will shape the rest of the project are made, and because of this, higher focus on risk and involvement of risk specialists should be expected.

Continuing onwards in the stage gate process from FEL-1 and all the way to handover to operations, there are specific requirements to conduct risk identification and populate the risk register. However, focusing on actual behavior rather on the requirements, it can be said that in many cases the resources allocated to perform risk identification in FEL-1 only allows for a superficial approach that is sufficient to enable risk modeling with the creation of the CBR as the end goal. The heavy lifting in terms of risk identification, with multiple facilitated workshops and interviews are normally not conducted before AFD and AFE, which can seem a bit too late. In accordance with Norwegian requirements, risk identifications are also done ahead of CCE updates every six months. Roughly speaking, if the team has done its job well in the previous phases, the need for conducting extensive risk identification or risk modeling should be limited at this point.

### **7.1.2 Risk analysis**

As with risk identification, the value adding part of risk analysis is to use the information gathered from the identification step and structure it in an analysis in the early project phases to provide input into the decision process and to strengthen the foundation in which important decisions are taken. At later stages, risk analysis can also prove its value in e.g. modeling of alternatives on how to best treat a risk, but it needs to be in the framework of decision support.

In the FEL stage gate process as mentioned in chapter 5.3, there are no requirements to conduct risk management activities before FEL-1, where the same observations as made for the risk identification step is valid. The risk analysis conducted in the early phases is quite limited in terms of resource allocation and scope, and does not provide the potential value it could be capable of.

The main focus of the risk management process and especially the risk analysis step in ConocoPhillips seems to be targeted towards populating the CBR as a PD&P specific deliverable for the integrated reviews and CCE updates. The downside of this approach is that risk analysis is not fully utilized for decision support, but instead used as a verification tool by upper management. There is little or no value from a risk management or indeed, project management perspective in populating a four-page document with 1000 numbers down to two decimal points on different risk element impacts and likelihoods.

While the CBR provide value for PD&P management with respect to evaluation and monitoring of projects, the value in a pure risk management perspective for the project is found in the discussions of likelihoods and potential impacts of the various risks as part of the process of building the risk model and verifying the results. In addition, the current process provides a more transparent way of getting to the contingency amount compared to just nominating a generic percentage value.



With that said, the appetite for and focus on detailed numeric information shown by senior executives in PD&P, and the hands-on approach exerted by these individuals in project reviews, does have the effect of driving commitment from the project manager and forcing him/her to take an active approach to and commit enough time and resources to risk management.

As a conclusion, it seems fair to say that risk analysis is used to drive risk awareness and to scrutinize the project, but it is not fully utilizing its potential in decision support

### **7.1.3 Risk evaluation**

The concept of risk evaluation is to take the results of the risk analysis and compare them with the risk acceptance criteria / risk tolerance of the organization/project and based on this evaluation decide on whether it is acceptable or not, where the following method of risk treatment is based on this decision. Setting of risk acceptance criteria's should always involve the relevant responsible senior management representative, where the main purpose of risk evaluation is to create awareness of the risks that one is willing to take and drive responsibility and consistency on how risks are treated.

For ConocoPhillips, the risk evaluation step is not part of the risk management process shown in Figure 5-1, which is supposed to be utilized by all the projects. Still, one could argue that the risk evaluation steps, at least on the corporate level, in some ways are maintained by the structure and system of authority limitations and different types of integrated and corporate reviews. That argument might work on the project as a whole seen from the corporate perspective, however it does not do anything in terms of an active risk management perspective for the specific project.

What is missing in the risk management process and in CPMS is requirements for a structured and formalized forum with the senior project management team and the projects main internal stakeholders where specific risks and the whole risk analysis is evaluated with main treatment strategies agreed upon as the final outcome of the evaluation part of the process.

The way it is done now, it seems to be more of an informal process internally in the project management team, and often as part of the risk treatment discussion between a risk coordinator and the relevant risk / action-owner.

As a conclusion, it seems to be a good idea to ask the question whether a risk is acceptable before committing to and pursuing any risk treatment actions. The evaluation should be done as part of a structured process.

#### **7.1.4 Risk treatment**

Risk treatment is the final of the four indicated steps in the risk management process; whereas in the ideal setting after using risk identification and risk analysis for decision support, one is left with a spectrum of risks that one has to evaluate and according to the outcome of this evaluation decide on a treatment strategy. The treatment strategies can take form in accepting the risk, eliminating the risk, sharing the risk, reducing the likelihood of the risk and/or reducing the impact of the risk. With the appropriate risk specific strategy in place, the work related to risk treatment is to come up with and follow through on specific actions capable of achieving the desired strategy. The value add from successful implementation of risk treatment can be instrumental and key to the project being a success or not. If one by active management of a risk can take the appropriate actions ahead of time and reduce the impact or even totally eliminating it, there is a lot of money and time to be saved that the project as a whole can benefit from.

One can sum up risk treatment to the key point of using the information gathered in the previous risk management steps and actively steering the project out of harm's way. On the other side, if one is not utilizing risk management to make informed decisions or to drive active treatment of identified risks, one is basically left with a "check the box" exercise that provide limited if any value.

For ConocoPhillips there are requirements to establish risk mitigation plans, with actions and accountable action owners etc as part of the risk register for all project phases from FEL-1 and onwards. In reality, the effort expended in the first project stages are limited and tailored towards satisfying the minimum requirements in CPMS, which in the case of risk treatment makes sense. It makes sense since it is only after getting AFE approval that the project is fully committed and exposed to all the identified risks.

The implementation of risk treatment processes vary quite a lot from project to project, and in the past, it seemed to be a bit forgotten between the risk modeling and the focus on generating CBR numbers. However, in the last year or so, there seems to have risen a new founded passion for driving the risk treatment process, where parts of the NCP risking group have gotten in front, leading the way engaging continuously with the project team, following up on outstanding actions, risk status and improvement potential.

Based on observations made over the last one and half years, it seems like the main obstacle towards implementing a whole-hearted rigorous approach on risk treatment process is found in allocating enough resources and the right person to do the day-to-day job of following up and engaging with the project team to complete their actions. For most projects, the risk coordinator role is a split task between the risk specialist and some other member of the project team, where both parts have other responsibilities as well. What is missing then is a dedicated resource for each project that takes on the risk coordinator role, located together with and as part of the project management team, fully committed to work risks on a daily basis.

The coordinator needs to have good knowledge about risk management processes, but most of all the person needs to be able to engage and communicate effectively with a wide variety of people and have the special skill to quickly tear down the wall most people construct around themselves and gain their trust.

### **7.1.5 Attitude towards risk management**

In general, there is a fair bit of sound and unsound skepticism towards risk management. The concerns can on a high level be split in two categories, whereas one is a lack of understanding of the purpose, the process and the methodology, whilst the other is related to real experience of risk management not being anything else than a “check the box” exercise.

A typical example related to knowledge gap is the underlying desire of wanting to quantify every aspect of the risk process, and generate fancy reports. This is often accompanied by an unwillingness to actually provide ones best assessment of probability and impact, and instead wanting to rely only on pure data. The good thing of being limited by knowledge is that one can achieve dramatically improvements by educating people and removing the knowledge barrier.

It is more serious when key people on a project have an attitude towards risk management as not providing any value. Their prior experience can in many cases justify their view, making it a hard challenge to overcome.

For NCP run projects, there is a mix of reception, attitude and commitment that risk specialist receives by the various projects and its leaders. It does seem that projects in late phases or with project managers that has been part of the risk process on prior projects tend to develop a positive enthusiasm for risk management, utilizing it as tool to drive discussions and implement actions within their project team. In addition, and as mentioned previously, it helps that the project manager is fully aware of the upcoming project reviews with PD&P, and the expectation senior executive management have towards risk management.

The take back from this must be that rigorous education and practical positive experience with risk management as a tool is the way to go to improve perception and commitment in the long run. To end up with a pro-risk management organization, tailored risk management process that is set up to provide value in every step of the way should be sought after, while “check the box” activities should be eliminated.

## 7.2 Benefits of detailed Monte Carlo simulation

The main purpose of utilizing a Monte Carlo model is to be able to analyze a wide set of variables and complex dependencies in one go, with the intent of establishing some insight on the range of potential outcomes for the entire project. The true benefit of Monte Carlo is then found in analysis where there are many variables, and full impact of the variables working together is hard to derive by the use of simpler methods as CPM, PERT or pure sensitivity checks.

With the right Monte Carlo modeling tool, one is able to integrate numerous parameters and settings. A typical outcome of the seemingly endless opportunities to tweak and customize the model, is that one tries to incorporate more elements than one would ever have imagined possible if left with a more simplistic method. In reality, there is a fair chance that too much of the time and effort spent on risk management activities in such a setting will be targeted towards implementing the last percentage worth of details, and by doing so losing track of the overall picture.

The fully integrated cost and schedule risk model utilized by NCP is the most advanced project risk modeling approach taken within the PD&P universe. As previously mentioned the standard PD&P method is to build two separate models for cost and schedule and then feed the results of the schedule risk model into the cost risk model. On observation of how the license partners on the NCS conduct risk analysis for their projects, it also seems reasonable to claim that the risk analysis conducted by NCP is at least as advanced as that of the company peer group. The important question to ask then, is whether more advanced and complex models is a good thing?

If more complex is equivalent with integrating cost estimate, schedule and risk register, which is elements with clear dependencies between them into the model, and evaluate how these elements interact with each other, then the answer is yes. Where the rationale is that the combined result of these elements can have a tremendous common effect, which can be difficult to assess from separate stand-alone models.

On the other hand, if complexity is achieved by introducing an array of parameters, constraints, risk links, sophisticated correlation factors, and x number of variances, then the answer is no. Whereas a pitfall with introducing all the above-mentioned factors is that one are tweaking parameters with a potential to inflict only minor changes to the overall outcome. In addition, a more serious downside is that the analyst and outside viewers might actually take the results literally as the truth. Why wouldn't they? If one starts to discuss whether the correlation factor should be 0.79 or 0.8, it is natural to think that this is pure science, in which one can expect answers down to two decimal places to be accurate. In reality, they should probably discuss whether a risk has a 5 % or a 50 % likelihood of occurrence.

The main message is then that there needs to be a match between the level of details put into an analysis, and the knowledge base that is used to support it. Simpler is often better.

Again going back to NCPs integrated cost and schedule risk models, there should be no doubt towards the benefit of integrating cost, schedule and risks into one model and the overall method in which this is done. However, some of the five different sets of variances, the advanced correlation settings, the carry-over logic and the factiles output analysis are all elements/parameters that probably could be taken out of the model without sacrificing any insight.

As a tentative conclusion, it seems like the risk modeling conducted by NCP is second to none in terms of complexity. There is perhaps such a passion for the modeling tools themselves and its technical capabilities, that there is not a question of whether an element provides any additional value in a model, but more a question of how it can be implemented. This behavior is also driven by upper management with an enormous appetite for data and detailed information.

### **7.3 Project team incentives**

When trying to explain why people act the way they do, and make the choices that they make, an answer can normally be found in studying their incentives. Incentive theory can be used to explain and rationalize almost every type of behavior observed in the corporate world.

Major infrastructure projects are no different from the rest of the world. One could probably argue that it is one of the corporate scenes where one would expect to find the greatest misalignment of incentives between the various project stakeholders, exemplified by the project owners, license partners, the project team, contractors, various branches of government and other industrial bodies.

Focusing in on the incentives for the project team and the project manager related to risk management, they can roughly be split into two segments. The first segment is related to compliance with CPMS, which is necessary to get the project through the various approval gates, and beneficially in terms of long-term development opportunities, as big corporations tend to acknowledge people who stays within their pre-defined framework of how things should be done.

The second segment of incentives is related to how a project manager and his/her team is evaluated on how the project performs compared to the cost estimate and schedule at the time of project sanction. Knowing in advance that no matter what happens they will be held accountable for those two numbers, there will clearly exist a strong incentive to build in as much buffer/contingency as possible into the budget and schedule used for sanction.

Since the project management team is heavily involved in the process of creating and has to take ownership of the cost estimate, the schedule and the risking results, there is without a doubt ample of opportunities to adjust ones degree of belief towards likelihoods and impact levels etc. to raise the overall values up to the “theoretical” maximum. In addition there will in

most cases exist an opportunity to hide contingency in the deterministic estimate and schedule which is supposed to be “risk free”.

It is hard to point out any clear evidence that this is really happening, but as circumstantial evidence is regarded, some conclusions can be drawn from studying contingency percentages at AFE for the PD&P wide portfolio of projects. In the latest CBR trend analysis conducted January 2012 it can be observed that the majority of projects hover close to 15 % contingency at AFE, which just happens to be the upper expected threshold.

#### **7.4 Real content or just padding?**

Remembering that the purpose of risk modeling is to provide a structured analysis of the overall combined risks related to the project cost and schedule in order to adequately fund and evaluate projects, an important question to ask, is whether the P50 funding amount is based on “real” content or is a mean of padding the budget?

Starting with the cost estimate as one of risk model inputs, where can one draw the line between deterministic and probabilistic cost element contribution? If the cost estimator is given the task to provide his/her best estimate for the project cost, it is natural to expect that risk elements is present to some extent in the best estimate. Serving as an example that illustrates the paradox, one can look at vessel campaigns and weather risk. For long vessel campaigns with wave height constraints, it would be well within the cost estimator’s best estimate to include some downtime for waiting on weather in the deterministic cost estimate, even though it should be fully accounted for by the probabilistic weather calendar. In other words, it is virtually impossible to accurately define the border between the deterministic versus the probabilistic model input, hence there will always be a chance of double dipping in terms of including the probabilistic element in both parts of the model.

Focusing further on cost, the probabilistic elements that are assigned in terms of total cost variance on one side and the bucketed variance group of labor productivity rate, labor cost rate and weight on the other side, can often be a source of double dipping. The cost estimate itself is mainly built on the three mentioned parameters, and by assigning a variance to every one of them, there is virtually “no” uncertainty associated with the cost estimate left i.e. the total cost estimate will in that case be a source of double dipping.

Continuing with pure schedule variance, it is hard to see how one can separate a delay in an activity as planned from labor productivity and/or weight variance, which is already covered directly in the cost estimate variance. In other words, there is a chance of triple dipping for some of the cost estimate aspect. Finally, to secure the quadruple dipping for some cost elements, one typical find that some of the pure risks in the risk register and the model are related directly to scope growth and labor productivity.

Almost inevitably, and despite the risk specialist's conscious attempt to avoid double dipping, the same element is likely to appear more than once in the model. In particular, it is hard to see how one can actually avoid double dipping with the current requirements to add five different variances to the analysis.

Another source of skewing the P50 value up and to the right is the presence of threats and the absence of opportunities in the model. Opportunities have not been modeled to any wide extent for the current portfolio of major projects managed by NCP, where the portfolio itself represents a significant opportunity in terms of simultaneous execution. For example, the potential of shifting the installation sequence and utilization of heavy lift vessel to account for the actual development of multiple project objects under the same overall heavy lift contract should be represented as an opportunity. Another example is found by examining the economies of scale, and especially those associated by the functional parts of the organization and NCP project management for the portfolio of minor modification projects.

Again as a tentative conclusion, by taking the elements listed below into account, it seems fair to expect that even though much of the model content is real enough and justifiable, there is a lot of potential for padding of the budget and the schedule.

Sources for padding of the budget:

- high potential for double dipping of the probabilistic elements included in the model
- difficulty of getting a "risk free" deterministic input to start with
- unwillingness to include opportunities and economies of scale
- project management teams incentives to bucket as much money as they can get away with, either as part of the deterministic assessment or in form of contingency

One could expect that by studying a large portfolio of completed projects, one would be able to spot trends and determine whether padding of the budgets is a real problem or not. The major issue then, is that money that has been approved has a tendency to be spent, so it is hard to get a fair comparison. On the other hand, if the company were successful in its effort to fund their projects at a P50 level, one would in the long run expect to see the final costs coming in evenly distributed around the P50. The hypothesis testing will have to be a case for the future when a bigger set of relevant data is available to conduct the analysis on.

## 7.5 Predictability versus efficiency

Of PD&Ps four goals, the goals related to predictability and competitiveness are of special interest in terms of risk management as discussed in this thesis.

Predictability is in this case the ability to deliver the project on the promises set for cost and schedule at project sanction. However, if predictability is the only measurement of success, then success is easy to achieve. It is just a case of incorporating enough buffer in the cost estimate and the project schedule. In other words, for it to make sense having predictability as a main success criteria, there needs to be an additional criteria including some measure of efficiency. ConocoPhillips is using competitiveness relative to their peer group as a measure of efficiency, where the direct comparison of executed projects between different oil companies might work well for smaller, similar conveyor belt type of projects onshore America, but it is an entirely different story offshore on the NCS. Some benchmarking is possible, but in terms of living up to the definition of projects, these projects are in most cases truly one-off and unique, making it very difficult to compare them.

As discussed in previous chapters, there are many opportunities to pad the budget and project schedule beyond a “reasonable” P50 number. At first glance, this does not match very well with the outspoken goal of predictability, and even though the project has a higher chance of coming in under budget and ahead of time, there are a lot of negative sides related to diverging from the P50 estimate.

One of the major downsides is related to the fact that approved funding is usually spent, making the budget a self-fulfilling prophesy. On the other hand, if the budget is for the P75 amount, and the project ends up spending the P50 amount, a whole lot of capital that could be put into work elsewhere has been tied up, with the cost of lost opportunities that this represents.

The question to ask is why PD&P is providing requirements for the risk analysis that without a doubt gives the project team ample of opportunity to pad their budget, and at the same time commit to predictability as one of their core values? The answer is related to the same incentives as discussed for the project management team in previous chapters. ConocoPhillips and PD&P executives are probably more concerned for the ripple effect related to overspending than what they are for capital and spending inefficiency.

Media, governments, partners and stock market tend to react quickly and negatively on the news of serious cost overruns on major projects, potentially leading to the fall of one or more of the companies senior executives<sup>9</sup> together with a fall in the share price. In that case, it might not be a bad idea for the people involved to make sure that the projects deliver, even if it means allowing the projects to seriously pad their budgets.

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<sup>9</sup> Until now, all except one of the former Statoil Chief Executive Officers has had to leave their position based on project overruns.



## 7.6 Capex versus value

When managing a project and subsequently conducting a risk analysis, setting the context for the analysis in assigning areas of responsibilities as discussed in chapters 2.4.2 and 4.7 is an important decision that might have huge impacts on the outcome.

In ConocoPhillips, the project manager is normally just responsible for the cost and schedule related to the facilities part of the overall development. However, as a rule of thumb for a simple wellhead platform in the North Sea, the capex cost related to facilities is normally not more than 50% of the total capex, where the remaining 50 % is due to drilling of production wells.

Being responsible for just the facilities part of the development enables the project manager to focus on delivering according to schedule and on budget. At the same time, it has the potential to create a lot of tension in the overall organization and create inefficiency in terms of sub optimization for the company as a whole, the partners and the government. The tension and potential for sub optimization is created in relation to decisions that provide conflicting incentives to the various internal stakeholders, mainly projects, operations and drilling. Every unit will initially want to do what is best for them and not necessarily what is best for the company on an overall level.

To be able to consider the broad company view and reduce the likelihood of sub optimization, it is essential that a project director is made responsible for the entire development, and not only 50 % of the capex. This means that the project director will have to be measured on the overall project value instead of just cost and schedule.

A challenge with measuring on value is as previously mentioned in chapter 2.6.1 the issue with time span of the entire development. If it takes 50 years from start of development until decommissioning is complete, that is a bit too long time to hold incentives for the project manager. When saying that, it should be possible to extract high accuracy estimates within a couple of years of production.

Another issue with steering the project using value as the main criteria for the project manager, is related to the politics of how changes are perceived by external stakeholders. Even when steering by value, one would still be required to set a cost estimate and a schedule that the project in some way will be compared against. Meaning that if the project has to make major changes while in execution to incorporate recently discovered future growth potential where the changes provides a positive value to the owners, this might still be perceived negatively by the media and government due to delays and cost overruns.

In terms of economic rationale, value is the only sensible steering parameter. However, the challenges related to organization structure, measurability and complexity/transparency of value compared to a simple budget and schedule probably stops many companies from doing so.

## 8 Recommendations

Based on the background knowledge provided and reviews of ConocoPhillips project and risk management processes, there are some areas that stand out, which in the view of the author have some potential for improvement that might be worth investigating further.

### 8.1 Project organization

The current organization structure where NCP is only responsible for delivering the facilities part of the overall development, and as a result, only approx. 50 % of the capital expenditure, should be revised. A structure with a project director on top responsible for all aspects of the development is suggested as an alternative organization form. The project director should in this case be held accountable for the business case. A simplified schematic suggestion can be seen in Figure 8-1.

Such an organization form would have a better chance of sorting out the conflicts of interest that exist between the different departments by ensuring consolidation at a lower level in the business unit. With the current approach, consolidation of interest is not achieved before issues reach the level of the managing director in Norway. Resolving the consolidation issues and adhering to value based decision criteria is thought to have high potential of avoiding sub-optimized decision-making. For project risk management, such a change in the organization should also lead the way in changing the risking focus from cost and schedule to overall value for the benefit of all stakeholders.

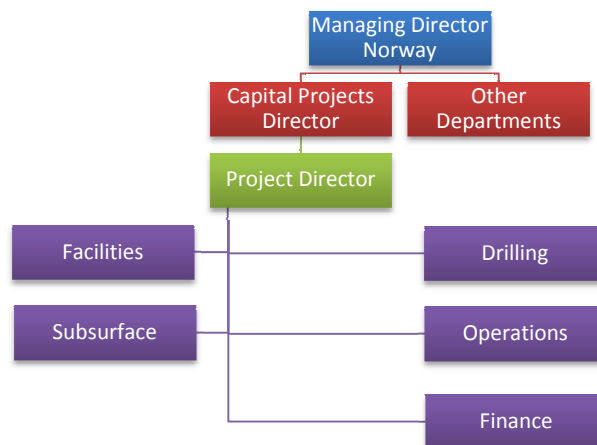


Figure 8-1: Suggested Organization Structure

## **8.2 FEL stage-gate process**

As discussed in the sections about FEL deliverables, there are no requirements related to project risk management before FEL-1, while many of the most important decisions regarding concepts are taken in advance of this. With the current practice, risk management is in many ways only used for management verification of investment budget and schedule, and as a result missing the opportunities in using risk management actively for decision support.

It is suggested that risk specialists become involved and that requirements for risk identification and analysis tailored for decision support are incorporated in FEL-0 and earlier phases to ensure that all potential concepts are assessed not only to its deterministic value, but also weighed according to its inherent risk picture.

With the current practice, pre FEL-1 work is led by a group consisting mainly of project integration managers, which is based outside of NCP and PD&Ps area of responsibility. By implementing the suggestions from chapter 8.1, one would pave the way for extending NCPs responsibilities to the total project lifespan and as a natural consequence of this, risk management should be a natural part of this extended responsibility with requirements before FEL-1.

## **8.3 Risk management process**

The current risk management process is iterative, meaning that a project is supposed to go through every step in the process at least once during each of the project stages. In addition, there is a shortfall in the utilized process compared to the standardize ISO risk management process, and then especially in terms of the crucial risk evaluation step.

It is therefore suggested that an ISO risk management equivalent process with main elements as risk- identification, analysis, evaluation and treatment is established, where the focus is oriented towards identification, analysis, and evaluation all the way up to AFE approval, and subsequent focus on risk treatment of the residual risks in the execution and operate phase of the project. A simplified risk process together with the FEL process is shown in Figure 8-2.

Putting weight on and formalizing the risk evaluation phase of the process is necessary to ensure that there is an informed and structured method/forum for assessing risks against the company, the BUs and the projects risk tolerance and acceptance criteria, without leaving the decision up to the individual risk/action owner.

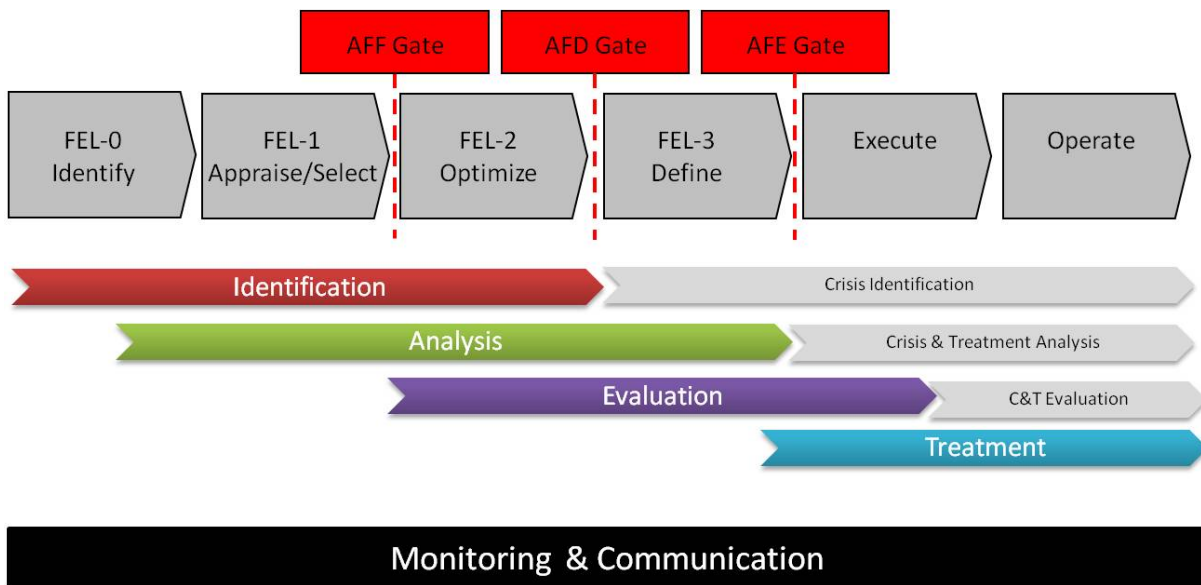


Figure 8-2: Risk process suggestion & FEL Stage gate process

## 8.4 Risk analysis

Risk analysis is currently heavily oriented towards calculating contingency numbers and populating the CBR with a seemingly endless amount of information. There is a high degree of complexity in the inputs going into the model, the parameter settings and simulation output interpretation.

As indicated in the previous chapters, it is recommended that risk analysis is incorporated at an earlier stage in a projects life and tailored towards decision support rather than just generating CBR numbers. Focus should also be shifted towards total project value instead of only cost and schedule risk analysis for the facility part of the project. Still, there will be a need to evaluate time and cost in the higher-level models. For that purpose, it is recommended that the integrated model approach currently used by NCP be continued, while the complexity and detail levels in analysis inputs i.e. multiple set of double dipping variances are removed and /or is greatly simplified. The detail levels needs to match and be reasonable compared to the knowledge levels.

Risk analysis for the sake of risk analysis, i.e. verification of data, has little or no value unless it leads to informed decision-making and/or set focus on treatment actions.

## **8.5 Risk organization**

With the varying nature of the work conducted in the various risk management phases it is suggested that a clearer distinction between a risk specialist and a risk coordinator is made. One can often see that the analytical personality required in the initial phase, leading risk identification workshop, building a risk model and interpreting the results are quite different from the engaging and outgoing type best suited to follow up and drive risk treatment on a daily basis with the project team. The risk coordinator should be a dedicated resource located together with and as a part of the project team for the entire duration of the project execution.

The risk specialist should on the other hand take more responsibility in the early phases of the project and if possible try to stick with the project all the way up to sanction.

## 9 Summary & Conclusion

ConocoPhillips and its central organization for project development has over the last six to seven years transformed into a huge unit with functional expertise covering all aspects of project and infrastructure development in the oil and gas industry. The Norwegian project organization is mature and regarded as part of the PD&P universe, with significant experience in developing the Ekofisk legacy asset for more than 40 years.

The experience is combined with a rigorous system for developing and maturing projects through a stage gate process to ensure that critical issues are worked in the early phases when the ability to affect the project is high and the related costs of changes are low. Progression from one stage to the next requires approval according to a corporate system of authority limitation to ensure that the company as a whole is committing to the right individual projects as well as its total portfolio. Supporting the approval process there is a comprehensive set of different peer and management reviews of technical, economical, HSE and strategic aspect of the development to ensure that the senior executives make their decisions based on a consistent set of information.

The capital projects management system outlines an extensive set of risk management deliverables throughout the stage gate process and implementation of a risk management process all the way up to project handover to operations. The risk process is focused around creating a probabilistic integrated cost and schedule risk model where the results in terms of P50 values for cost and completion dates are used as the premise for project sanction.

The probabilistic Monte-Carlo model incorporating the project schedule, cost estimate, risk register, weather calendars etc. is a result of inputs and discussion with the broad project team dedicating a substantial amount of their time to the process. The modeling methodology and implementation is highly advanced and in top class as far as the company peer group is concerned.

It seems that ConocoPhillips is on the right track with the enthusiasm and commitment exerted for risk management. However, there are still some potential for improvement that has been identified, varying from small deficiencies in processes, to more fundamental issues around incentivizing key players and organizational design. Some can be fixed with minor adjustments, others with more extensive changes in approach, naturally with pros and cons attached to them.

When setting out in writing this thesis the intention was to establish whether the current risk management system implemented by ConocoPhillips adds value. Based on the above brief summary and the discussion before, it can be concluded that the risk management system utilized by ConocoPhillips does add value in the delivery of major infrastructure projects. However, the strength of this conclusion is limited due to the system seemingly being set up to primarily provide predictability ahead of other values that can be derived from risk

management. Although predictability around the premised cost and schedule is important for project owners at sanction and government regulators, ConocoPhillips may not be using risk management to enable better project outcomes that everyone would benefit from.

For ConocoPhillips to truly be best in class, four key improvement themes emerge from the discussion. Firstly, that significant additional value can be achieved by reducing the amount of sub-optimized decision-making. Creating a more integrated project organization accountable for the overall economics of the development will create the right incentives for the project organization to look beyond just cost and schedule.

Secondly, the existing analytical and probabilistic method in terms of the integrated Monte-Carlo models as currently utilized by NCP should be continued, but it needs to be done in a more simplistic manner, balancing all the parameters and detail level one is trying to incorporate into the model with a realistic knowledge level.

Thirdly, projects could also benefit from a refined risk management process, where the various steps are tailored to fit the different project stages, where most weight is put on identification and risk analysis in the early phases, and risk treatment from late FEL-3 stage and onwards.

Finally, it is especially recommended that risk identification and analysis should be utilized earlier in the development phase, where more of its potential could be unlocked during the initial concept screening. Keeping in mind that the true value of risk assessments is found in using the results as inputs in the decision process, and not as a verification tool confirming what one already knows.

To conclude, it can be said that ConocoPhillips, PD&P and NCP have taken some solid steps forward over the last couple of years, developing a rigorous management system and implementing a risk management process with highly advanced risk modeling capabilities. To continue the improvement and keep adding value it seems necessary to evaluate the true value of risk management and target the areas with the highest potential benefit. The refocused approach should be less about adding complexity designed to achieve predictability. Instead, it should offer appropriately detailed risk identification and analysis to enable better informed decisions, and thereby achieving better project outcomes.

## 10 Bibliography

### **Aven, Sindre**

Verdivurdering av et oljeprosjekt- En realopsjonstilnærming  
Value assessment of an oil project- an real option approach  
Bergen : Norges Handelshøyskole, master thesis in economics, 2010.

### **Aven, Terje**

Risikostyring. Grunnleggende prinsipper og ideer.  
Risk Management. Fundamental principles and ideas  
Oslo : Universitetsforlaget, 2007

### **Aven, Terje; Røed, Willy & Wiencke, Herman Steen**

Risikoanalyse. Prinsipper og metoder, med anvendelser  
Risk Analysis. Principles and methods with applications  
Oslo : Universitetsforlaget, 2008

### **Bjelland, Anders**

The connection between risk- and activity level.  
Stavanger : UIS, master thesis in industrial economics, 2010

### **Brealey, Richard A. ; Myers, Stewart C. & Allen Franklin**

Principle of Corporate Finance  
New York : McGraw-Hil, 2006

### **Chapman, Chris and Ward, Stephen**

Managing Project Risk and Uncertainty  
West Sussex : Wiley, 2002

### **Chapman, Chris and Ward, Stephen**

Project Risk Management. Processes, Techniques and insights  
West Sussex : Wiley, 2000

### **Chapman, Chris**

Project risk analysis and management- PRAM the generic process  
International Journal of Project Management. Vol 15, No 5. - 1997. - pp. 273-281

### **Clark, Forrest D. and Lorenzoni, A.B.** Applied Cost Engineering

New York : Marcel Dekker, 1997.

### **ConocoPhillips, About Us**

April 6, 2012

<http://www.conocophillips.com/EN/about/Pages/index.aspx>.



**ConocoPhillips, Our History**

April 6, 2012

[http://www.conocophillips.com/EN/about/who\\_we\\_are/history/Pages/index.aspx](http://www.conocophillips.com/EN/about/who_we_are/history/Pages/index.aspx).

**Hetland, Per Willy**

Praktisk Prosjektledelse

Practical Project Management

Norsk Forening for Prosjektledelse 2003.

**International Organization for Standardization**

ISO 10006:2003

March 15, 2012

[http://www.iso.org/iso/catalogue\\_detail.htm?csnumber=36643](http://www.iso.org/iso/catalogue_detail.htm?csnumber=36643).

**International Organization for Standardization**

ISO 31000:2009

April 4, 2012

[http://www.iso.org/iso/catalogue\\_detail?csnumber=43170](http://www.iso.org/iso/catalogue_detail?csnumber=43170).

**Jacobsen, Dag Ingvar & Thorsvik, Jan**

Hvordan Organisasjoner fungerer

How organizations works

Bergen : Fagbokforlaget, 2007

**Myers, Stewart C.**

Finance Theory and Financial Strategy

Interfaces. 1984. - pp. 126-137.

**NCP**

NCPMS Supplement to Risk Management Standard NCP-PP-F-00004

ConocoPhillips internal document

Stavanger 2009

**Norwegian Petroleum Museum**

Ekofisk Industrial Heritage

April 6, 2012

<http://www.kulturminne-ekofisk.no/subindex.asp?iSelectedMenuItemId=1001&iMin=3&iMax=30&iContentMenuRootId=1001>.

**NPD**

The Resource Report 2011

April 6, 2012

<http://www.npd.no/en/Publications/Resource-Reports/2011/>.

**PD&P**

Project Execution Plan Key Procedure CPMS-PMT-PR-006  
ConocoPhillips internal document  
Houston 2011

**PD&P**

Project Phase Deliverables Workbok CPMS-PMT-PR-032  
ConocoPhillips internal document  
Houston 2011

**PD&P**

Project Risk Management Guide CPMS-PMT-GU-001  
ConocoPhillips internal document  
Houston 2009

**PD&P**

Risk Implementation Procedure CPMS-PMT-PR-013  
ConocoPhillips internal document  
Houston 2011

**PD&P**

Risk Management Standard CPMS-PMT-MS-002  
ConocoPhillips internal document  
Houston 2011

**Pindyck, Robert S & Rubinfeld, Daniel L.**

Microeconomics  
New Jersey : Pearson Prentice Hall, 2005

**Project Management Institute**

A guide to the Project Management Body of Knowledge  
Pennsylvania : Project Management Institute, Inc, 2008

**Rausand, M & Utne, I.B**

Risikoanalyse - teori og metoder  
Risk Analysis - theory and methods  
Trondheim : Tapir Akademisk Forlag, 2009

**Wikipedia**

Monte Carlo Method  
April 2, 2012

[http://en.wikipedia.org/wiki/Monte\\_Carlo\\_method#Computational\\_mathematics.](http://en.wikipedia.org/wiki/Monte_Carlo_method#Computational_mathematics)



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