Master's degree thesis

LOG950 Logistics

Economic Appraisal in Gas Transport Infrastructure Development

Katsiaryna Shaton

Number of pages including this page: 131

Molde, 24.05.2011

Molde University College

Publication agreement

Title: Economic appraisal in gas transport infrastructure development

Author(s): Katsiaryna Shaton

Subject code: LOG950

ECTS credits: 30

Year: 2011

Supervisor: Arild Hervik

Agreement on electronic publication of master thesis

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Theses with a confidentiality agreement will not be published.

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

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

Date: 24.05.2011

Preface

This thesis represents the mandatory final part of the Master of Science Degree in Logistics at Molde University College.

Tanking the opportunity, I would like to express my deepest gratitude to Professor Arild Hervik for being my supervisor and for his guidance throughout the process of writing this thesis. Furthermore, I would like to give my thanks to Professor Svein Bråthen for all his help, precious advices and constructive recommendations.

I sincerely thank my family for all they are doing for me. Without their everlasting support, encouragement, care and belief in me a lot of things would have been impossible. And I would like to express my endless gratefulness to God, who gave me this great opportunity to study at Molde University College, who saved and guided me on this way. “Unless the Lord builds the house, the workers labour in vain” (Psalm 127:1).

Molde, May 2011.

Katsiaryna Shaton

Abstract

The purpose of this research is to study appraisal practice in gas transport infrastructure development on the Norwegian continental shelf and suggest possible adjustments of the existing approach. Analysis of the current practice and Gassco's activities led us to the conclusion that infrastructure development is a point, where different goals of the gas sector actors come to a conflict.

We compared the state of appraisal practices among Norwegian infrastructure providers, Gassco, Statnett and Avinor, in order to define specificity of appraisal practice in natural gas infrastructure development. We considered recommended methodologies proposed by handbooks and guidelines and discussed one particular example of project evaluation in each sector. In the discussion of the particular projects, special attention was paid to relevant impacts. We defined analogies and differences between the impacts evaluated in different sectors.

We came to a conclusion that Gassco has conceptual reasons to have appraisal practice different from Statnett and Avinor, because of its special role. Defined conflict of interests is reflected on infrastructure appraisal practice. Evaluation of a certain project is performed twice: once by a company, which initiates facility installation and once by Gassco. As companies have no incentives to take into account public interest, important social impacts are neglected in the evaluation. Two main aspects of Gassco's involvement into infrastructure development process were defined: (1) Gassco ensures the system approach to the gas transport network development; (2) Its responsibility is to conduct a comprehensive socio-economic analysis of the project, taking into consideration all the related impacts that are neglected in technical and financial analysis made by companies.

Taking into account practice of the two other considered Norwegian infrastructure providers and the nature of the projects in gas transport sector, we concluded that cost-benefit analysis is the most suitable and reliable tool for the economic impact assessment in the sector and it provides a good basis for the decision making. Development of a handbook on socio-economic analysis in gas transport sector can be useful. We discussed main attributes of such a handbook; by generalizing of the defined for Luva project benefits we developed a set of relevant impacts for socio-economic evaluation and defined groups affected by gas transport infrastructure development.

CONTENT

List of figures

List of tables

List of abbreviations

AD – Ministry of Labour

BCR – Benefit-cast ratio

BOG – Decision to Implement

BOK – Concretization Decision

BOV – Decision to Continue

CBA – Cost-benefit analysis

CEA – Cost effectiveness analysis

EU – European Union

FIA – Field-specific Impact Assessment

IA – Impact Assessment

KILE – Kvalitetsjusterte inntektsrammer ved ikke levert energi

LLN – Langeled North

LTMC – Long term marginal cost

MCA – Multi-criteria analysis

MPE – Ministry of Petroleum and Energy

NCS – Norwegian Continental shelf

NGL – Natural Gas Liquids

NPD – Norwegian Petroleum Directorate

NPV – Net present value

NVE – Norwegian Water Resources and Energy Directorate

PANDA – Plan- og Analysemodell for Næring, Demografi og Arbeidsmarked

PDO – Plan for Development and Operation

PIO – Plan for Installation and Operation

RIA – Regional Impact Assessment

SDR – Social discount rate

STPR – Social time preference rate

VOT – Value of time

WTP – Willingness-to-pay

1 INTRODUCTION

Norwegian petroleum industry has rather short history, only in December 1969 the first significant discovery was done, Ekofisk (Facts, 2010). Since that time oil and natural gas plays a crucial role for the economy of country and is of high importance in supply of energy in Europe. Today Norway is the second largest gas exporter and the sixth largest oil exporter in the world. There are 65 fields in production on the Norwegian continental shelf, which produced 2.3 million barrels of oil per day and 102.7 billion standard cubic metres (scm) of gas in 2009 (www.gassco.no). Norwegian gas contributes approximately 15 per cent of the European gas consumption. There are sales agreements with buyers in Germany, France, Belgium, the UK, the Netherlands, Spain, Italy, the Czech Republic, Austria and Denmark (Facts, 2010).

Petroleum activities generate considerable revenues for the state. The petroleum sector's share in Norwegian GDP is 22%, it contributes 27% to the total state revenues and it amounts to 47% of total exports. The share of natural gas in Norwegian petroleum export is steadily growing. The share of natural gas in total petroleum sales is expected to increase up to 50 per cent in 2013. In terms of energy content, gas exports were about eight times larger than the average Norwegian production of electricity in 2009 (Facts, 2010).

Norwegian natural gas is mainly transported by a large submarine system (Figure 1-1), which is the most extensive offshore upstream pipeline system in the world. It consists of a network of more than 7800 km of pipelines and its capacity is about 120 billion scm per year (Facts, 2010). When new production fields are developed, transport infrastructure must be available to deliver petroleum to onshore facilities. Therefore, transport infrastructure on the NCS is in constant development: new transport facilities are planned, new solutions are being worked out in order to increase efficiency of the existing transport system (Xu and Haugen, 2008).

Figure 1-1 *Map of Gas Pipelines* (Source: Norwegian Petroleum Directorate)

Infrastructure development on the Norwegian continental shelf represents a point of great public concern. “One reason why infrastructure investments are in focus is that they are perceived as important generic instruments for enhancing economic development and regional balance” (Bråthen, 2001). Because of significant costs of infrastructure development and its possible significant socio-economic consequences, the evaluation process needs to be as accurate and comprehensive as possible and presents a great interest as a topic of research in field of logistics.

The role of economic impact assessment and evaluation methods can be formulated as comparing the future consequences of various choices in an explicit and systematic manner (Voogd 1996). However, economic impact assessment is not a straightforward task. There are several main reasons for that. A major reason is the increasing technical and organizational complexity of infrastructure development. There is a number of regulations that must be taken into account in infrastructure planning, e.g. safety standards and environmental protection. One more reason is a shift towards more communicative-based processes of infrastructure development: private sector and citizens are becoming more and more involved in the infrastructure planning process. These reasons make systematic and comprehensive project evaluation to be a complicated task (Niekerk and Voogd, 1999).

1.1 Statement of purpose

The first step in any research endeavour is to formulate the problem (Cooper, 1998). The purpose of this research is ***to study appraisal practice in gas transport infrastructure development on the Norwegian continental shelf and suggest possible adjustments of the existing methodology***.

To pursue this purpose we define three tasks. Complexity of petroleum sector makes it necessary to study current practice of gas transport infrastructure development and operation. The first task is:

1. *To consider specificity of gas infrastructure operation and development in Norway: regulation, process and responsible actors.*

The postulation of this task aims to provide a basis for explanation of appraisal practice characteristics in gas infrastructure development. State owned company Gassco takes the main responsibility for infrastructure development assessments. That is why this company will be in particular focus of the research.

The second task can be formulated as follows:

2. *To assess the state of appraisal practices among Norwegian infrastructure providers, within the goal of defining shortcomings of appraisal practice in natural gas infrastructure development.*

In this research we consider three Norwegian infrastructure providers: Gassco, Avinor and Statnett. Despite the fact that this companies operate on different markets, their infrastructure development processes have much in common. Comparison with appraisal practices in fields of electricity supply and aviation will help to define the particular features of appraisal practice in gas infrastructure development.

The third and final task of the research is the following:

3. *To investigate if there is a potential need for adjustments in appraisal practice and, if any, to suggest possible improvements.*

Accomplishment of the two first tasks will provide a basis for fulfilment of the third one. Based on the results of current practice study we suppose to explain conceptual difference of appraisal in gas sector; and then, work out a set of suggestions for possible improvements of gas infrastructure appraisal methodology, based on the results of appraisal practice analysis of other infrastructure providers and taking into account specificity of natural gas transport infrastructure operation and development.

1.2 Structure of the thesis

Chapter 2 of the thesis pursues the first introduced task: to describe properties of gas infrastructure operation and development on the NCS. The main purpose of this chapter is to provide an information basis for the research. We studied organization of petroleum sector in Norway and operatorship of gas transport network. Then, we thoroughly analyzed Norwegian legislation on petroleum activities in order to present an overview of the main roles and responsibilities of the players on the market and to define their relevance to the gas transport infrastructure development process. The sequence of steps in the established procedures of infrastructure development was studied. Information, provided in this Chapter is used as basis for explanation and interpretation of the results of empirical study.

Methodology of the empirical study is presented in Chapter 3. In this Chapter we formulated research questions, which help us to accomplish formulated objectives. Then we described the research design and offer arguments to approve the method of comparative case study as a suitable methodology for the purposes of our research. The next three sections present a case study protocol: the logic of case selection; the way of data collection and description of the sources of information; the approach to data analysis, based on the proposed set of case-study questions. The last section of this chapter presents criteria, which were used to evaluate the quality of the research.

In Chapter 4 we described a theoretical framework of the research. As the most commonly used analytical tool in socio-economic evaluation is cost-benefit analysis, we provide rather extended overview of CBA in four subsections: definition and application, conceptual foundation, methodology and its criticism and limitations. In addition, we briefly described two more approaches to socio-economic analysis - cost-effectiveness analysis and multi-criteria analysis, their main characteristics and applications. Then we made a literature review to define specific methodological features of appraisal practice in three considered sectors: natural gas transportation, electricity supply and aviation.

The second formulated task, which is in fact the main one, is accomplished in Chapter 5. The description of regulation framework for appraisal practice in all sectors in Norway is given in the first section of the chapter. Then, the state of appraisal practices of the three Norwegian infrastructure providers: Statnett, Avinor and Gassco, was assessed in the three following sections. The analysis of cases was based on the developed set of case study questions. It is organized in the following way: firstly, we described recommended methodology for the sector and then discussed particular projects: Sima-Samnanger power line project, expansion of Bergen airport Flesland and gas evacuation from Luva field in the Norwegian sea. In the last section, we discuss the cases and present the findings of our case study and our suggestions related to the third task of the research.

Chapter 6 concludes the research. In the first section we summarize all the findings and discuss whether all the defined objectives were fulfilled in the research. The second section is devoted to the limitations of the presented study and directions of the further research.

2 NORWEGIAN GAS TRANSPORT INFRASTRUCTURE OPERATORSHIP AND DEVELOPMENT

The aim of this chapter is to study and describe natural gas transport infrastructure operation and development in Norway. Specific attention will be paid to the government regulation and legislation in natural gas transportation on the Norwegian continental shelf. Relationships between interested parties will be also analyzed in order to define how these interactions influence gas infrastructure development. Findings of this chapter will be used as a basis for explanation of the results of the main part of this research – comparative analysis of infrastructure development appraisal practices.

2.1 Organization of petroleum sector in Norway

There is the following national organization of petroleum sector in Norway (Facts, 2010):

The Storting (Norwegian parliament), establishes the framework for all Norwegian petroleum activities. All matters of high public importance should be discussed by the Storting, it includes opening of new areas for petroleum activities, major development projects etc. The Storting supervises the Government and the public administration. Its method of influence to petroleum sector mainly includes legislation (www.stortinget.no).

The Government holds the executive power over petroleum policy and is responsible to the Storting for this policy. The government applies its policy through the ministries and subordinate directorates and agencies (www.regjeringen.no). The responsibility for executing the various roles within the petroleum policy is shared as follows (Figure 2-1):

- The Ministry of Petroleum and Energy (MPE) is responsible for resource management on the Norwegian continental shelf and for the sector as a whole. In addition, the Ministry has a particular responsibility for supervising the state-owned corporations, Petoro AS and Gassco AS, as well as the oil company in which the state holds a majority interest, Statoil ASA (http://www.regjeringen.no).
- The Norwegian Petroleum Directorate (NPD) is subordinate to the Ministry of Petroleum and Energy. The NPD plays a key role in petroleum resource management, and is an advisory body for the Ministry of Petroleum and Energy.

The NPD is responsible to control over the activities related to exploration and production of petroleum deposits on the NCS (www.npd.no).

- The Ministry of Labour is responsible for health, the working environment and safety;
- The Ministry of Finance is responsible for state revenues;
- The Ministry of Fisheries and Coastal Affairs is responsible for oil spill contingency measures;
- The Ministry of the Environment is responsible for the external environment.

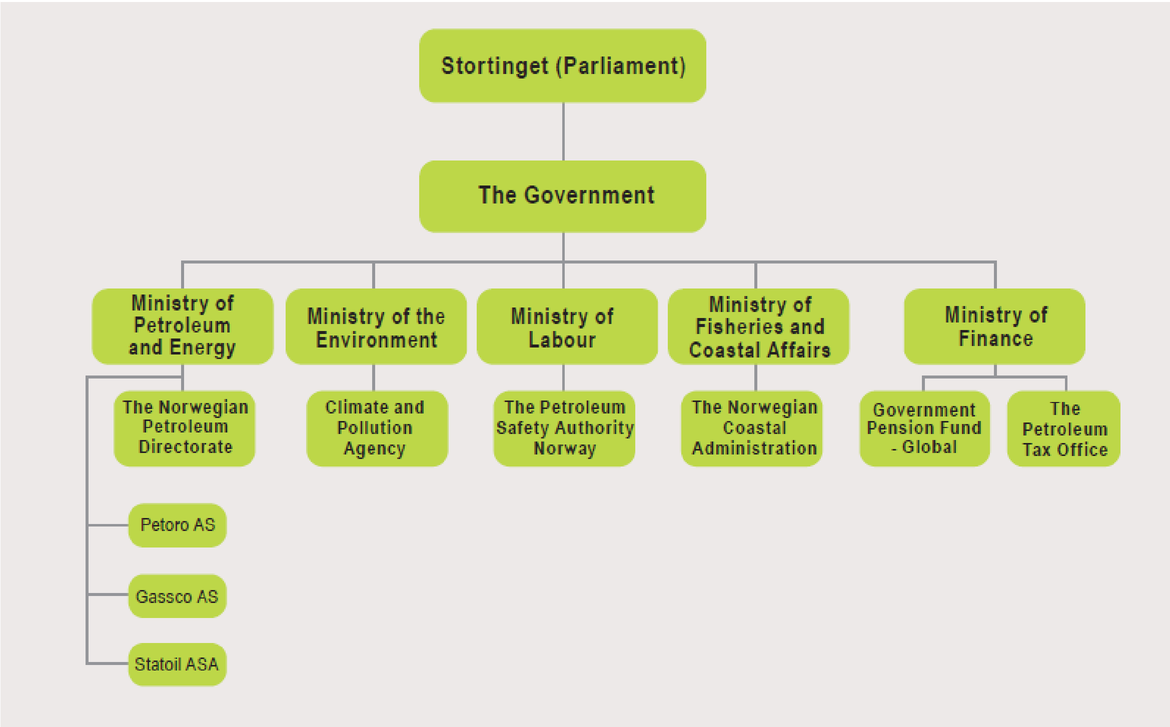

Figure 2-1 *State organization of the petroleum sector* (Source: Facts, 2010)

There can be defined three central instruments that are used used by the Ministry of Petroleum and Energy in connection with development of new infrastructure and when the use of the existing infrastructure is changed (Facts, 2010):

- the joint ownership Gassled (ownership);
- the operator Gassco AS (operatorship);
- and regulated conditions for access to the transport system (regulation).

Let us briefly describe the first part of this triad, **ownership**, in this section; operatorship and regulation will be discussed in the following sections.

In the spring of 2001, the Government asked the relevant companies to establish a unified ownership structure for gas export. The **Gassled** ownership agreement was signed on 20 December 2002, and came into effect on 1 January 2003. It represents the merger of nine gas transport facilities into a single partnership. This partnership serves as the formal owner of the Norwegian gas transport infrastructure. Gassled's licence runs to 2028.

Table 2-1 *Gassled joint venture owners*[1] (data from www.gassco.no)

Petoro AS	45.793%
Statoil Petroleum AS	28.480%
Total E&P Norge AS	6.102%
ExxonMobil Expl. & Prod. Norway AS	8.036%
A/S Norske Shell	5.006%
Norsea Gas AS	2.261%
ConocoPhillips Skandinavia AS	1.678%
Eni Norge AS	1.276%
DONG E&P Norge AS	0.983%
GDF SUEZ E&P Norge AS	0.304%
RWE Dea Norge AS	0.081%

Gassled encompasses all rich and dry gas facilities that are currently in use or are planned to be used by parties other than the owners (third party use). New pipelines and transport-related facilities are also intended to be included in Gassled. Today Gassled includes: Europipe I, Europipe II, Franpipe, Norpipe, Oseberg Gas Transport, Statpipe, Tampen Link, Vesterled, Zeepipe, Åsgard Transport, Langeled, Norne Gas Transport System, Kvitebjørn Gas pipeline, Kollsnes gas processing plant and Kårstø gas and condensate processing plant. The receiving terminals for Norwegian gas in Germany, Belgium, France and the United Kingdom are, entirely or partly, owned by Gassled (Facts, 2010).

We would like to mention that Gassled ownership includes almost all gas transport infrastructure on the NCS, but there are several pipelines, that are not a part of Gassled: Draugen Gas Export, Gjøa Gas Export, Grane Gas Pipeline, Haltenpipe, Heidrun Gas Export, Oseberg Transport System and several oil pipelines.

[1] There is information about possible sale of the part of Gassled to foreign companies (12.04.2011, Aftenposten)

2.2 *Operatorship of gas transport network*

Gassco AS is the operating company for Gassled. Relationships between Gassco and Gassled are thoroughly described in a 150-pages document **"Terms and conditions for transportation of gas in Gassled** (1 June 2010)", which is also called Operation Manual. This document gives us the following definition:

> "The Operator is Gassled's representative under the Transportation Agreement. The Operator will conduct all operations in the Transportation System and, on behalf of Gassled, provide the Transportation Services and execute all Gassled's rights and obligations under the Transportation Agreement". Where "Operator" means Gassco AS or its successor as determined by the Ministry.

So, as Gassco takes the responsibility of operatorship of most of the transport system on the Norwegian continental shelf, this company and its activities and interactions determine the focus of our attention in the research.

Gassco is a limited company owned by the Norwegian state, established in 2001, which operates the gas transport network on the NCS. Framework conditions for Gassco, including the relationship between it and the owners of the gas transport system are determined by the Norwegian government. (Gassco's Annual Report 2009).

So, Gassco acts as an Operator of gas transport system on behalf of owners of infrastructure, but it is regulated by the government. It means that we can analyze Gassco's activities and responsibilities from two points of view: in relevance to Norwegian governance and to owners of infrastructure, oil and gas companies.

Frame work conditions for Gassco are determined by the government in Norwegian Petroleum Activities Act (Gassco's Annual Report 2009). From the government side, Gassco's activities are regulated by Ministry of Petroleum and Energy, Oil and Gas Department, Section for Gas and Infrastructure (www.regjeringen.no). Gassco's relationships with Gassled joint venture present its relationship with oil and gas companies. They are regulated by the Act and also by the operator agreement with the Gassled joint venture.

The division of Gassco's responsibilities and between government and oil and companies its regulation can be presented in the form of the following graph (Figure 2-2):

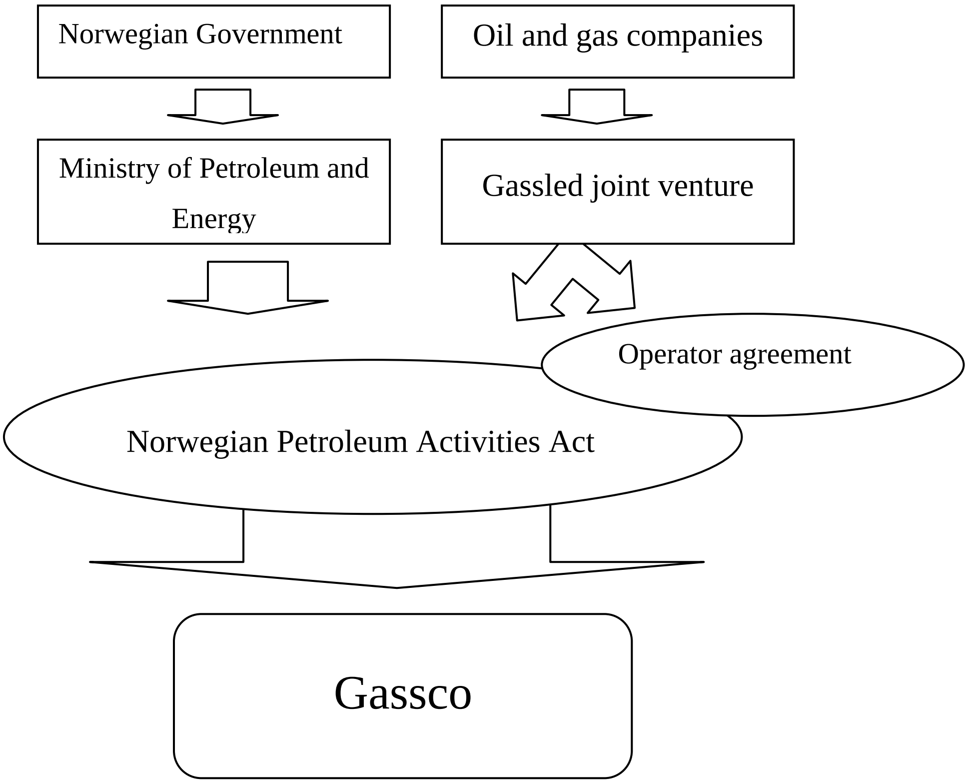

Figure 2-2 *Gassco's relations with Government and oil and gas companies*

Gassco plays several roles (www.gassco.no). They are divided into two groups: normal and special operatorship. **Special operatorship** includes system operation, capacity administration and infrastructure development and is regulated according to Norwegian Petroleum Activities Act. So, we can conclude that activities performed under special operatorship mainly refer to the relationships with Norwegian government. There are three roles, which can be referred to special operatorship responsibilities:

1. *Allocating capacity in the infrastructure*. Gassco allocates the capacity available at any given time in the pipelines and transport-related facilities.
2. *System operation*. Gassco treat all companies equally when transporting Norwegian gas to the right location, in the correct volume and to the right quality.
3. *Development of the gas transport system*. This covers Gassco's role in planning future pipelines and transport-related facilities (process plants and receiving terminals) (www.gassco.no).

Normal operatorship refers to Gassco's work on behalf of transport infrastructure owners – oil and gas companies. "The normal operatorship refers to the technical operation of plants and installations pursuant to the Norwegian Petroleum Act's provisions on operator responsibility. These duties are also regulated in the operator agreement with the Gassled joint venture (www.gassco.no)".

These relations can be presented in the following view (Figure 2-2, the ownership of developed infrastructure is marked with the dashed line).

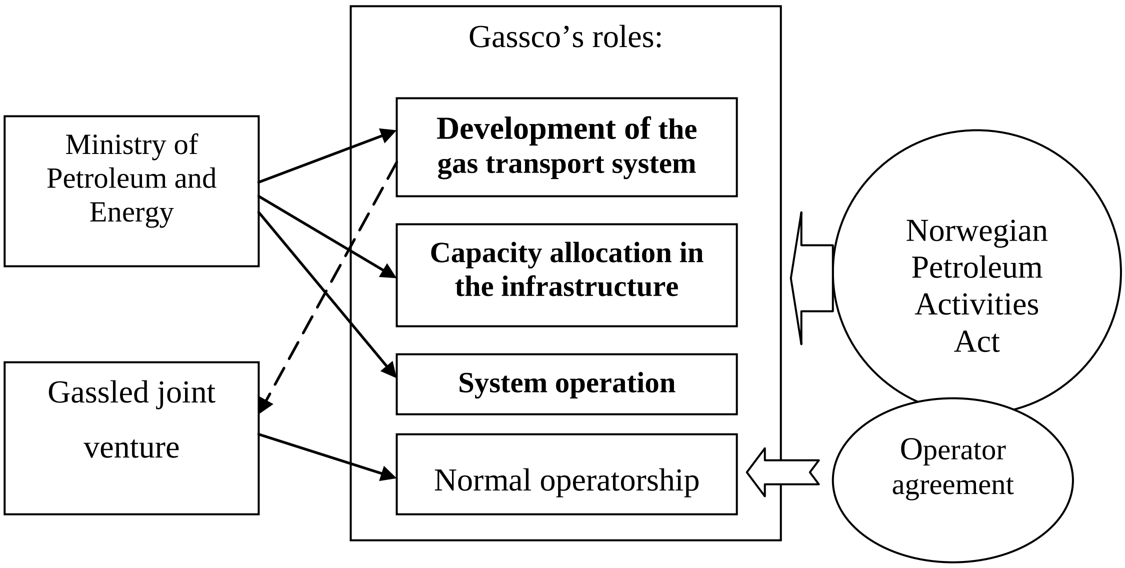

Figure 2-3 *Roles of Gassco on the market*

In the following sections we present the description of these main types of activities in details, based on the related legislation.

2.3 Regulation framework

Gassco's activities are mainly regulated through the following documents:

1 Petroleum Act: Act relating to petroleum activities (the Petroleum Act), 29 November 1996, No. 72;

2 Petroleum Regulations: Regulations to the Act relating to petroleum activities, 27 June 1997, No. 65;

3 Regulations relating to stipulation of tariffs, etc. for specific facilities, 20 December 2002, No. 1724;

4 Regulations relating to third party access to facilities, 20 December 2005, No. 162;

The main regulating document is Norwegian Petroleum Activities Act. This document is widely referred in relevance with Gassco's activities, but one can find there only one section (4-9, named **Extended operator responsibility for the overall operation of upstream pipeline network etc.**), where in a general form the operator responsibility over the upstream pipeline network is described. It is stated that the Ministry of Petroleum and energy "may appoint someone to assume extended operator responsibility for the overall operation of upstream pipeline network and associated facilities, including undertake change of operator when warranted for particular reasons". There is no concrete identification of Gassco as operator, but it is stated that the operator should act in accordance with "prudent technical and sound economic principles", and it is highlighted that activities should be neutral and non-discriminatory.

There is one issue in the same section of the Act that is worth to mention. Actually, it states that operator, Gassco, has a right to influence decisions of infrastructure owners:

> "The King may issue further rules relating to the responsibility as mentioned in the first and second paragraphs, including deciding that whoever has been assigned to assume this responsibility, shall also make decisions in respect of access to upstream pipeline network, and may **order owners** and users of upstream pipeline network and associated facilities and licensees of production licences where petroleum is produced, **to adapt their activities**. Such order might be given to ensure prudent resource management and efficient operation of the of upstream pipeline network in question".

While Norwegian Petroleum Activities Act presents rather general issues, **Regulations to Norwegian Petroleum Activities Act** (Royal Decree 27 June 1997 pursuant to Act 29 November 1996 no 72 relating to petroleum activities) provides precise description of the Gassco's operator responsibilities. We are mostly interested in Chapter 9 if this document, namely "Access to upstream pipeline networks".

The operator responsibility for the transport system is described in the Section 66 of Regulation. It is stated that the operator are responsible for the operation of the upstream pipeline network, including maintenance and maintenance planning. Here we also find statements about prudent and non-discriminatory manner of acting. Operator's activities in case if unforeseen events are also described in this Section.

We would like to highlight the following sentence found in this Section:

> "Owners of upstream pipeline networks may not instruct the operator in his performance of tasks assigned to him in or pursuant to this chapter, unless otherwise is specifically stipulated in these regulations".

We see it as a formal separation between two points of Gassco's responsibilities, Norwegian government and oil and gas companies. Responsibilities described in this Section are related to Gassco's performance as a governmental authority, and saying that owners of infrastructure may not instruct operator in these activities, this statement clearly distinguishes two areas of Gassco's work.

2.4 *Capacity allocation*

Capacity allocation is one of the main Gassco's responsibilities. Twice a year Gassco holds booking rounds in which shippers can reserve spare capacity in the gas transport system. From January 2003, it is conducted through a special web-enabled solution, named **GasViaGassled**, which is used both for buying and selling capacity in the Norwegian gas transport system. GasViaGassled are used by authorized shippers, companies with a duly substantiated need to transport gas from the NCS. This system provides possibilities to:

- book capacity in the primary market (day, short, medium and long term);
- sell and buy capacity in the secondary market (day, short, medium and long terms), with deals closed in the market-place automatically confirmed by the TSO, and shown in the overview of the shipper's own bookings;
- check bookings of a shipper for any day at any time;
- compare current nominations with bookings;
- check capacity position for any day (spare capacity, restrictions);
- rebook capacity between points when spare capacity is available.

2.4.1 Primary and secondary markets

As we see, there is a separation of agreements on two markets: primary and secondary. In **Regulations to Norwegian Petroleum Activities Act** we can found definitions of agreements on primary and secondary markets:

> An "agreement in the primary market" means an agreement for the right to use spare capacity in upstream pipeline networks entered into by a natural gas undertaking or eligible customer with the owner of the upstream pipeline network acting in his capacity as owner, or with the operator acting on behalf of the owner in his capacity as owner.

An "agreement in the secondary market" means an agreement for the transfer of rights to use capacity in upstream pipeline networks other than contracts in the primary market.

Detailed regulation concerning primary market we find in the Section 61. The process is conducted as follows. Firstly, the owner of infrastructure, Gassled, makes spare capacity available to the operator, Gassco. Then natural gas undertakings and eligible customers enter into the agreements in the primary market with the operator, who acts on behalf of the owner. Gassco presents recommendations to the owner what shall be considered as physically available capacity and cannot base determination of this spare capacity without its approval by the owner.

"Spare capacity" means the capacity that is physically available at any time, with the exception of the capacity necessary to meet existing contracts concerning transportation of natural gas and the right to use capacity in the upstream pipeline network, and to ensure efficient operation of the upstream pipeline network".

Then Gassco appoints a time when natural gas undertakings and eligible customers can reserve a right to use spare capacity. Reservation of spare capacity can be made on the short-term and long-term basis. Rights to use spare capacity on a long-term basis shall be allocated before rights to use spare capacity on a short-term basis. But anyway a part of the spare capacity shall be retained for allocation on a short-term basis.

If the sum of the reservations applied for exceeds the spare capacity, rights to use the spare capacity are allocated according to a distribution formula. The distribution formula is determined by the operator for a specific period of time, based on the production of the companies, and on their sales, loans or purchases of natural gas that give rise to a need for transport and processing in the upstream pipeline network, adjusted for their existing rights of use.

In the Section 64 of the Regulation we find description of **secondary market**. It is stated that if a party who has a right to use capacity has no longer need for this capacity or its part, the natural gas undertakings and eligible customers can have a right of access to this capacity. The right to use capacity can be transferred to to other party. The task of Gassco is to decide whether the conditions for right to access are satisfied in the agreement.

Gassco arranges and conducts a market place for transferring rights to use capacity in upstream pipeline networks. It also draws up rules for the market place, which should be approved by the Ministry.

2.4.2 Tariff system

For transportation of gas through the pipeline network on the Norwegian continental shelf third party companies pay tariffs. In section 63 of Regulation to the Norwegian Petroleum Activities Act one can find primary information about tariffs for gas transportation. It is called "**Tariff for agreement in the primary market**". In addition to this document, there are also **Regulations relating to the stipulation of tariffs etc. for certain facilities,** laid down by the Ministry of Petroleum and Energy 20 December 2002, which gives even more extended information**.** We would like to highlight the following important issues.

The tariffs are used on the primary market. According to Section 61 of the Regulation "The owner shall make spare capacity in upstream pipeline network in the **primary market** available to the operator, who shall make it available collectively. Spare capacity may only be made available to natural gas undertakings and eligible customers. Agreements in the primary market are to be entered into with the operator on behalf of the owner".

A tariff shall be paid for the right the user has to capacity in the upstream pipeline network irrespective of whether that capacity is actually used or not.

The tariff consists of a capital element and an operating element. From the microeconomic point of view it is called **long-term marginal cost pricing**.

The Tariffs for the Transportation Services shall be calculated in accordance with *"Forskrift om fastsettelse av tariffer m.v. for bestemte innretninger av 20. desember 2002"* given by the Ministry and as amended from time to time. The tariffs shall be stipulated by the following formula:

$$t = \left(K + \frac{I}{Q} + U \right) \bullet E + \frac{O}{Q}$$

Capital Element Operating Element

where:

t = tariff per unit for the right to use an entry, exit or processing;

K = fixed part of the capital element per unit;

Q = estimated aggregate reserved capacity for the year in question;

I = annual element calculated for investments to maintain the system;

U = element calculated for investments related to extensions of the system;

E = escalation factor;

O = anticipated operating costs.

Comments to this formula are given in the Regulation: “The capital element is stipulated by the Ministry. When stipulating it, consideration shall be given to promoting the best possible management of resources. Furthermore, the capital element must be so stipulated that the owner can expect a **reasonable return** on the capital invested. Other special circumstances may also be taken into account. The operating element must be such that neither the owner nor the operator **has any loss or profit** on management of the upstream pipeline network, other than the return stipulated pursuant to the fourth paragraph”. But further one can find an issue that gives some freedom: “The Ministry may stipulate which costs shall be taken into account when calculating the operating element. If consideration of efficient management so dictates, the Ministry may consent to exemption from the principle as mentioned in the first sentence of this paragraph”.

In Regulations relating to the stipulation of tariffs one can find the detailed description of transport facilities divided into areas A, B, C, D; definitions of entries, exits and processing on each area. There are monetary values of the variables in the formula determined in this document:

- Values of fived part of capital element (K) are determined in details for each Area for a certain year, i.e. for Area A, K is set from 5,5 – 18 øre per Sm^3 **.**
- Reserved capacity (Q) is not determined monetary and it should be estimated by the operator for a certain year for different areas and services.
- Investments related to maintenance of the system (I) are stipulated by the Ministry “for each investment of this type and shall be calculated as an annuity within the remaining license period”. It is highlighted that the annuity shell be so stipulated that the owners could get a reasonable return on total investments.

- Investments related to expansion of the system (U) are also stipulated by the Ministry.
- Escalating factor (E) is stipulated each year on the basis of the Norwegian consumer price index published by the Central Bureau of Statistics. It is the ratio between the last index published before 1 January of the same year and the corresponding index as of 1 January 2002 (108.9). If the ratio is less than 1.0, E shall equal 1.0.
- Anticipated operating costs (O) are calculated be the operator at the beginning of the year for each area. In addition to current operating costs, individual investments that do not exceed the defined in the document limit sums may be included in O for the different areas, but the sum of the individual investments that may be included in O per year shall not exceed up to three times the limit sum in each area. If at the end of the year the operator collects operating costs that differ from the actual operating costs, an adjustment shall be made for the difference in the estimate of O for the following year within the same area.

When tariffs are specified and calculated, how are they paid and received? Answer to this question can be found in the mentioned above document: **"Terms and conditions for transportation of gas in Gassled (**1 June 2010**)**. According this document, tariffs are handled as follows. On or before the 7th Business Day of each Month, the Operator shall submit an invoice to the Shipper showing the total amount payable by the Shipper to Gassled for the preceding Month. The invoice shall inter alia specify:

a. The quantities of Gas delivered by the Shipper, processed and redelivered by Gassled on each Entry and Exit Point, respectively, and the quantities of Off-spec Gas, if any, delivered or redelivered;
b. The Booked Capacity;
c. The Tariffs applicable;
d. Deductions, if any.

The amount payable by the Shipper shall be paid and credited to bank accounts designated by Gassled on the 20th day of the Month in which the invoice was submitted or not later than 10 days after receipt of said invoice, whichever date comes later.

We would like to highlight that Gassco does not receive any payment, it calculates amounts payable by the shippers and submit invoices, but these amounts are paid directly to Gassled.

2.5 Infrastructure development procedures

One of the most important Gassco's responsibilities is to contribute to comprehensive further development of the Norwegian gas infrastructure. It means that when new developments are considered, all Norwegian gas, not only resources under development should be included in evaluation. This is also necessary to ensure efficient exploitation of the existing gas transport system, it may contribute to the reduction, or postponement, of the need for new investments. Gassco's task is to coordinate the processes for further development of the upstream gas transport network, and to assess the need for further development.

It is stated on the Gassco's web-site:

> "Together with the industry, Gassco has created a work process for developing the annual transport plan to ensure that all relevant information needed for continuous improvement of the gas transport network is collected, and that all participants involved in this process act in accordance with **agreed procedures**. The work process for infrastructure development is also designed to ensure that the upstream pipeline networks are developed in line with **established procedures**. "

There is natural question, what are the "agreed" and "established" procedures? To answer this and other questions we will address the legislation.

2.5.1 Infrastructure development initiation

Consideration of infrastructure development we start with the Section 4-2 of the Norwegian Petroleum Activities Act "**Plan for development and operation of petroleum deposits**" (further this plan will be called PDO):

> "If a licensee decides to develop a petroleum deposit, the licensee shall submit to the Ministry for approval a plan for development and operation of the petroleum deposit.

> The plan shall contain an account of economic aspects, resource aspects, technical, safety related, commercial and environmental aspects, as well as information as to how a facility may be decommissioned and disposed of when the petroleum activities have ceased. **The plan shall also comprise information on facilities for transportation or utilisation…".**

Usually new infrastructure development process is initiated by a company as a part of a project for development of a new petroleum deposit.

The content of the plan is described in Sections 21 – 22 a,b,c of the Regulation to Norwegian Petroleum Activities Act. Section 21 gives the description of the development in PDO. It should include detailed description of development strategy and concept, description of technical solutions, information on management systems, information on economic aspects and ***information on facilities for transportation or utilization***.

Sections 22a – 22c gives the requirements to impact assessment in PDO. There is a detailed description of what impact assessment in PDO shall take into account. Transport facilities are one of the items. So, as we see, assessment of infrastructure development is a part of the whole project for new petroleum deposit development. While initiating the development of new petroleum deposit one should include in his plan installation of the transport facilities.

If a firm decides to install the facility outside the scope of petroleum deposit development it can apply for a specific license to install a facility, this plan is called PIO (Section 4-3 of the Act, **Specific licence to install and to operate facilities for transport and utilisation of petroleum**):

> "The Ministry may on specified conditions grant a specific licence to install and to operate facilities when right to install and to operate facilities does not follow from an approved plan for development and operation pursuant to Section 4-2.
>
> Application shall be submitted containing plan for the construction, placing, operation and use of facilities as mentioned in the first paragraph, including shipment facilities, pipelines, liquefaction facilities, facilities for generation and transmission of electric power and other facilities for transportation or utilisation of petroleum".

In the Section 28 of the Regulation to the Norwegian Petroleum Activities Act "License to install and to operate facilities for transport and utilization of petroleum facilities" one can find a description of the initiation of infrastructure facilities installation.

It is started with the application for a license to install and to operate facilities, which should include a plan with the description of the project and impact assessment. There is only one comment here to impact assessment:

> "An application for a license to install and to operate facilities, cf the Act Section 4-3 first paragraph shall include a plan which is to contain a description of the project and an impact assessment. Any comments given to the impact assessment shall be included in the approval process in relation to the plan to install and operate facilities".

This application should be forwarded to the Ministry of Energy and Petroleum and to the Ministry of Labour and Social Inclusion with a copy to the Norwegian Petroleum Directorate and to the Petroleum Safety Authority Norway.

There are three main conditions which are stipulated by the Ministry for each license to install and operate facilities:

a) The ownership of the facility;
b) The landing point of the pipeline;
c) The routing, dimension and capacity of the pipeline.

Further, in Section 29 we see the description of the contents of a plan to install and operate facilities. This plan to install and operate facilities should enlighten economic, resource related, technical, environmental and safety aspects of the project.

According to the Regulation a plan of facility installation and development should contain:

a. Information on the destination of the pipeline, route, dimension and transportation capacity, as well as the criteria for the choices that have been made;
b. Information on the ownership of the facility;
c. A description of technical solutions;
d. Information on management systems;
e. Information on operation and maintenance;
f. Information on economic aspects;
g. Information as to what licenses, approvals or consents have been applied for, pursuant to other applicable legislation;
h. Information as to how the facilities may be disposed of when the petroleum activities have ceased;

i. A description of technical measures for emergency preparedness;
j. Information on other factors of importance to the resource management;
k. Other information required pursuant to the safety regulations in force at any time.

There are no requirements on impact assessment for PIOs in the Regulations, as it is for PDOs, but it is still a compulsory part of PIOs. Both PDOs and PIOs consist of a development or installation section and an impact assessment section.

2.5.2 Authorities' involvement

Studying further the Regulation to the Norwegian Petroleum Activities Act, we find Section 66A "**Further development of the upstream gas pipeline network".** This section is supplemented to Section 66 **"**The operator responsibility for the transport system" and regulates the relevance of Gassco to the infrastructure development. Firstly, it is stated that "further development of the upstream gas pipeline system and associated facilities with a view towards achieving comprehensive transport and treatment solutions for the petroleum activities" is a responsibility of the operator.

When licensee needs capacity for transport or treatment of natural gas, it shall inform Gassco. Operator shall determine which potential solutions shall be considered and ensure that such an evaluation is carried out.

So, earlier, in Sections 28-29 we saw that installation of the new transport facilities is initiated by the interested company with the application for the license and impact assessment is conducted by this party. In Section 66A infrastructure development considerations relates to the notification to Gassco from the natural gas undertakings about their needs. To tie up all this information and present consistent picture of the process we address the following document, issued by Norwegian Petroleum Directorate on 4 February 2010: "*Guidelines for plan for development and operation of a petroleum deposit (PDO) and plan for installation and operation of facilities for transport and utilisation of petroleum (PIO)*". The purpose of the guidelines is to provide advice on how a PDO or PIO can be prepared in accordance with the authorities' requirements, explaining the assessment processes in details.

> "PDOs/PIOs shall be submitted to the MPE (Ministry of Petroleum and Energy) and the AD (Ministry of Labour), with copies to the NPD (Norwegian Petroleum

Directorate) and PSA (Petroleum Safety Authority). *For PIOs relating to gas transport or treatment, or PDOs where treatment and pipeline transport of gas is included, copies shall also be sent to Gassco.* The MPE coordinates the processing of the plan. AD, NPD and Gassco (if applicable) submit their evaluations to the MPE. The PSA submits its evaluation to AD".

So, from this point we see the involvement of Gassco to the assessment process. This complicated system of information flows is presented on the Figure 2-4.

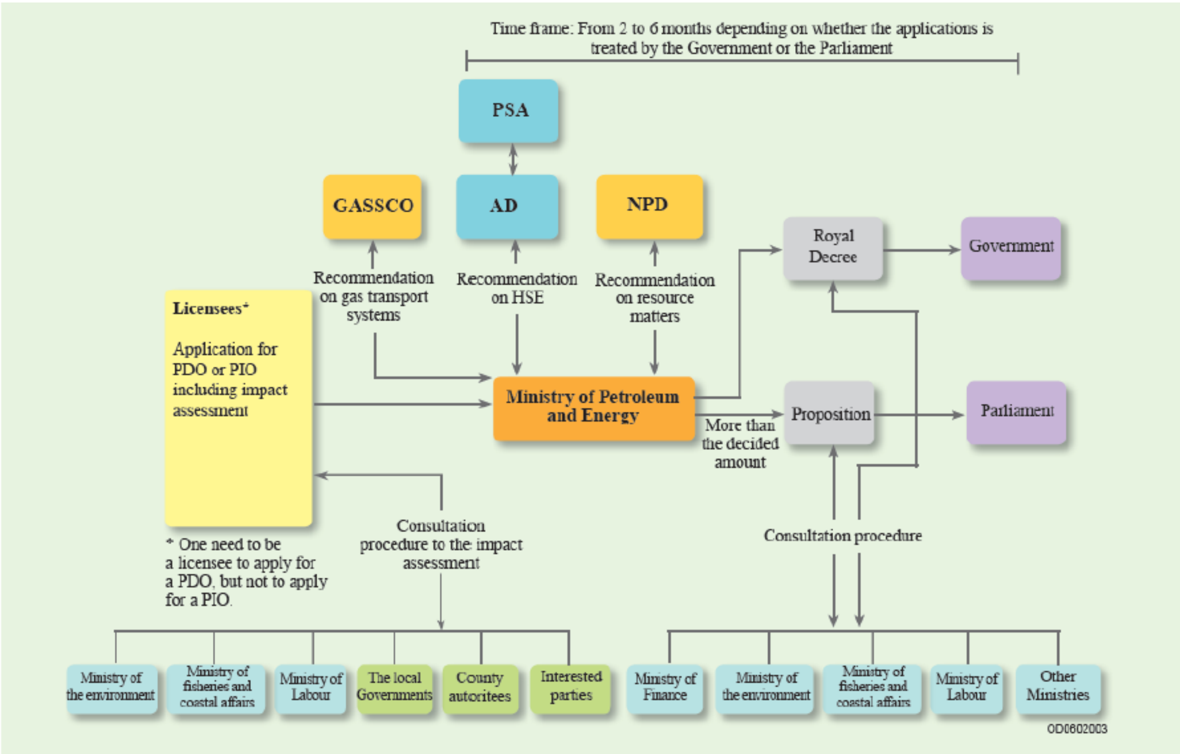

Figure 2-4 *Administrative procedure PDO and PIO* (Source: Guidelines for PDO and PIO)

The planning phase can be divided into three main steps:

- *The feasibility studies*, determine whether a business idea can be concretized into a business opportunity. This phase is concluded with a "concretization decision" (BOK – in terms of the guidelines), which should include a description of one or more concepts with cost frameworks.
- *The conceptual studies* concretize the technical and financial basis for a business opportunity in such a way that profitability and feasibility of implementation can be documented for the concept. The conceptual studies lead to a "decision to continue" (BOV – in terms of the guidelines).

– *The pre-engineering* further develops the basis for a business concept to such a level that a final "decision to implement" (BOG – in terms of the guidelines) can be made, and the PDO or PIO can be submitted to the authorities.

We will try to follow how this process is going in particular relevance to transport infrastructure development and Gassco.

Prior to each decision, the licensees should contact Gassco. A meeting with Gassco may be relevant for the purpose of discussing the alternatives that are being studied during the time period between BOK and BOV. Before the licensees select the development concept (BOV), Gassco will send a report to the MPE giving an account of the various alternatives. When BOV is complete, applicants for a permit for installation and operation must make the results of their conceptual studies available to Gassco.

Gassco does not make decisions concerning further development of the upstream gas pipeline network; it is up to the companies that finance a project to make the decision on whether or not to submit a potential plan for installation and operation. But Gassco has a strong involvement in all new transport projects. As part of its responsibility, Gassco shall evaluate further development of the gas transport system and associated facilities in accordance to its goal of comprehensive transport system development.

The interaction between the licensees and Gassco during the planning phase is shown on the Figure 2-5.

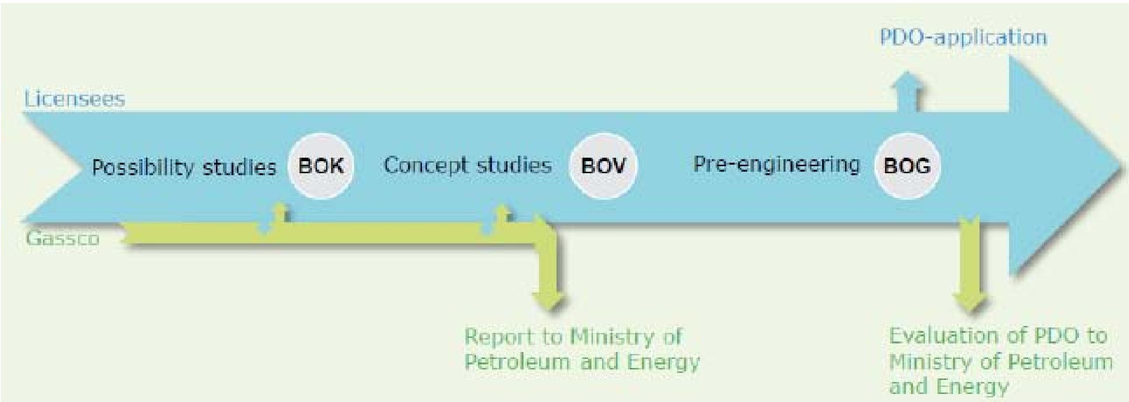

Figure 2-5 *Interaction between the licensees and Gassco in infrastructure planning* (Source: Guidelines for PDO and PIO).

So, Gassco is involved in all planning process and its task is to evaluate comprehensive general transport solutions for the petroleum activities.

2.5.3 Infrastructure development as a conflict of interests

In general, described above scheme of gas infrastructure development can be categorized as so-called *bottom-up approach,* when government is a participant of infrastructure development and an initiator is an interested company (Niekerk and Voogd, 1999). Gassco recommends solutions, makes assessments, but does not itself invest in infrastructure. There are oil and gas companies who finance all infrastructure projects, and they own facilities they invested into. So, we can define three main involved parties in the infrastructure development process:

- Oil and gas companies, who initiates development of new infrastructure, and invest into new facilities;
- Gassco, who coordinates the process and makes assessments;
- Norwegian government that regulates all the petroleum activities on the NCS.

Let us define what goals that these parties pursue. Pipeline owners are interested in making profit from their activities and investments. Authorities' goal is to ensure that the Norwegian natural gas resources are fully exploited, that the infrastructure is utilized in the most efficient way. If we consider Gassco as a kind of separate organization, as a bureaucracy, we assume such goals as the salaries, public reputation, the maximization the size of the organization (Niskanen, 1971). As it stated in the article by Xu (2010), the interests of authorities and Gassco can be united for the reason that their general purpose can be expressed as maximization of throughput and the overall capacity of the transport system. But anyway we have at least two groups of interest in infrastructure development: owners of infrastructure and authorities (including Gassco). *So, we can conclude that there is a conflict of interests between the authorities and owners of the transport infrastructure.* This issue can be of high importance, because one party makes assessments and recommend solutions, another finances these projects.

We claim that the conflict of interests has a reflection on the infrastructure appraisal practice. We will confirm or reject this proposition in accordance with results of the case study.

3 METHODOLOGY OF RESEARCH

As it was mentioned in an article on logistics research, “at the core of every research effort is the notion of methodological soundness and rigor” (Halldórsson and Aastrup, 2003). Issues described in this chapter present the methodological basis of the research. Firstly, we formulate research questions, which purpose is to pursue the objective of the study. Then we describe research design. Here we present the logic and method that links our research questions with empirical data and. Then we introduce the way of case selection and briefly describe their nature. Further the specification of data follows with presentation of main data sources and classification of collected data. Next the method of data analysis will be described and specific case study questions presented.

3.1 Research questions

To fulfil the purpose of the research we introduce the following research questions:

1. What appraisal methods and criteria are applied for infrastructure development projects evaluation?
2. What are the specific features (virtues and shortcomings) of the existing appraisal methodology for natural gas infrastructure development projects?
3. How this specificity of appraisal practice in gas infrastructure development can be explained?
4. What possible improvements can be applied for gas transport infrastructure appraisal practice?

We believe that answers to presented questions will allow us to fully disclose our research topic. To address these research questions we propose to use a comparative case study method.

3.2 Research design

“A research design is the logic that links the data to be collected (and conclusions to be drawn) to the initial questions of the study” (Yin, 2003, p. 19). The logic, which links research questions of our study to collected empirical data, is a ***comparative case study*** method. To justify the choice of this methodology we address approved in literature research design principles. Specifically, we tried to follow research design recommendation of L. Ellram (1996) and R.K. Yin (2003).

Bryman (2001) defines five types of social research design: experimental design, cross-sectional or social survey design, longitudinal design, case study design and comparative design. When comparative design is applied in relation to a qualitative research strategy, it takes the form of a multiple-case study.

Comparative case method as a methodological tool is widely used in public policy process in order to provide reasonable recommendations for future policy actions. As the final aim of this research is to propose possible improvements of current appraisal practice in field of natural gas transportation, this methodology can be accepted as suitable. Yin (2003) directly defines this methodology as a distinctive form of a multiple-case study. “Multiple cases design should be used to either predict similar results among replications, or to show contrasting results, but for predictable, explainable reasons” (Ellram, 1996).

Yin (2003) states that case study is a “preferred strategy when “how” or “why” questions are being posed”. Actually, presented above research questions can be generalized as “How do Norwegian infrastructure providers assess their infrastructure development projects?” and “Why gas transport infrastructure development projects are evaluated in one or another manner?” So, chosen methodology corresponds to research questions and the objective of this study.

Ellram defines four possible objectives of research: exploration, explanation, description, prediction. Presented above objective and existence of these “how” and “why” questions creates the ***exploratory nature*** of this research (Yin, 2003). “In exploratory research, the issue could be how or why is something being done? A case study methodology would be desirable in those circumstances because it provides depth and insight into a little known phenomenon” (Ellram, 1996, p. 98).

The benefits of case studies for the purposes of researches like ours have been illustrated a lot of times, primarily because of their information richness and the ability to answer mentioned questions (Eisenhardt, 1989; Ellram, 1996; Yin, 2003). One specific benefit of the Case study research was expressed as “[it] enables the possibility to check for validity of responses due to the nature of personal communication and experienced interviewers”

(Blome and Schoenherr, 2011). Case studies also can give an analytical generalization to theory and support model building for future research on statistical data (Yin, 2003).

Ellram (1996) point out that "the case study method generally emphasizes qualitative, indepth study of one or small number of cases". We emphasize the ***qualitative nature*** of this research, although the analysis will include both qualitative and quantitative data.

"Case studies focus on holistic situations in real life settings, and tend to have set boundaries of interest, such as an organization, a particular industry, or a particular type of operation" (Ellram, 1996). Let us define the boundaries of interest in this research. The main point of attention of this study is appraisal practices applied by infrastructure providers for the evaluation of new projects, particularly in natural gas transportation, air transportation and electricity supply in Norway. ***The unit of analysis*** in the research can be formulated as an *infrastructure development appraisal methodology*.

Infrastructure development practice applied by a company, infrastructure provider, in each of the three mentioned industries is considered as a "case". Three cases will be analyzed according to established **case study protocol** (Yin, 2003). A case study protocol should have the following sections: (1) An overview of the case study project; (2) Field procedures (general sources of information, data collection procedures); (3) Case study questions ("table shells" for the specific arrays of data); (4) A guide for the case study report. In subsequent sections we present the protocol of our case study.

3.3 Case selection

In this research infrastructure development appraisal practices will be studied on examples of three Norwegian companies: Gassco AS, Statnett SF and Avinor. These companies operate on different markets, and provide different services. But they have three important common characteristics. They:

- Own / operate a network,
- Are owned by Norwegian government,
- Are infrastructure providers with natural monopoly characteristics.

Their common goal is to present public interest in the most efficient way. Infrastructure development is their responsibility and a point of great importance.

Let us briefly describe theoretical description of common characteristics that allow us to compare appraisal practices of these so different companies.

Networks are often described in terms of interrelations between nodes and links. Links bundle streams of goods or services between nodes (Kunneke, 1999). Examples of this are flows of gas between producers, distributors and final consumers. Nodes can be characterized as connectors between similar links that alter the direction of the flows in the network, or as points of exchange in which goods or services enter or exit the grid (Economides and Encanoua, 1996). From an economic perspective, it is characteristic of networks that its components are strictly complementary to each other. Goods and services can only be generated by interaction between specific nodes and links. In the gas sector, the economic good of 'gas products' can only be provided if producers, transporters, distributors and traders cooperate in a specific way in order to deliver gas to consumers.

Natural monopoly is a specific type of monopoly. Carlton and Perloff (2004), state that "when total production costs would rise if two or more firms produced instead of one, the single firm in a market is called a "natural monopoly" (p. 104). In simple words, technical definition of natural monopoly can be formulated as follows: a firm producing a single homogeneous product is a natural monopoly when it is less costly to produce any level of output of this product within a single firm than with two or more firms. In addition, this "cost dominance" relationship must hold over the full range of market demand for this product Q = D(p) (Joskow, 2005). Posner (1969, p. 548) writes that natural monopoly "does not refer to the actual number of sellers in a market but to the relationship between demand and the technology of supply."

Electric and natural gas utilities often are cited as examples of natural monopolies. The essential characteristic of a natural monopoly is that its fixed costs are very large relative to its variable costs. Technically, a firm is a natural monopoly if it has a superadditive technology (Tschirhart, 1995). Berg and Tschirhart (1988) define subadditivity if no combination of multiple firms can collectively produce industry output at lower cost than a monopolist. Gordon et al (2003) state that a sufficient condition to ensure subadditivity is the existence of economies of scale.

The following two sub-sections presents a short description of Statnett and Avinor' characteristics with emphasize in there infrastructure development activities. Gassco, as a company of the "main" case, was thoroughly described in Chapter 2 of the paper.

Statnett SF

Statnett is Norway’s national main grid owner and operator. Company is responsible for all high voltage electricity transmission and distribution in Norway. Statnett SF is a public enterprise, owned by the Norwegian State through the Ministry of Petroleum and Energy and regulated by the National State Enterprise Act (www.statnett.no).

Statnett is also responsible for necessary ***development of the main grid infrastructure***. This responsibility supposes that Statnett should control whether available grid capacity corresponds to market demand. It includes new power lines and control systems, system protection, acquisition, disposal, modernization of substations, transmission lines, etc.

To fulfil the task of providing adequate grid capacity Statnett has a 10-years grid development plan, which is updated every year according to changing market environment in Norway and European Union. Plans of grid development should take into consideration not only power balance, but also environmental policy and governmental regulation. The importance and significance of electricity transmission and distribution makes it necessary to consider development project from a socio-economic point of view and take into account a number of various impacts. As most of the transmission facilities that are currently under planning involve new international cable connections (Linking Norway to continental Europe, NORD.LINK - subsea cable to Germany, NorNed 2 - a second cable to the Netherlands, Cable to the UK), it requires even more comprehensive appraisal approaches in order to work out and accept projects with the highest socio-economic benefits and best environmental solutions.

Avinor AS

Avinor AS is a state owned limited company that operates most of the civil airports in Norway, except Torp Sandefjord and Rygge airports. The Norwegian state, namely Norwegian Ministry of Transport and Communications owns 100 percent of the share capital of the company. The Royal Ministry of Transport and Communications also regulates charges that Avinor uses for airports and air traffic (www.avinor.no).

Avinor owns and operates 46 airports in Norway (twelve out of these 46 in cooperation with the armed forces). *Avinor is responsible for planning and developing of the Norwegian airport network*. Logically, this responsibility to develop includes also assessment of infrastructure projects. Companies’ activities also includes operatorship of air traffic control towers, control centres and technical infrastructure for aircraft navigation. Avinor also operates three Area Control Centers: Bodø Air Traffic Control Center, Stavanger Air Traffic Control Center and Oslo ATCC (www.avinor.no).

Total assets of Avinor are about 20.1 billion NOK. Total revenue is approximately 7,400 million NOK. Revenues comes mainly two from sources: around 56 percent - from aeronautical charges paid by airlines and 44 percent - from commercial activities like parking, hotels, rental income and other use of Avinor's infrastructure. Avinor is a self-financed company, it does not receive any state subsidies. Operation of non-profitable airports and other obligations is financed with the profit made by the largest airports (www.avinor.com).

Increasing air traffic facilitates the need of adequate capacity. And the complexity of aviation sector compiles a big number of interested sides. Avinor should find the most efficient way to satisfy the needs of regulatory authorities, passengers, employees and owners. Company’s activities should also correspond to environmental regulations and support the regional trade and industry at the same time. All these factors make infrastructure appraisal practice to be of extremely high importance and require approved comprehensive methodology.

Here we would like to make a remark about natural monopoly characteristics of considered companies. If Statnett is a typical example of natural monopoly, in case of Avinor it is not so clear. There is a practice in many countries of the World, when airport ownership is privatized. So, we cannot handle the whole airport network as a natural monopoly, but one particular airport can be considered as a natural monopoly.

3.4 Data collection

“Case study protocol […] is intended to guide the investigator in carrying out the data collection from a single-case study ([…] even if the single case is one of several in a multiple-case study)” (Yin, 2003, p. 67). As a part of the case study protocol we define the pattern of data collection for our comparative case study.

Data set for each case consists of two main parts. The first part is related to the governmental methodological recommendations for the economic impact assessment for each industry. Documentary evidence of this data set includes regulation Acts, guidelines, handbooks and other documents related to established impact assessment procedures in considered industries.

Second part of data set is related to appraisal practices of considered companies (Gassco, Avinor, Statnett). Collecting data about appraisal practice in each case we took one representative example of recent infrastructure development project in addition to documents with the general appraisal methodological recommendations for chosen industries. Specifically, we took Gassco's project of connecting the Luva field to production facilities, Statnett's Hardanger power line project and Avinor's plan of increasing capacity of Bergen airport Flesland. Source for this information is all types of published information with examples of infrastructure development appraisal.

In addition to mentioned two main groups of data, we also use companies' documentation, annual reports, website information, magazine and newspaper reports, and interviews with informants related to considered projects, in order to fulfil possible blanks in our understanding of appraisal practices.

The list of the documents used to collect materials about infrastructure appraisal practices includes:

Table 3-1 *Documental sources of information*

Relevance to	Document
Norway	Veileder i samfunnsøkonomiske analyse, Finansdepartementet. 2005.
	Nytte-kostnadsanalyser. Prinsipper for lønnsomhetsvurderinger i offentlig sektor. Norges Offentlige Utredninger. NOU 1997: 27.
	Nytte-kostnadsanalyser. Veiledning i bruk av lønnsomhetsvurderinger i offentlig sektor. Norges Offentlige Utredninger. NOU 1998: 16.
Gassco	st. Meld.nr. 47 (2003-2004) Om innovasjonsverksemda for miljøvennlege gasskraftteknologiar mv. Olje- og energidepartement
	Guidelines for plan for development and operation of a petroleum deposit (PDO) and plan for installation and operation of facilities for transport and utilisation of petroleum (PIO). 4 February 2010.
Statnett	Samfunnsøkonomisk analyse av energiprosjekter. Håndbok, NVE, 2003
	Samfunnsøkonomiske virkninger. Rapport fra sjøkabelutredningen. Utvalg iv, 1. februar 2011

	Kommentarer til den samfunns- økonomiske analysen av 420 kV ledning Sima-Samnanger. Arbeidsnotat nr. 40/09
	Oppdatert vurdering av forsyningssikkerheten inn mot Bergensområdet vinteren 2009-2010, Notat, 10.9.2010
Avinor	Samfunnsmessige Analyser Innen Luftfart: Samfunnsøkonomi og ringvirkninger. Del 1: Veileder
	Samfunnsmessige Analyser Innen Luftfart. Del 2: Exempelsamling
	En samfunnsmessig analyse av behovet for videreutvikling av Bergen Lufthavn, Flesland. 2005,Møreforskning Molde AS, Rapport 0505

According to common classification (Bryman, 2001), our data can be categorized as secondary, qualitative and quantitative empirical data.

3.5 Data analysis

As a main part of case study protocol we need to formulate a case study questions (Blome and Schoenherr, 2011). This set of questions provides a basis for comparison of the cases. Nakamura (2000) proposed a set of questions for the international comparison of methodologies for transport infrastructure projects. Taking into consideration specificity of current research (comparison infrastructure projects among three different industries), we modified the list of Nakamura's questions. So, we propose the following set of questions to be answered during the cases' analysis and their comparison:

1. ***Are there any established or recommended appraisal methods in the sector***?
    - Handbook;
    - Government recommendations;
    - Guidelines etc.
2. ***What appraisal methods are used in economic impact assessment***?
    - Cost-Benefit Analysis;
    - Other methods (MCA, Cost-effectiveness analysis, cost-impact analysis, consequences analysis, etc.)
3. ***What impacts are evaluated and how they are monetized or quantified***?

The particular focus of analysis will be given to environmental impacts and security of supply.

4. ***What decision criteria are used in evaluation***?
    - Net present value;
    - Internal rate of return;
    - Benefit-cost ratio.
5. ***How network effects are evaluated***?
6. ***Are regional impacts of the projects considered?***
7. ***How robust is analysis, how sensitivity analysis or scenario analysis is performed?***
8. ***How the results of applied appraisal methodology are used in final decision making***?

After the comparison of appraisal practices we suppose to answer the question:

9. ***How the differences in appraisal practices can be explained?***

Presented questions will provide the basis for **within-case** analysis, and then **cross-case** analysis (Eisenhardt and Graebner, 2007; Yin, 2003) to detect communalities and differences in appraisal practices in infrastructure development; and virtues and shortcomings of existing appraisal methodology in natural gas transport infrastructure. Introduced above research framework will be implied in Chapters 5 and 6 of the thesis.

3.6 Research quality

As Silverman (2001) point out, the issues of reliability and validity are important, because in them the objectivity and credibility of social scientific research is at stake. "The aim of the social science is to produce descriptions of a social world – not just any descriptions, but descriptions that in some controllable way correspond to the social world that is being described" (Perakyla in the book edited by Silverman, 2006).

Literature search (Mentzer and Kahn, 1995; Ellram, 1996) showed that the quality of logistics research is commonly judged based on concepts of validity and reliability. There are three approved types of validity (Blome and Schoenherr, 2011), and the list of research quality criteria is as follows:

- **Construct validity** establishes correct operational measures for the concepts being studied;

- **Internal validity** establishes a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished by spurious relationships (Ellram (1996) argues that internal validity is irrelevant for those case studies that are solely exploratory or descriptive in nature) ;
- **External validity** establishes a domain in which the study's findings can be generalized;
- **Reliability** demonstrates that the operations of a study can be repeated, with the same results (Blome and Schoenherr, 2011).

Each of the criteria is relevant to a particular phase of research, Yin (2003) links reliability and construct validity of the research to the phase of data collection; and external validity to research design.

Ellram (1996) states that in a case study context, there are two keys to reliability: use of a case study protocol, and development of a case study data base. A case study protocol includes the interview guide, as well as the procedures to be followed in using the test instrument. Yin (2003, p. 67) agrees that the "protocol is a major way of increasing the reliability of case study research".

To address the problem of validity Ellram proposes the use of triangulation. "Triangulation, which is the use of the different techniques to study the same phenomenon, provides validity within the case study method. The three primary qualitative techniques that may be used as part of the case study method are direct observation, recordings, and interviews" (Ellram, 1996).

Yin (2003) states that triangulation addresses both problems of construct validity and reliability. He presents four types of triangulation: of data source (data triangulation), among different evaluators (investigator triangulation), of perspectives to the same data set (theory triangulation), of methods (methodological triangulation). In our research we can address the first type of triangulation – using multiple sources of evidence. Collecting data we used documents, archival records, interviews and direct observation.

So, the way of data collection (data triangulation) and design of this research (presence of a case study protocol) allows us to say that our study complies with the research quality criteria of reliability and validity.

4 LITERATURE REVIEW

An explorative case study has a legitimate reason for not having any propositions (Yin, 2003). We have no purpose to confirm or apply some theoretical propositions or hypotheses in this research; the only proposition was made in the end of Chapter 2, based on analysis of the current practice. The purpose of our study is purely explorative, comparison with appraisal practices from aviation and electricity supply is used to detect specific features of appraisal practice particularly in gas transportation. One can ask a question, what the use of theory review is in the research of this type. Objectives of this Chapter can be formulated as follows:

- to study what methods can be and are applied in appraisal practices in infrastructure development;
- to describe the most widely used approaches, their advantages and limitations in order to provide reliable adjustments of existing appraisal practice;
- to provide a good theoretical framework for systematic description of the cases (Bråthen, 2001).

As Yin (2003) mentioned, theory review works as a kind of guidance in data collection. It helps to figure out what particular data are relevant for the case study.

The most commonly used analytical tools in socio-economic evaluation are cost-effectiveness analysis, cost-benefit analysis and multi-criteria analysis (Dobes and Bennet, 2010). In the following sections we consider them in turn.

4.1 Cost-benefit analysis

CBA, as a name of particular method, is widely used in relevance to socio-economic impact assessment. 'Impact assessment is about making the best possible decision using the best available information in a systematic and proper manner. (…) It is (also) an essential part of good governance and a key to sustainable development' (Au, 2002). In other words, it is a standardized (formalized) process to provide information about the impacts of possible actions, with the aim of 'improving' decision-making about these actions (Nooteboom, 2007). The main challenge when assessing impacts of large-scale infrastructure projects is to find a rational and trustworthy method to compare the advantages and disadvantages of the project, and to distinguish between the alternative characteristics of the project. Today, methodology of Cost-benefit analysis is the most common economic impact assessment approach (Bråthen, 2001; Vickerman, 2007; Salling and Banister, 2009).

4.1.1 Definition and application

Dobes and Bennet (2009) make a parallel between decision making of individuals and government. Individuals make decision how to allocate their available resources to reach the maximum level of personal happiness. Government is supposed to do the same, but with respect to well-being of the whole community. But the task of Government is much more complex due to the fact, that there are a lot of individuals with their own wishes and preferences and Government should balance between conflicting interests in the society. Government also needs to take into account spill-over affects when one particular section of the society can inflict on the others. Doing its evaluation government lacks the data that can adequately reflect the values that individuals place on non-market goods as clean air etc. And to assist government in decision making, cost-benefit analysis was developed.

Some underlying concepts of cost-benefit analysis were originated in Europe in the 1840s, but it is still under constant development, e.g. the use of CBA in environmental economics is a relatively new occurrence. In 1930s regulations were set by the US government which made use of CBA mandatory in certain circumstances. CBA techniques go back to President Roosevelt's Flood Control Act (1936), which set the familiar requirement of 'the benefits to whomsoever they accrue to be in excess of the estimated costs' (Lakshmanan, 2011).

The two underlying concepts which originated from Europe are the concepts of consumer surplus and externality. The concept of consumer surplus was proposed by Jules Dupuit in 1844, when he pointed out that the users of roads and bridges in France enjoyed benefits, that exceeded the tolls they paid for the usage. In the 1920s Pigou developed the concept of externality by arguing that there is a difference between private economic production and public economic product. A firm theoretical framework for CBA was finally established in 1950s with works by three eminent economists: Eckstein, Krutilla and McKean, which methodologically utilized neoclassical welfare economics in relation with CBA (Mishan and Quah, 2007).

Reasonable planning before implementation of public projects includes a preparation of a set of feasible alternative plans and the selection of the most efficient plan from among them. CBA is the evaluation method that is commonly used for evaluation and ranking public investment projects (Odeck, 1996; Nyborg, 1996).

CBA method differs from another project evaluation tools, in particular from financial analysis (Nas, 1996). Financial analysis, which is primarily used in private sector, aims to determine which outcomes are best from the point of private interests. Expected cash flows and revenues are considered as benefits, when payments to factors of production as costs. Third-party's affects are excluded from cost-revenue calculations. CBA, on its turn, is particularly designed for the evaluation of public projects, and all outcomes are evaluated on the basis of public interest.

Considering the methodology of CBA we should highlight it micro-level of application. "The advantage of the CBA method is the ability to cover the distinctive characteristics of particular projects on the micro level (Bråthen and Hervik, 1997)". "Cost-Benefit Analysis (CBA) is the favoured tool for assessing [...] microeconomic benefits (Lakshmanan, 2011)".So, CBA is a microbased policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society. It provides a framework that allows governments to "assess and compare the social costs and benefits of the full range of impacts of a proposed action, whether they involve marketed goods, environmental impacts, or regulatory controls (Dobes and Bennet, 2009)". Here we would lie to emphasize the comprehensive nature of CBA, because there are some terminological misunderstandings. As Dobes and Bennet (2009) state, "[n]on-economists are often unaware of the comprehensive nature of cost-benefit analysis, or confuse the term 'economic' with purely commercial or financial considerations, and seek to complement it with further environmental or social perspectives". Economists often use the term 'social cost-benefit analysis', although the term 'cost-benefit analysis' is more commonly used nowadays.

Performing CBA one should try to consider all of the costs and benefits to society as a whole, and to end up with net total benefits, equal to social benefits minus the social costs (Boardman et al., 2006). In simple words, the basic rationale of CBA lies in the idea that things are worth doing if the benefits resulting from doing them outweigh their costs (Sen, 2000).

4.1.2 Conceptual foundation

Public project analysis requires a theoretical framework for identification and assessment of costs and benefits from society's perspective. Welfare economics and public finance provide a foundation for such framework (Nas, 1996).

We have no purpose to present the whole extended and complicated theory underling CBA, but we introduce only basic concepts: Pareto optimality, social welfare function, consumer and producer surplus, willingness-to-pay and opportunity costs.

Pareto Optimality and Social Welfare Function

The conceptual basis of CBA is **Pareto optimality**. Pareto optimality as an efficiency norm, which describes the conditions necessary to achieve optimal resource allocation. "It is a state of economic affairs where no one can be made better off without simultaneously making at least one other person worse off (Nas, 1996)". So, if a policy has positive net benefits, then it is possible to find a set of transfers, or "side payments" that makes at least one person better off without making anyone else worse off (Boardman et al, 2006).

There are three underlining efficiency conditions: production efficiency, exchange efficiency and allocative efficiency. Production efficiency is such resource allocation, where it is no possible to increase the output of one good without reducing the output of some other good. Exchange efficiency implies that for a particular allocation to be Pareto optimal, produced output should be efficiently distributed among the consumers. To satisfy the allocative efficiency condition, both the exchange and the production efficiency conditions should be reached (Nas, 1996). Such resource allocation that corresponds to allocative efficiency condition can be presented as Potential Pareto frontier. Any point below this frontier is inefficient, because it is still possible to improve welfare by reallocation of resources, doing at least one person better off without doing any one worse off. Movement towards the frontier means potential Pareto improvements over the status quo point (Figure 4-1). This movement is also called Kaldor-Hicks improvement, which is commonly used as an efficiency norm in CBA. **Kaldor-Hicks** criterion is formulated as follows: A policy should be adopted if and only if those who will gain could fully compensate those who will lose and still be better off. It means that only policies that have positive net benefits are adopted (Boardman et al, 2006).

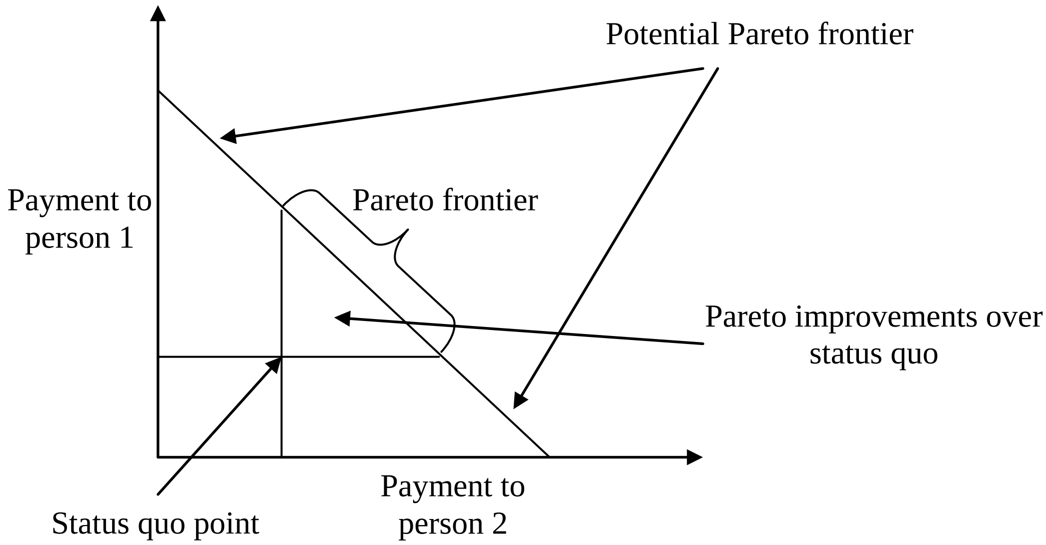

Figure 4-1 *Potential Pareto improvements* (Source: Boardman et al, 2006)

Using Pareto optimality as a criterion, it is possible to distinguish between efficient and inefficient utility distributions, but Pareto analysis does not provide a framework for comparison of two solutions that are both efficient. This comparison requires society's distributional norms. **Social welfare function** reflects distributional ethics of the society (Nas, 1996). Social indifferent curves W_1, W_2 ... W_n represent alternative combinations of individual utilities among which society is indifferent. Movement from lower indifferent curve to upper means increase in social welfare. A point of tangency (A) between the frontier and the highest attainable social indifferent curve, presents a Pareto optimum-welfare maximum allocation (Figure 4-2).

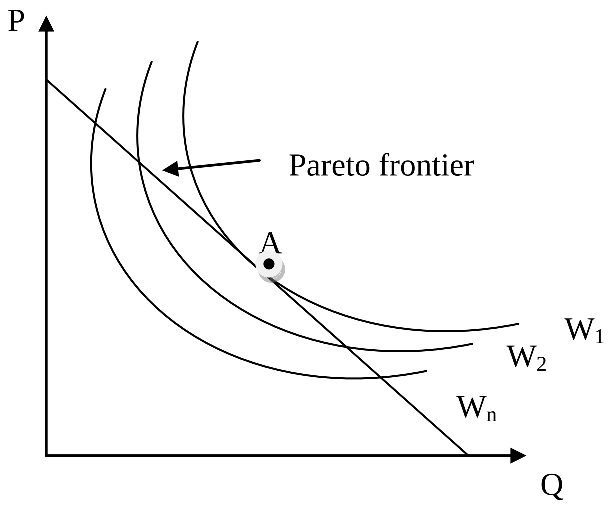

Figure 4-2 *Pareto optimum-welfare maximum allocation* (Source: modified from Nas, 1996)

Consumer and Producer Surplus

Consumer surplus is a monetary measure of the maximum gain that an individual can obtain from a product as a given price (Nas, 1996). "The concept is defined as the difference between the maximum amount that an individual would be willing to pay for a good and the actual amount paid (Nas 1996, p. 67)".

Producer surplus can be described as the supply-side equivalent to consumer surplus. "As changes in prices resulting from government policies have impacts on consumers that can be valued in terms of changes in consumer surplus, price changes also results in impacts on producers that can be valued in terms of changes in producer surplus, or as changes in the economic profits of firms in the market (Boardman et al. 2006, p. 58)" The producer surplus is the difference between the market value of the factor and its opportunity cost (Nas, 1996).

The sum of consumer surplus and producer surplus is called social surplus (Figure 4-3).

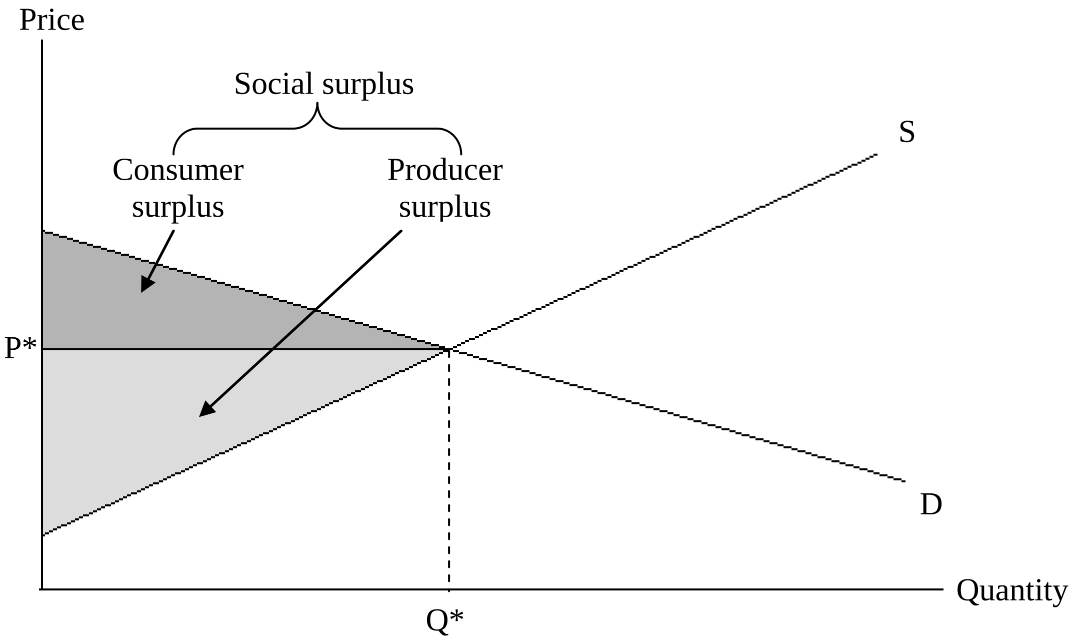

Figure 4-3 *Social Surplus* (Source: Boardman et al, 2006)

Through this figure we can tie up concepts of Pareto efficiency and social surplus. In the conditions of well-functioning perfectly competitive markets and absent of market failures, the market equilibrium maximizes social surplus. This equilibrium point is said to be allocatively efficient, because here it is not possible to make someone better off without making someone else worse off.

Willingness-To-Pay and Opportunity Cost

Unlike the financial analysis, which is based on marked prices, CBA operates with the concepts of the **willingness-to-pay** (WTP) and **opportunity cost** for measuring costs and benefits.

Benefits to society are measured as an aggregation of individuals' willingness to pay, and social costs reflect opportunities that are missed by employing available resources in a certain project. To descried the concept of net benefits through the WTP and opportunity cost we address the example given by Dobes and Bennet (2009) about water.

An individual's willingness to pay for water may be several thousands of dollars a year. But the price actually paid for water by an individual may be much lower, e.g. ten dollars per year. The difference between the individual's willingness to pay and the price they pay is defined as the benefit generated from the consumption of the water. It reflects the fact that the benefit is not defined only by the price, but by the willingness to pay. The net social benefit of making water available to all the individuals in a community is the present value of the difference between the sum of the residents' net willingness to pay (their 'consumers surplus') and the sum of the opportunity costs of the resources used for supply the water.

So, if the net benefits of the project as measured by the willingness-to-pay of all affected individuals are positive, then there are sets of contributions and payments that would make the policy a Pareto improvement over the status quo.

4.1.3 Methodology of CBA

Nas (1996) defines four essential steps in CBA: identification of relevant costs and benefits, measurement of costs and benefits, comparison of cost and benefit streams during the lifetime of a project, and project selection. Boardman et al. (2006) propose detailed extended list of steps in CBA:

1. *To specify the set of alternative projects*. Analyst can generate a plenty of alternatives, changing one dimension of the project after another, but on practice he or she can perform the analysis only of several most promising alternatives.

2. *To decide whose benefits and costs count*. There is often a question whether an analysis should be performed from the global, national, state or local perspective.

3. *To catalogue the impacts quantitatively over the life of the project*. Cataloguing of impacts means defining the inputs and outputs related to the project and the task of analyst is not to omit critical issues. This issue will be considered in details in relevance to particular applications of CBA in the last sections of this chapter.

4. *To predict the impacts quantitatively*. Quantitative prediction is the most difficult part of analysis due to the following reasons: the targets of programs can respond in unexpected ways, they may exhibit compensating or opportunistic behaviour; existing of substitution or spillover effects.

5. *To monetize all impacts.* Monetizing is complicated in sense that not everything has its exact market price, e.g. unit of time saved, lives saved etc. This issue will be also discussed in the section devoted to cost-effectiveness analysis.

6. *To discount benefits and costs to obtain present values.* The question here is a proper choice of a discount rate, which will be discussed more detailed below.

7. *To compute the net present value of each alternative*. Net present value of an alternative equals to the difference between the present value of the benefits and the present value of the costs.

8. To perform sensitivity analysis. Sensitivity analysis is performed to take into account uncertainty of future outcomes of the project.

9. To make a recommendation.

To investigate how CBA is applied on practice for appraisal of investment projects we address the EU Guidelines to CBA of Investment Projects (2008). This approach is based on CBA, but includes some preliminary steps, which are defined as necessary requirements for CBA. The following main stages of project appraisal are defined: (1) Context analysis and Project objective; (2) Project identification; (3) Feasibility and Option analysis; (4) Financial analysis; (5) Economic analysis; (6) Risk assessment.

The sequence of actions and the logic are described on the following graph:

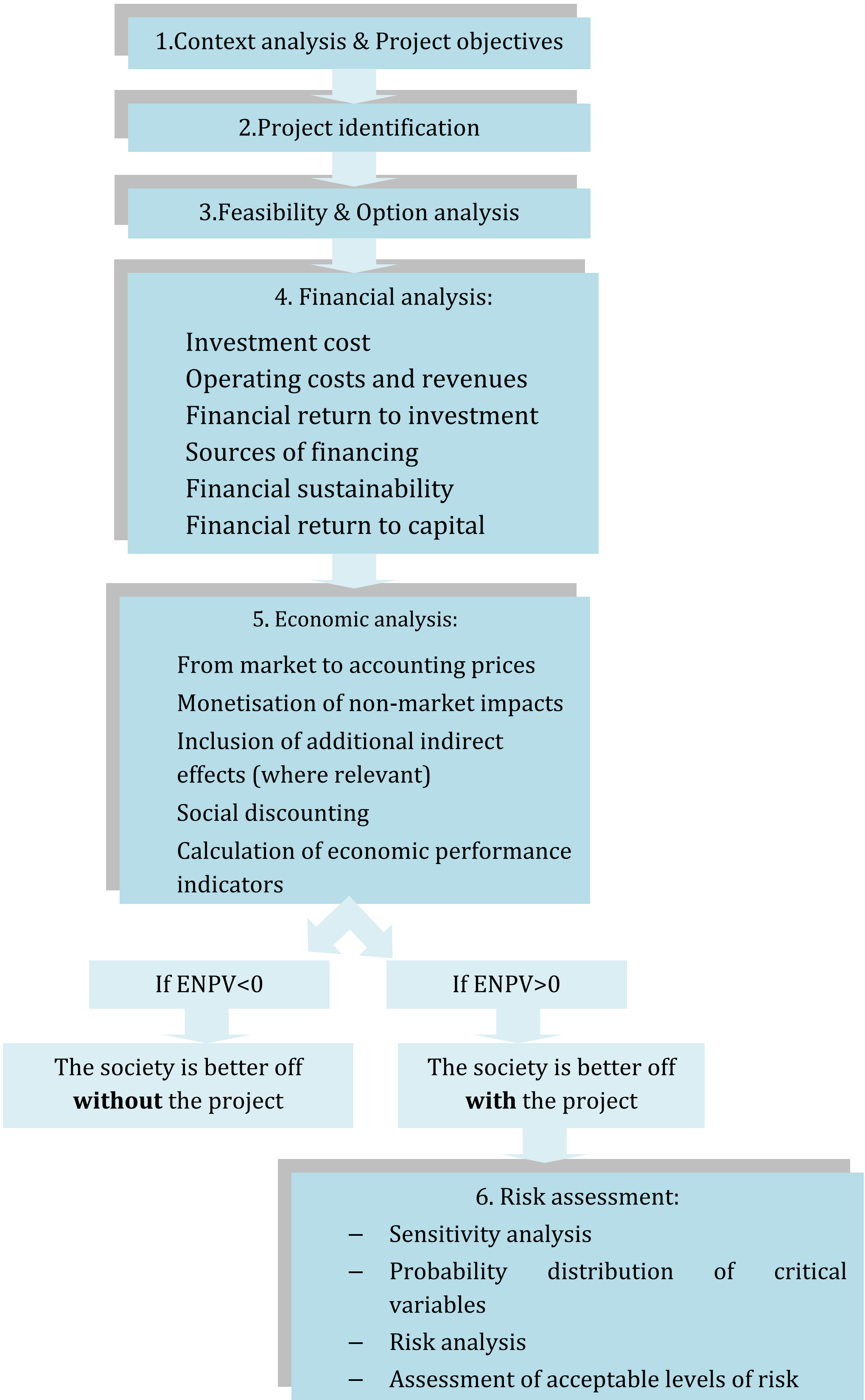

Figure 4-4 *Structure of project appraisal* (Modified from EU guide to CBA of Investment Projects, 2008)

Further we will briefly describe steps of appraisal proposed by EU guide to CBA of Investment Projects (If other is not stated, reference is to EU Guidelines).

- ***Context analysis*** assumes the investigation of social, economic and institutional conditions, in which project is supposed to be implemented. It includes demand analysis, which consists of demand forecast for goods or services produced by the project even for non-revenue projects as an indicator of regional environment. In cases of energy and transport infrastructure special attention should be paid to the nature of networks and their mutual dependency and accessibility. On this stage clear socio-economic objectives should be defined and connected to the investment programme.

- "A project can be defined as an operation comprising a series of works, activities or services intended to accomplish an indivisible task of a precise economic or technical nature; one which has well defined goals (EU guidelines, 2008, p. 30)". ***Project identification*** is assumed to be accomplished if:
  - the object is a self-sufficient unit of analysis;
  - indirect and network effects are taken into account;
  - proper social perspective has been adopted ('standing issue').

- ***Feasibility and Option analysis***. Examples of options are different routes or technologies for transport projects, alternative locations of a plant, different peak-load arrangements for energy projects, or efficiency improvements rather than construction of new infrastructure. Generating feasible options analyst should also include a forecast without project as a basis for comparison of options. It is called 'business as usual' forecast or 'do nothing' scenario, which, however, not necessary is non-costly, because it can include maintenance and operating costs.

- The purpose of ***financial analysis*** is to use forecasted cash flows generated by the project in order to calculate net return indicators (financial net present value and financial internal rate of return). It should be based on: (1) total investment costs (fixed investments, start-up costs, changes in working capital); (2) total operating costs and revenues; (3) financial return on investment cost; (4) sources of financing; (5) financial sustainability.

- ***The economic analysis*** appraises the contributions to the economic welfare of the region or country where the project will be implemented. In contrast to financial analysis, it is made on behalf of the whole of society instead of just the owners of the infrastructure.

The methodology of economic analysis is summarized in the following five steps: (1) conversion of market to accounting prices; (2) monetization of non-market impacts; (3) inclusion of additional indirect effects (if relevant); (4) discounting of the estimated costs and benefits; (5) calculation of the economic performance indicators (economic net present value, economic rate of return and B/C ratio).

(1) As it was stated, the objective of CBA is to appraise the social value of the investment. Observed prices, which can be set by markets or by governments, often do not provide a good measure of the social opportunity cost of inputs and outputs. This can happen when real prices are distorted because of inefficient markets or Government sets non cost-reflective tariffs of public services. So, the key issue here is to make calculations not on the basis of observed market prices that do not reflect the social opportunity cost of inputs and outputs, but to use shadow prices, based on the social opportunity cost. The usual approach is to convert market prices into accounting prices using appropriate standard conversion factors, which usually are provided by the planning authorities or calculated for special cases.

(2) There may be project, when market values for costs and benefits are not available: e.g. environmental, social or health effects, which are significant in achieving the project's goals and thus need to be evaluated and included in the project appraisal. The most frequently used method is the willingness-to-pay (WTP) approach, which was shortly described above. Willingness-to-pay, or users' preferences, can be observed either indirectly, by observing consumers' behaviour in a similar market or directly, by administering ad hoc questionnaires (but this is often less reliable). In the cases, when estimation of WTP is impossible or irrelevant, long-run marginal cost (LRMC) can be used as an accounting rule. Usually WTP is higher than LRMC in empirical estimates, and sometimes an average of the two is appropriate.

(3) Indirect effects are quantity or price changes occurring in secondary markets. Indirect effects that occur on efficient secondary markets should not be included in CBA, if costs and benefits on primary market were properly evaluated by shadow prices. Otherwise, adding these effects leads to double-counting. But if secondary market is distorted by the existence of taxes, subsidies, monopoly power and externalities, prices are not equal to social marginal opportunity costs. In these circumstances indirect effects should, in

principle, be measured and considered. However, in practice, the magnitude of indirect effects is often not significant for CBA and results in a negligible bias.

(4) Costs and benefits occurring at different times must be discounted. There are three approaches to the choice of the discount rate that have been proposed by Walshe and Daffern (1990):

- a rate equal to that at which the private sector discounts future net benefits derived from investments;
- an average rate obtained from the discount rates used by the private sector in evaluating investment, non-productive investment and consumption;
- a rate which expresses society's preference for consumption now as opposed to consumption by future generations.

In EU Guidelines (2008) the term "social discount rate" is used to differ it from financial rate of return. SDR "should reflect the social view on how future benefits and costs are to be valued against present ones". Described in the guidelines theoretical approaches to SDR definition are the following:

- Marginal public investments should have the same return as the private ones, as public projects can displace private projects;
- Social discount rate should be derived from the predicted long-term growth in the economy, in the social time preference approach;
- A third approach, which is especially relevant in the appraisal of very long-term projects, is based on the application of variable rates over time. The idea is to use decreasing marginal discount rates over time and give more weight to project impacts on future generations.

In recent time the social time preference rate (STPR) approach becoming the most promising. This approach is based on the long term rate of growth in the economy and takes into account the preference for benefits over time, considering the expectation of increased income, public expenditure and consumption. The formula for the social time preference rate can be expressed as follows:

$$r = eg + p$$

where **r** is the real social discount rate of public funds expressed in a certain currency; **g** is the growth rate of public expenditure; **e** is the elasticity of marginal social welfare with respect to public expenditure, and **p** is a rate of pure time preference.

On practice discount rates for social projects appraisal are pre-estimated and recommended by planning authorities. E.g. the European Commission has suggested using social discount rates: 5.5% for the Cohesion countries and 3.5% for the others in 2007-2013 (EU Guidelines, 2008).

Sáez and Requena (2007) proposed the method of calculation "critical environmental rate". The idea is based on the intergenerational discounting, which purpose is to "defend the rationality of applying simultaneously in the same CBA exercise discount rates for intangible effects (e.g. environmental) that are different than those we use for tangible ones" (p. 715). There are two reasons for distinguishing of environmental rate:

- Since environmental goods are not market goods, individuals have different preferences and act differently when dealing with "merchandise" that when handling with "environmental goods".

- The hypothesis of the marginal decline in utility consumption will not hold for environmental goods.

(5) NPV is the most important and reliable social CBA indicator and usually is used as the main economic performance signal for project appraisal. But it is not the only decision rule that can be used on practice. Mishan and Quah (2007) defined the following "crude" investment criteria:

- *Cut-off period.* A certain period is chosen over which the money invested must be fully recouped. Such a criterion may be implied in cases of innovation in products or methods that cannot be protected by a patent, and which innovations are likely to be copied by competing firms within two or three years. The shortcomings of this criterion are obvious: if the returns were not expected to accrue mainly in the first few years but mainly after after the first few years, worthwhile projects would be rejected.

- *Pay-off period* (or capital recovery method). The investment options are ranked according to the number of years necessary to recoup the initial outlay. Another way of expressing almost the same concept is pay-off period rate of return. This method is used in same situations as described above: when imitation by competitors is anticipated, or in circumstances of political uncertainty, one of the overriding considerations is safety. The shortcoming is that the approach favours short-term investments over long-term ones.

- *The average rate of return*. One just adds together all subsequent positive net benefits, divides this sum by the number of years and expresses the resulting figure as a percentage of the initial outlay. There is an assumption that all the figures have been corrected for uncertainty. Modified version of this criterion is the average rate of return including the initial outlay (Mishan and Quah, 2007).

The more familiar and more sophisticated criteria are commonly used in CBA: net present value, benefit-cost ratio and internal rate of return (Nas, 1996).

- *NPV*. The stream of benefits and costs, either separately or in the form of a net benefits stream, are discounted to find their present value:

$$NPV = -I_o + \sum_{n=1}^{N} \frac{NB_n}{(1+r)^n}$$

Where I_o is the initial investment cost, r is the discount rate, NB_n is the benefit stream that begins at Year 1 (n=1), and N is the project's lifetime.

- *A benefit-cost ratio* is used to determine the feasibility of the project during any given year or over the whole time span. It can be calculated by taking either the present value of future benefits over the present value of costs including investment and annual operating costs, or the present value of future net benefits over the one-time investment costs.

- *Internal rate of return* is a specific discount rate that results in a zero NPV. It equates the present value of future net benefits with the initial investment costs:

$$0 = -I_o + \sum_{n=1}^{N} \frac{NB_n}{(1+\pi)^n}$$

where π is the IRR. The project is accepted if IRR exceeds the market rate of return or other rate that is accepted in the public sector.

- ***A risk assessment*** assumes estimation of the probability that considered project will achieve a satisfactory performance. The recommended steps for assessing the project risk are (EU guidelines, 2008): sensitivity analysis, probability distributions for critical variables, risk analysis, assessment of acceptable levels of risk, risk prevention.

The purpose of sensitivity analysis is to acknowledge the underlying uncertainty. Boardman et al (2006) consider three approaches to doing sensitivity analysis: partial sensitivity analysis, worst- and best-case analysis and Monte Carlo sensitivity analysis.

The base-case assumptions, which are supposed to be the most representative, produce an estimate of net benefits with the most expected values. Partial sensitivity analysis is implied to show what are the net benefits, if one of the assumptions is changed, while others are being held constant (Boardman et al, 2006).

Worst- and best-case analysis is typically performed by selecting various combinations for each input variable, running the model with a worst and best case scenario (Salling and Banister, 2009). These combinations of possible values around the best guess are commonly called ‘‘what if” scenarios. But the number of ‘‘what if” scenario combinations increases rapidly.

Monte Carlo sensitivity analysis is the most technically complicated among these three approaches. It provides some range or probability distribution or possible outcomes. If there more than two or three stochastic parameters in the calculation of net benefits, the result of sensitivity analysis is too voluminous to be of any practical help to a decision-maker. “But if sensitivity analysis is possible so, apart from the extra arithmetic effort, is a Monte Carlo analysis. Both involve picking a set of particular values of the stochastic parameters, calculating the answer and then repeating the process. The Monte Carlo analysis merely picks values according to probabilities and repeats the process sufficiently often to generate a probability distribution of the benefits (Kendall, 1971)”.

There are some other approaches to manage the uncertainty in CBA in addition to sensitivity analysis: optimism Bias, quantitative risk analysis, use of expected values, etc.

As it is noticed, the greatest problem in transport project appraisal is so-called ‘appraisal optimism’ (Mackie and Preston, 1998). This issue was conceptualized as Optimism Bias that reflects the tendency for a project’s costs to be underestimated (Flyvbjerg et al, 2002) and demand forecasts to be overestimated (Salling and Banister, 2009). The Optimism Bias can be defined as the percentage difference between ex-ante and ex-post estimates from the final outcome of the projects (Flyvbjerg and COWI, 2004). These levels of uncertainty can be applied in ex-ante based project appraisal studies, but they are often disregarded in most appraisal schemes.

4.1.4 Criticism and limitations

"A common objection against the Cost-Benefit Analysis (CBA) is the problem of including external effects (e.g. network effects) into the analytic framework (Bråthen and Hervik, 1997)".

Cost-benefit analysis uses social surplus as a measure of welfare, but there is as argue, that real social benefits comprise several impacts, that are not captured in conventional CBA. Imperfect market with externalities and increasing return to scale may induce economic growth, thus some significant benefits can be not captured in analysis. Regional impacts of new infrastructure are ordinarily not in focus in the CBA, but it is the issue of high importance for politicians, who are to make a decision. "In general, regional impacts are mid- and long-term effects of the infrastructure investments, even though some shifts in economic activity based on expectations may take place even before the new infrastructure is constructed (Bråthen and Hervik, 1997)".

Bråthen and Hervik (1997) define four main groups of effects which may take place in transport infrastructure development:

1. Extended infrastructure may change the firms' investment behaviour in the considered area; it can affect the local travel behaviour and the value-of-time. This effects are not captured by ex ante CBA calculations,
2. **Local external effects** may occur if other firms in the area are affected through agglomeration effects.
3. **Global external effects** can be present, where increased profits and activity caused by extended infrastructure creates investments and possible agglomeration effects outside the local area. 'Spillover effects' to other parts of the economy are also possible.
4. Pure **distributional effects** are a common result of radical changes in transport infrastructure. These effects are connected to relocation of firms and households without any economic impact.

If these external impacts are significant, they can be measured in the macro studies GDP by means of production functions (e.g. Cobb-Douglas function). If CBA measures net benefits by changes in consumer's surplus, macro studies do it by changes in GDP. Theoretically, the difference between benefits calculated in micro studies and net benefits from CBA for the same project during the same period, is supposed to present the spillover benefits that are not captured on the micro level (Bråthen, 2001).

Dobes and Bennet (2010) define one more critical issue in CBA. There is an implicit assumption in CBA that the marginal utility of money does not differ between individuals. An additional dollar may have different values for individuals with different income. That is why some projects can have distributional consequences different than expected. The use of Kaldor-Hicks potential compensation test pays no attention who receives benefits and who pays costs of applied policy, the only criterion is positive net benefit for society. This problem is solved on practice by using distributionally weighted CBA (Boardman et al, 2006). There are three arguments for giving greater weight to a unit of money received or paid by a low-income person in comparison with higher-income persons: (1) Income has diminishing marginal utility; (2) The income distribution should be more equal; (3)The 'one person, one vote' principle should apply.

Distributional weights are numbers – 1, 1.2, etc. - that are given to reflect the values placed to a unit of money for a certain income group. Obvious difficulties are to determine this numbers. It can be based on estimation of the income elasticity of demand for each good effected by the government policy which is evaluated. Taking this information one can calculate the change in consumer surplus for each effected group (Boardman et al, 2006).

One of the methods to deal with shortcoming of CBA is ex post analysis. It is conducted at the end of a project, and the main purpose of it is to evaluate the real actual costs and benefits resulted from a project. So, it has a "learning" function and helps to improve the quality and objectivity of ex ante analysis of likely projects (Boardman et al, 2006; Hervik and Bråthen, 1997).

4.2 Other appraisal methods

Cost-benefit analysis has also been a subject to criticism for being overly focused on economic efficiency, and that not all impacts can be expressed in monetary units. In this section we will shortly present approaches which are supposed to deal with these issues: multi-criteria analysis and cost-effectiveness analysis.

4.2.1 Multi-criteria analysis

As part of reaction to the criticism of CBA, Italian and Dutch researchers in the 1970s began to work increasingly with multi-criteria analysis.

Multi-Criteria Analysis (MCA) is defined as a family of algorithms used to select alternatives according to a set of chosen criteria and their relative 'weights'. If CBA focuses on one unique criterion, the maximization of social welfare, Multi Criteria Analysis is a tool, which can comprise a set of different objectives, e.g. environmental impact, safety, economy, accessibility, and integration for road projects (UK Department of Environment, Transport and the Regions, 1998).

EU guidelines (2008) propose the following approach to exercise MCA:

- Objectives should be expressed in measurable variables. They should not be redundant but could be alternative;
- When the vector of objectives has been determined, a technique should be found to aggregate information and to make a choice; the objectives should have assigned weights reflecting the relative importance given to them by the policy-maker;
- Definition of the appraisal criteria; these criteria could refer to the priorities pursued by the different parties involved or they could refer to particular evaluation aspects;
- Impact analysis: this activity involves describing, for each of the chosen criteria, the effects it produces. Results could be quantitative or qualitative;
- Forecast of the effects of the intervention in terms of the selected criteria; from the results coming from the previous stage a score, or a normalized value, is assigned;
- Identification of the typology of subjects involved in the intervention and the determination of respective preference weights accorded to different criteria;
- Scores under each criterion are then aggregated to give a numerical evaluation of the intervention; the result can then be compared with the result for other similar interventions.

In its simple form, multi-criteria analysis assumes selecting a set of ‘impacts’ or ‘goals’ to be achieved by a certain project. Then analyst assigns a score to each selected impact on the extent of the effect. The scores are adjusted by multiplying them by some weights that are chosen by the analyst to reflect the relative importance of each impact. The scores are then “standardized” mathematically, and summed up arithmetically to provide an indication of net benefit.

A Goals Achievement Matrix is the most common form of presenting multi-criteria analysis (Table 4-1). The purpose of a Goals Achievement Matrix is to identify a set of key ‘impacts’ or objectives that are supposed to be achieved by the project implementation, with an indication of the relative contribution of each impact to the achievement of the project as a whole.

Table 4-1 *Hypothetical goals achievement matrix for evaluation of an environmental conservation option* (Example from Dobes and Bennet, 2009)

Attribute	Units	Impact	Score (-4 to +4)	Weight (per cent)	Weight-adjusted score
Vegetation area	ha	1500	+2	20	40
Number of species recovered	#	3	+4	40	160
Water savings	ML	15	+1	10	10
People employed	#	7	+1	10	10
Cost	$ (000)	14	-4	20	-80
Total				100	+140

The first column in the table lists the criteria that are relevant to deciding whether to subject an area of bush land to a conservation measure. A second column reflects the fact that contributions of each impact are measured in different units. The third column presents the scores that reflect the ‘values’ placed by the analyst to each criteria. And then these scores are multiplied by the determined weights and final weight-adjusted score is calculated. In this example a weight-adjusted score of +140 has been recorded. This score should be compared to a similarly derived score of alternative projects, including a ‘do nothing’ scenario where current activities are set unchanged.

Limitation and criticism of MCA

Discussion of MCA is commonly based on the comparison of it to CBA. The starting point for cost-benefit analysis is to estimate all effect of a certain project on society as a whole, to aggregate the costs and benefits that accrue to all individuals in current area. In contrast, the analyst who employs multi-criteria analysis starts implicitly from a position of “client advocate" or "issue advocate". This difference between cost-benefit and multi-criteria analysis occurs due to the fact that analysts themselves select the criteria (impacts) that they personally consider to be evaluated. The probability that the results are biased in favour of a proposal can be very high, and by this reason this method is subjected to the influence of interest groups (Dobes and Bennet, 2010).

Another important critical issue is a problem of dimensionality. Multi-criteria analysis breaches this principle adding impacts measured in different units. Replacement with a score or multiplication by weight does not solve the problem of incompatible dimensions. Cost-benefit analysis solves the problem by converting all costs and benefits to a standard dimension – monetary units.

Multi-criteria analysis is also incapable of comparisons between unrelated programs, when they are supposed to be implemented from the same resources, because their impacts or attributes are so different. An advantage of cost-benefit analysis is that it permits comparisons between projects of different nature, because it evaluates all projects and policies on the common basis (Dobes and Bennet, 2009).

Strengths and weaknesses of MCA can be concluded in the following table.

Table 4-2 *Strengths and shortcomings of MCA for public decisions* (modified from Gamper et al., 2007)

Strengths of MCA	Shortcomings of MCA
Openness to divergent values and opinions	Possible subjectivity of analyst's assessment
Capability to tackle qualitative and intangible factors	Problem of dimensionality
Conflict resolution; helps reaching a political compromise	Difficult inter-comparison of case studies
Supports a broad stakeholder participation	Technical complexity, e.g. choice of parameters
Preferences revealed in a more direct and practical way	Decisions on the degree of simplification of the decision content
	Experts' reluctance to share their knowledge/power
	Information bias from certain stakeholder groups to strengthen their power

However, considerable effort has been made over the last decade to reconcile advantages of cost-benefit analysis with the advantages of multi-criteria analysis approach (e.g. Barfod et al, 2011). The main idea here is to determine and assess benefits with the methodology of CBA, then to rank them with weights, scores and values generated by the multi-criteria approach. The robustness of the decision will be also evaluated through the sensitivity analysis, which can be supplemented by changes in weights (Berechman, 2009). This combination of MCA and CBA are used primarily in transport sector.

4.2.2 Cost-effectiveness analysis

Analyst can often quantify impacts but not always can monetize them all (Boardman et al, 2006). If the analyst reduces the problem to that which is measurable, then he can be fairly accused of ignoring the most important parts of the problem. When the output of a project is undefined or cannot be measured in monetary units, CBA is of limited use and analysts consider an alternative procedure – Cost-effectiveness analysis (CEA).

CEA commonly is used in two situations: (1) to select a project that would yield the least cost production of a given output; (2) to choose a project that would yield the maximum output at a given cost (Nas, 1996).

Cost-effectiveness has advantages when comparisons are made between alternative policies that have the same output. It is particularly applicable when the decision about a certain measure already made, for political or other reasons, and the only remaining issue is the relative cost of alternative methods or scales of implementation (Dobes and Bennet, 2010).

CEA compares mutually exclusive alternatives in terms of the ration of their costs and a single quantified effectiveness measure (Boardman et al, 2006). The main point here is that this effectiveness measure should not be monetized. It is widely used in such areas as health (e.g. mammography screening programmes, Wang et al, 2001; vocational rehabilitation, Alf, 1997) and defence policy. E.g. policy makers may be willing to predict the number of lives saved by the project implementation in healthcare, but they don’t want to value in monetary units human lives (e.g. Mishan, 1971). The cost-effectiveness ratios of such programmes are usually expressed as dollars per life saved.

Costs and effectiveness are always measured incrementally. If we consider two policies, a and b, the cost-effectiveness ratio of policy a in relevance to policy b will be calculated as follows:

$$CE_{ab} = \frac{C_a - C_b}{E_a - E_b}$$

where C_a and C_b are cost of alternatives a and b correspondingly, E_a and E_b are the numbers of effectiveness units produced by alternatives a and b (Boardman et al, 2006).

As a ratio of an effect (output) and a cost (input), a cost effectiveness ratio measures efficiency. The key disadvantage of CEA is that it measures technical efficiency, but not allocative efficiency. It can provide information on the relative cost efficiency of one measure compared to another, but it cannot show whether the implementation of the projects produce net benefits to society or not. In particular, cost-effectiveness analysis tells us nothing about the "do-nothing" case (Dobes and Bennet, 2010).

In some applications, particularly in health care, CEA takes a form of cost-utility analysis. In CUA the incremental costs of alternatives policies are compared to the health changes, which are usually measured in quality-adjusted life-years (QALYs) or disability-adjusted life-years (DALYs). CUA is most useful when alternative policies suppose a trade-off between quality of life and length of life (Weinstein, 1995; Boardman et al, 2006).

CBA assumes the use of welfare economics when calculate benefits, but on practice, economists link CEA and CBA in that sense and use welfare economic framework for economic evaluations in CEA. Dolan and Edlin (2002) attempted to develop a welfare economic bridge between CBA and cost-effectiveness analysis. In the result they developed "an impossibility theorem that shows it is not possible to link CBA and CEA if:

(i) the axioms of expected utility theory hold;
(ii) the quality-adjusted life-year (QALY) model is valid in a welfare economic sense;
(iii) illness affects the ability to enjoy consumption" (p. 827).

4.3 Economic impact assessment in infrastructure development

Among all applications of CBA and other appraisal methods in public decision making transport infrastructure development has an extraordinary place. There have been done a plenty of researches in parts of the world, written articles (Arnott, 1997; Bristow and Nellthorp, 2000; Damart and Roy, 2009; Stevens, 2004; Tsamboulas and Mikroudis, 2000) and handbooks (Berechman, 2009; Haezendonck, 2007) in the field of transport infrastructure appraisal. Specifically, there are an enormous number of academic articles devoted to railway infrastructure development (Carrera-Gómez et al, 2006; Fröidh, 2008; Nash, 1991), national roads investment projects. (Kern and Rajkovič, 2008; Nyborg, 1996; Nellthorp and Mackie, 2000) and public urban transportation (Phani et al, 2004; Tudela et al, 2006).

The purpose of this research requires an overview of CBA applications in aviation, electricity networks and petroleum transportation. The volume of available researches in these fields are not so large as for railways and public roads, but still significant to make a consistent review. The objective of this section is to figure out, what specific impacts are assessed in each field and what are the particular methods of their calculation.

4.3.1 Electricity infrastructure assessment

There are also various aspects of electricity infrastructure assessment that are considered in literature. We present a short review of application of CBA in relevance to appraisal in electricity sector.

In the article by Nooij (2011) we find a case study of the application of CBA for two projects in electricity sector: decisions to build interconnectors in Europe, one, called NorNed, between the Netherlands and Norway, and the second one is the East–West Interconnector between Ireland and the UK. There are costs and benefits that are considered in CBA of electricity supply options, presented in the article. The cost side includes impacts, which mainly follow from calculations made by engineers: investment costs, operational and maintenance costs, environmental impact, real options, the impact of electricity losses, other system costs (frequency control, spinning reserve and other ancillary services costs).

On the benefit side two main groups of benefits are considered: efficiency benefits and security of supply benefits, or reliability benefits.

Efficiency benefits include trade and competition benefits. Investing in interconnection and transmission means extension of network and gives possibilities of competition between generators. There are two types of efficiency that increased as the the result of network extension:

1 Allocative efficiency - the electricity goes to the consumer with the greatest WTP, but redistribution does not improve welfare;
2 Productive efficiency - the same electricity cannot be produced at a lower cost because of change in production levels of among producers.

Increased competition also reduces x-inefficiency, where firms could produce at a lower cost than they actually do, and it may also stimulate investments in R&D and new technologies, that increases dynamic efficiency.

Increase in security of supply is often the main reason for grid investments. A distinction can be made between investments necessary to maintain reliability, by meeting determined engineering reliability criteria, and investments to facilitate the market, including all non-reliability benefits.

Stirling (2001) analyzes technological risks associated with electricity generating options. Electricity supply options choice is strongly related to the governance of environmental risks. He distinguishes “scientific” and “precautionary” approaches to the appraisal of risk. A “scientific” approach includes mainly two techniques: comparative risk-assessment and cost-benefit analysis. Then the limitations of these approaches are discussed, e.g. whether CBA is able to “satisfactorily reflect the scope, complexity, disparity and subjectivity of different aspects of the environmental performance of energy technologies” (Stirling, 2001, p. 57). The impacts of alternative energy options are different in terms of their distribution over space, through and beyond the society. A ‘precautionary’ approach, in its turn, focuses on a rather different perspective of risk governance. It is characterized by inclusivity and pluralism in the appraisal of risks and benefits, and this approach is more “holistic”. In this article the possible application of multi-criteria analysis for risk assessment is also mentioned. More deep description of MCA in electricity sector one can find in the article by Diakoulaki et al (2007), where options are evaluated both with MCA and CBA.

Lee and Heydt (2004) study the costs and benefits both for consumers and producers of infrastructure development related to electric power quality. They consider a trade-off between the issues of cost and quality and discuss a power quality interactive–dynamic control mechanism to conceptualize the cost and benefit of power quality.

Afshar et al (2008) propose an approach for optimal determining reserve capacity in the electricity market. They describe a method for determining the optimum value of reserve capacity based on the cost of its provision and the benefit obtained from its availability. Suggested method is based on mixed-integer linear program. The idea is to increase the reserve up to the point where the marginal cost of procuring reserve is equal to the marginal value of the reserve capacity.

There is a specific issue in electricity sector about the power lines construction in urban and rural natural areas, which causes negative externalities on wildlife, human health and landscape. Navrud et al (2008) consider one of the external costs of power transmission lines, namely "aesthetic impacts on the landscape". In the article the estimated costs from aesthetic impacts on the landscape in urban area and find that the social benefits of avoiding these negative impacts is three times larger than the costs of burying the lines as underground cables.

To see how CBA for electricity sector is applied on practice we address the EU guide to CBA (2008).

In order to correctly *identify the project* in this field it is necessary to state its scale and dimension, and make an analysis of the market where the electricity will be sold; and to describe the engineering features of the planned infrastructure, which include:

- basic functional data: transport tension and capacity of power lines, number of inhabitants served and power or average supply per inhabitant;
- physical features: route and length of power lines, section of electricity conductors, the size of the area served by the network and its routes;
- characteristics of the network and location of internal nodes and links with electricity network;
- typical construction of power lines;
- technical features of the plants for transformation, or sectoring stations;
- technical features of the other service structures;
- significant technical elements: important intersections, remote control and telecommunications systems.

The key information for the *feasibility and option analysis* in electricity supply projects is the demand for energy, seasonal and long-term trends and the demand curve for a typical day. The options analysis can include different technologies for transporting electricity: e.g. direct or alternating current, transport tension; different district networks, and alternatives for satisfying the demand for energy: e.g. mixed use of gas and electricity instead of just electricity; the construction of a new power station on an island instead of underwater power lines (EU Guide, 2008).

Externalities to be considered in economic impact assessment are:

Benefits: the valorisation of the area served, quantifiable by the revaluation of real estate and land prices;

Costs:

- the negative externalities of possible impact on the environment (spoiling of scenery, naturalistic impact, loss of local land and real estate value due to disamenity, such as noise);
- the negative externalities due to the risk of accident;
- the negative externalities due to the opening of building sites, especially for urban networks: negative impact on housing, productive and service functions, mobility, agricultural framework and infrastructure.

Critical factors in risk assessment of electricity projects are: demand dynamics and operating costs. Uncertainty of the projects can be related to the following main variables:

- Forecasts of the elasticity of electricity consumption;
- The dynamics of purchase prices of electricity, conveyed by the distribution infrastructure;
- The dynamics of the sale prices of substitutes electricity.

4.3.2 Infrastructure appraisal in aviation

The most common project categories in aviation are: projects motivated from standards or regulations, projects with environment effects, CNS/ATM/ILS-services (improved equipment for navigation, communication and instrument landing), terminals, extended runways (Bråthen et al, 1999).

The economic evaluation of airport projects includes issues common to every cost-benefit analysis of a major investment in transport infrastructure (Jorge and de Rus, 2004), but has a set of particular features. Literature review shows that researchers often focus on approaches to estimate some particular impacts.

Hansen and Wei (1998), for example, studied how the increased hub airport capacity influences flight delays, with help of a statistical model, which includes such factors as weather, flight traffic level, airlines' schedule concentration and delays from the origin airport. Hansen et al. (1998) propose the method how to estimate passengers' benefit from airport expansion. They used two dimensions: the index of the passengers' transferring time and convenience at a hub airport and the number of passengers who are supposed to connect at the hub airport based on the schedule but would miss their connections because of flight delays.

In addition to listed above types of projects in aviation sector, there are researches that focus on other possible beneficial projects. E.g. Daniel (2002) presents an analysis of the costs and benefits associated with construction of additional taxiways at a mid-sized airport. The benefits obtained from reduced taxiing time, improved airport access, increased safety, decreased emissions, and reduced noise are calculated based on the changes in aircraft traffic patterns.

Jorge and de Rus (2004) propose a practical approach to efficiently but rather easily measure the benefits to passengers that result from the new airport projects. Wei and Hansen (2006) also considered passengers' benefits from airport capacity expansion. They classified them into two categories: direct benefits and indirect benefits. Indirect benefits are related to airlines' adaptation and service improvements after airport capacity expansion: due to increased runway capacity, airlines provide more flights and more connection opportunities for passengers; passengers would experience less waiting time in a trip. Direct benefits are obtained directly from airport expansion, without taking into account the airlines' adaptation in scheduling or services: if airport capacity is increased, passengers (the same number as before capacity expansion) will enjoy greater punctuality of flights and experience less congestion. They quantify the passengers' direct benefits from airport expansion by calculating the change in consumer surplus after the project implementation, based on the econometric passenger demand model for a hub-and-spoke network. Then, Wei (2008) presents an approach to quantify the indirect benefit, based on a passenger utility function developed for the passenger demand model.

Let us consider major points of CBA application in aviation on practice. Cost-benefit framework for aviation suggested by Norwegian Civil Aviation Authority and described by Bråthen (2001) includes the same main steps as presented above in general methodology of CBA. The first stage requires defining the project's objectives, "base case" and relevant alternatives. The second step includes identification of "losers" and "winners" of the project; description of alternatives according to "base case" (traffic forecasts and future capacity constraints); identification of impacts, that can be important but not captured be CBA.

The third step is to identify and categorize costs and benefits of the projects.

Table 4-3 *Identification of costs and benefits in aviation infrastructure* projects (Source: Bråthen, 2001)

Costs:	Benefits:
Adequate cost groups: fiscal tax adjustments, fixed prices	Changes in generalised travel costs
Who is paying the cost	Reduced capacity problems: - increased traffic; - reduced delays; - improved regularity.
External costs	External benefits
Financial cash flow	Financial cash flow

The fourth is to carry out the analysis: calculate costs and benefits, discount to a reference year and sensitivity analysis. And the fifth step is to present the results of analysis.

Relevant economic effects in aviation projects are referred to four groups of interest:

- **For passengers**: costs of alternative transport; number of passengers deterred; changes in accident risk; costs of delays;
- **For operators (airlines)**: time costs and operating costs, cost of delays, accident costs;
- **Investing company (owner)**: investment costs, operating costs;
- **Third parties: e**nvironment costs.

The point of particular attention in CBA for aviation is *generalized travel costs*, which consist of value of time (VOT), ticket costs and other monetary costs. The expression of VOT in monetary terms and its empirical estimation are the issues of discussion. Often VOT is the largest element in appraisal for aviation, and is commonly internalized in the tickets costs. In calculation of the savings in travel time, the purpose of the trip (business travel or private) is an important issue. VOT is usually calculates through average gross and net wages (Bråthen, 2001). One more specific feature of CBA in aviation is violation of the assumption of competitive market because of taxation system and presence of increasing return to scale.

The main external benefits and costs that should be considered in economic impact assessment of aviation infrastructure can be extracted from the general recommendation for airports and ports by the EU guide to CBA (2008):

External benefits:

- environmental impact reduction, due to better performing infrastructure and equipments, modal shift from highly polluting modes etc.;
- safety improvements and accident reduction, for modernisation projects, for both users and staff;
- indirect positive impacts on land values and real estate near to an airport, on economic activities (retail, hotels, restaurants etc.), with the warning to avoid double counting.

External costs:

- indirect negative impacts on land values and or economic activities;
- increased noise and pollution (local, regional and global effect);
- accident cost (the cost per accident consists of loss of statistical lives, injury costs, material costs and administration costs)s;
- environmental impacts and congestion due to traffic increase on the links connecting the nodal facilities to the main networks.

In the risk assessments of the projects the following **critical factors** should be considered: transport demand; investment and operating cost overruns; coordination with complementary projects (investments on the connecting links). Dealing with uncertainty in the project one should take into account the following main variables (EU Guide, 2008):

- Assumptions concerning GDP;
- Rate of increase of traffic over time;
- Competition with other existing infrastructure;
- Value of time for users;
- Investment costs;
- Maintenance costs;
- Fares and tariffs of the projected facility and of the competing ones.

The economic appraisal within aviation can be also based on cost-effectiveness analysis in circumstances when projects are motivated by regulation and standards, e.g. emissions reduction, and benefits cannot be monetized (Bråthen, 2001).

4.3.3 Gas transport infrastructure impact assessment

There are a significant number of researches in natural gas sector, where capacity expansion decisions are considered from a perspective of their impacts to market strictures or as means to improve the efficiency of gas markets. One of the objectives of these researches is to explore the possibility of using "excess" transport capacity as one of the instruments to control regional market power (Gasmi and Oviedo, 2010).

Article by Pelletier and Wortmann (2009) is devoted to the assessment of the risk to invest in gas transport infrastructure. They use a multi-stage linear program to simulate the redistribution of the natural gas flow in the grid system on a succession of contracting periods. The risk measured is the probability of a negative present net value for the investments. The model is tested on an example of two grids that are on alternative routes serving same destinations. The investment decisions proposed by the model are based on on the tariff policy and demand and supply forecasts.

In the paper by Hirschhausen (2008) the concept of 'security of supply' in natural gas is discussed in relevance to infrastructure investment and regulation. He states that much of the 'supply security' debate is linked to fears of insufficient infrastructure investment. And he connects the discussion of security of supply in natural gas sector to incentive problem in investment decisions.

Afgan et al (2007) focus on evaluation of the potential routes for natural gas supply to the south east and central European countries. Assessment of potential options of gas supply and capacity of transport facilities is based on a set of indicators:

- *Environmental indicator*. In the assessment of pollution from gas pipelines, it is considered that there are two kinds of emissions: indirect (combustion products from gas turbines) and direct (leakage of gas pipelines).
- *NG cost indicator*. This indicator is based on the present annual average cost of natural gas.
- *NG transport and royalty indicator*. The pipeline transport and royalty cost comprise the total cost for natural gas transport from the wellhead to the final terminal of the gas route. The royalty cost is as a percentage of the total gas cost, which includes natural gas cost and transport cost.
- *Investment indicator*. The investment cost consists of the total investment in the specific gas route and is based on the length of the pipeline and also on the characteristics of the ground: e.g. a submarine pipeline costs much more than an onshore pipeline.
- *NG demand indicator* is calculated by adding the total natural gas consumption in individual countries and dividing by the total population of the countries where the natural gas route exists.

There are also researches where gas transport infrastructure investments decisions are considered in connection to cost of congestion based on nodal price (Lochner, 2011), Monte Carlo valuation approach (Abadie and Chamorro, 2009; Finch et al, 2002), real options to deal with uncertainty (Mohn and Misund, 2009), but there are very little available literature on economic impact assessment in gas transportation.

In the article by Dey (2002) the model of cross-country pipeline project appraisal, based on the application of analytic hierarchy process (AHP), is presented. At first, the description of the current project feasibility analysis process of cross-country petroleum pipelines is presented and is summarized on the following figure:

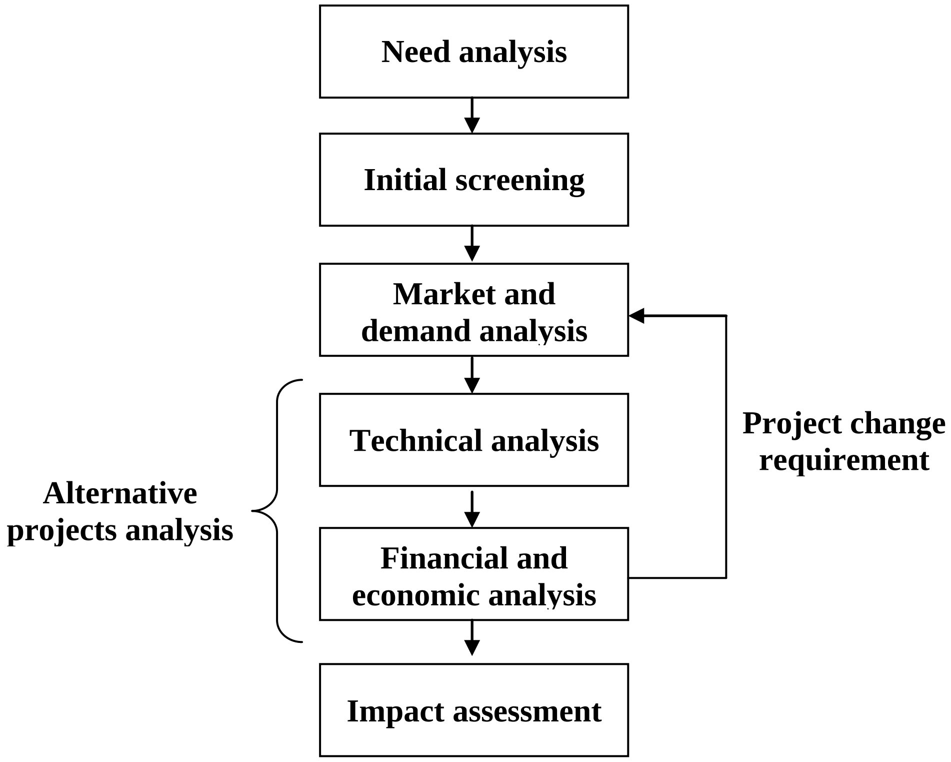

Figure 4-5 *Project feasibility analysis of cross-country petroleum pipelines* (Source: Dey, 2002)

This appraisal approach includes technical analysis, financial analysis, and economic analysis, which here is separated into two parts: socioeconomic impact assessment and environmental impact assessment.

Factors that are included in the ***technical analysi***s are summarized on figure 4-7.

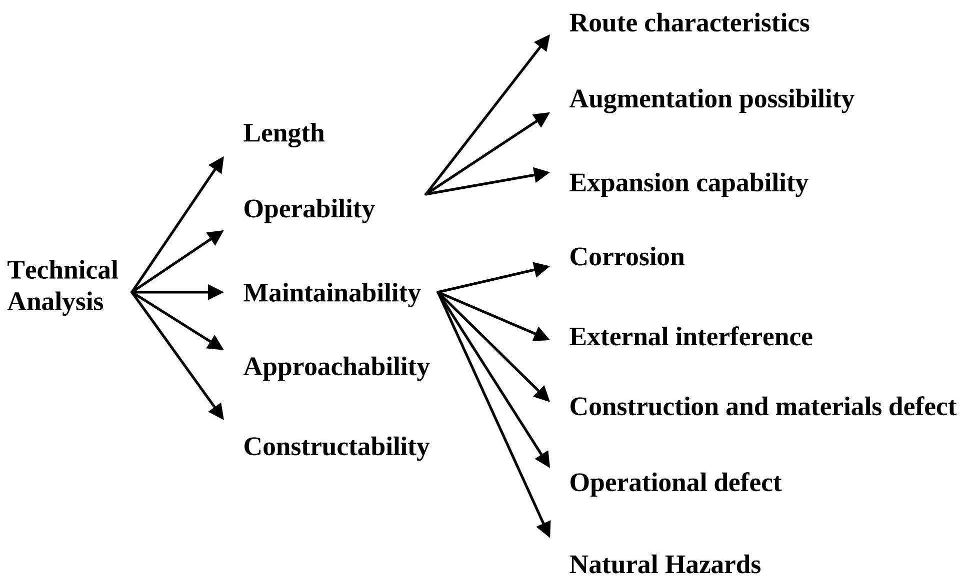

Figure 4-6 *Factors and sub-factors of technical analysis* (Source: Dey, 2002)

Next step is **financial analysis**, which aims to select the project on the basis of minimum cost with respect to capital and operating cost. **Economic analysis** includes environmental (Figure 4-8) and socio-economic (Figure 4-9) impact assessment. Pipelines are one of the safest modes of transportation of bulk energy. Its failure rate is much less in comparison to other modes. But pipelines failures can have catastrophic consequences (in 1993 in Venezuela 51 people were burnt to death when a gas pipeline failed and escaping gas got ignited; in 1994, a pipeline in New Jersey, USA failed, which resulted death of one person and injuring more than 50 people, etc.). Certainly all, even minor, disruption in pipeline operation lead to significant costs for business and can influence the environment (Dey, 2002).

The following factors are to be considered to assess environmental impact:

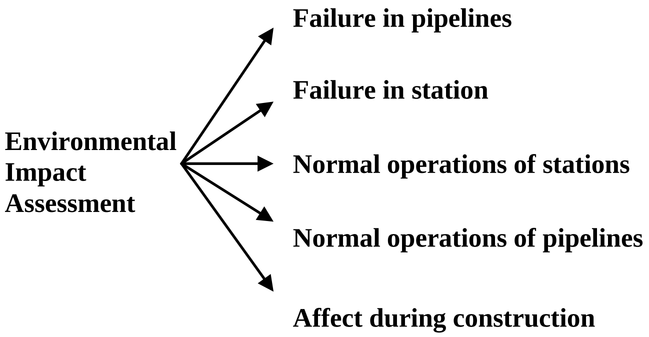

Figure 4-7 *Factors and sub-factors of environmental impact assessment* (Source: Dey, 2002)

Socio-economic impact assessment is conducted in relevance to the three stages of project: planning, construction, operation (Figure 4-9).

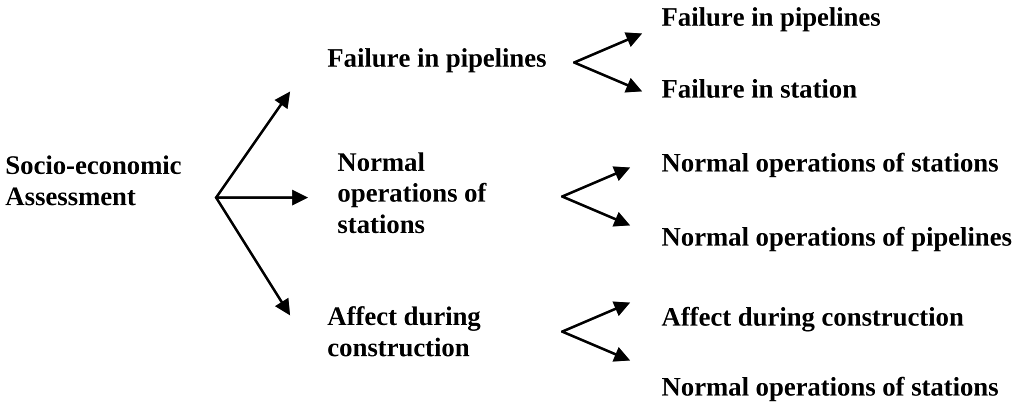

Figure 4-8 *Factors and sub-factors of socio-economic impact assessment* (modified from Dey, 2002)

At the planning stage the ROW (right of way) is required to acquire for construction, which often passes through agricultural land. It can determine payment of compensation for the land and provision of employment, alternative accommodation and other rehabilitation measures.

On the construction stage two socioeconomic issues should be addressed: the effect of employment generation and a new construction activity, which lead to an additional burden on local infrastructure facilities. Positive socio-economic impact is connected to the fact that the construction of new transport facility can induce substantial temporary employment. Negative impact can occur when construction activity involves movement of heavy vehicles, leading to disruption of other agriculture activities and local transport. The Operational stage of the project covers the whole period of “life” of the pipelines. However, there are no significant socio-economic impacts on this stage, because it does not generate additional employment or disruption of other infrastructure.

The main finding of this article can be expressed as follows. The problem of the current practice is that socio-economic impact assessment follows after the decision is made based on the financial and technical analysis. And actually, it purpose becomes to be just a mitigation of negative impacts of the chosen solution. Author proposes modification of the appraisal process in order to perform impact assessment simultaneously with technical and financial analysis.

After studying the main aspects of project appraisal in gas transportation, we can see how **particularly CBA** is applied, addressing again EU guidelines (2008).

According to the Guide, on the stage of project identification two issues are important:

1. To state its scale and dimension, accompanied by an analysis of the market where the product will be placed,
2. To describe the engineering features of the infrastructure with respect to:
    - *basic functional data*: nominal load and amount of gas transported annually by gas pipelines and storage capacity installed;
    - *physical features:* route and length of gas pipelines, nominal diameters of the gas pipelines;
    - characteristics of the network and location of internal nodes and links with pipelines;

- typical sections of the gas pipelines;
- technical features of the other service structures;
- *significant technical elements*: important intersections, overcoming large gradients, remote control and telecommunications systems (with data and sketches).

Feasibility and option analysis should take into consideration the demand for gas, seasonal and long-term trends; alternative routes for gas pipelines, various technologies (onshore, offshore) with respect to environmental and social factors.

On the stage of financial analysis inflows (fees for gas transportation, initial investments) and outflows (investment costs, operating costs) are considered. Investment costs include: spending for the design, land, construction and testing of the infrastructure, costs of the renewal of the short-life components. The maintenance and operating costs mainly comprise labour, materials and spare parts.

Environmental impact and risk assessment are essential aspects of economic analysis of gas infrastructure projects. Externalities to be considered are:

Benefits:

- transport capacity expansion which increases efficiency on the market and security of supply;
- positive regional impact due to stimulation of economic activity.

Costs:

- the negative externalities of possible impact on the environment (fishery in case of offshore pipelines) and on other infrastructure;
- the negative externalities due to the risk of accident.

Risk assessment in gas infrastructure projects are mainly connected to two critical factors: demand dynamics and operating costs. Uncertainty in investment decision should be handled through the following variables:

- Forecasts of growth rates;
- The dynamics of purchase prices of gas, conveyed by the transport infrastructure;
- The dynamics of the sale prices of substitutes gas.

5 EMPIRICAL ANALYSIS

This part of research is supposed to provide an overview of appraisal practices in electricity sector, aviation and natural gas transportation. It is based on governmental recommendations and practical examples from the sectors. The next subsection briefly describes the socio-economic appraisal framework provided by the Norwegian authorities to all the sectors. Then we present three case studies based on developed case-study protocol. The fifth subsection presents discussion of cases, their comparison and our findings.

5.1 Socio-economic appraisal framework

There are three main documents that provide a framework for the socio-economic analysis for all sectors in Norway:

1. NOU 1997: 27. Nytte-kostnadsanalyser. Prinsipper for lønnsomhetsvurderinger i offentlig sector;
2. NOU 1998: 16. Nytte-kostnadsanalyser. Veiledning i bruk av lønnsomhetsvurderinger i offentlig sector;
3. Veileder i samfunnsøkonomiske analyser. Finansdepartementet, 2005.

The last one is the most comprehensive and is based on previous two. It provides the general framework for the social analysis, which is based mainly on CBA (cost-effectiveness analysis and cost-impact analysis are also mentioned). There one can find recommendations for:

1. The structure of the appraisal;
2. The approaches to quantify and monetize social profitability of the projects;
3. The concepts of network effects, imperfect markets, the use of taxes;
4. Approaches how to deal with risks and uncertainty;
5. The evaluation of non-market goods as value of time and accident costs.

Then, an overview of socio-economic analysis in particular sectors is provided. There are direct references to the Handbook for socio-economic analysis of energy projects (“Samfunnsøkonomisk analyse av energiprosjekter”, published by the Norwegian Water Resources and Energy Directorate (NVE) in 2003) and to the Handbook for the socio-economic analysis of the projects in aviation (”Samfunnsmessige analyser innen luftfart. Samfunnsøkonomi og ringvirkninger”, developed by Møreforsking Molde AS and Transportøkonomisk Institutt in 2006). But there are no recommendations for impact assessment in petroleum sector in these Guidelines.

5.2 Case 1: Electricity

Handbook on social-economic analysis of energy projects

There is a handbook recommended for project evaluation in energy sector: “Samfunnsøkonomisk analyse av energiprosjekter”, developed by the Norwegian Water Resources and Energy Directorate (NVE) in 2003. The first part of the handbook gives general discretion of socio-economic analysis based on CBA: benefits and costs evaluation, NPV, benefit-cost ratio, CEA, difference between socio-economic analysis and financial analysis, dealing with uncertainty, discount rates, and quite large consideration devoted to environmental costs.

The second part discusses the practical implementation of socio-economic analysis in energy sector: production of electricity, power-line network solutions, heating energy, energy conservation measures.

The section devoted to the power-network solutions gives the following structure of appraisal.

1) **Project description and alternatives**

   The following items should be included in the description of the options:

– Geographical location;
– Existing consumer;
– Existing production;
– Existing supply facilities;
– Triggering the reason for the new measure;
– Current network level;
– Connection points in the network;
– Type of construction;
– Voltage Level;
– Thermal transmission;
– Null-alternative.

2) **Assumptions**

   The following prerequisites for the project should be specified:

– Physical life of the project;
– Analysis Period;

- Reference Time;
- Baseline scenario;
- Physical network limitations;
- Discount rate.

3) **Benefits**

   To calculate the benefit value of new transmission facilities, the following elements are to be evaluated:

- Annual reduction in interruption costs;
- Annual reduction in the costs of network losses and bottlenecks;
- Residual value of planned construction.

4) **Investment and operating costs**

   The cost of the planned transmission system consists of two elements:

- Investment costs;
- Operating and maintenance costs.

5) Summary and conclusion

   The calculation of net present value is assumed to define if the project is economically profitable. The interesting point here is that environmental assessment is not included into the NPV calculation. It is assumed to be evaluated in addition.

SIMA-SAMNANGER PROJECT

As it was stated above, to study the appraisal practice in energy sector we have chosen one of the recent projects, namely Sima-Samnanger project. In our analysis we used the latest comprehensive socio-economic analysis: "Rapport fra sjøkabelutredningen. Utvalg IV (1. februar 2011)" and article by Hervik et al (2011).

The central argument for a construction of new line between Sima and Samnanger was a security of supply in Bergen area. There are two main alternatives considered: concession line Sima-Samnanger and sea cable facility. The main reason of sea cable alternative consideration is the concession line is supposed to have significant negative impact on landscape around Hardanger fjord, which is one of the most attractive and famous fjord in Norway. The concession line touches several fjord districts: Sima, Osa, Ulvik, Granby, Klyve and Norheimsund. There are no crossings with the main arm of Hardanger fjord, but the concession line involves crossing of the fjord arms, specifically Osafjorden, Granby Lake and Fyksesund. Sea cable between Sima and Nordheimsund, in its turn, provides no landscape impacts, but it causes significant additional costs.

In addition to these two alternatives several others were considered. After discussion the following *list of alternatives* was included in the socio-economic analysis:

- Zero-alternative: concession line Sima-Samnanger;
- Sea cable between Sima and Norheimsund;
- Sima-Samnanger option 3.0 (north routes);
- Sima-Evanger;
- Sauda-Samnanger;
- Voltage upgrade of Sauda-Aurland with additional measures in production (reserve power plant or gas power).

Appraisal methodology

Socio-economic analysis of the project was performed according to the requirements of the NVE Guidelines and therefore based on cost-benefit approach. Because of impossibility to calculate WTP of critical impacts, the results of the analysis were performed in the form of comparison of costs and benefits.

Relevant impacts

All relevant impacts were divided into two parts: monetized (table 5-1) and non-monetized effects (table 5-2).

Table 5-1 *Overview of monetized impacts in socio-economic analysis of Sima-Samnanger project* (translated from Rapport fra sjøkabelutredningen. Utvalg IV)

Effects	Comments
Investment costs and operating costs for the main solution	Includes all major investments during the life-time of power line
Investment costs and operating costs for temporary solutions in a standby / construction period	Applies to all types of temporary measures conducted for network-, production-, or demand side (purchasing options for the reduction of consumption, for example)
Interruption costs measured by KILE	This is a change in interruption costs, that emerges as a result of investments in the measures mentioned above. It is primarily related to the failure of the various lines in the BKK-area.
Transmission losses	Changes in capacity of the lines determine changes in flow and transmission losses in the network as a whole. Flow losses of the new line

	are not considered.
Bottleneck costs	Capacity constraints in the network reduce the potential for imports to the BKK-area and export from the area. A new connection will reduce bottlenecks and thus reduce the costs.

Table 5-2 *Overview of non-monetized impacts in socio-economic analysis of Sima-Samnanger project* (translated from Rapport fra sjøkabelutredningen. Utvalg IV)

Effects	Comments
Security of supply	Covers the significance of the stability and reliability that is not captured by the monetized effects. It means an overall robustness of the system, not just the outcome and failures of a certain line. Both the efficiency and energy perspective can be relevant.
Nature and environmental impacts	Here is given an overall description of the nature, urban, and recreation areas that are affected and changed. In Statnett and NVE analysis were used the following dimensions: landscape, cultural heritage and cultural environment, recreation, environment, agriculture and forestry, tourism, conservation interests and intervention-free natural areas.
System and technical impacts	In this section includes positive and negative effects on power network, which are not taken into account in the numerical calculations or other non-priced effects. For example, flexibility for upgrades in the future or future investments that may be necessary. Consideration of an appropriate future overall network structure is included here.
Well-functioning power market	It relates to the size of the price areas, the impacts to effective competition etc.

Methods to monetize/quantify defined impacts

Interruption costs

Interruption costs were calculated by the methodology KILE (Kvalitetsjusterte inntektsrammer ved ikke levert energi), which means quality-adjusted income loss of not delivered energy, described in the Regulations for financial and technical reporting, income and tariffs for network operations (FOR 1999-03-11 nr 302). It is mentioned, however, that this methodology has several shortcomings, the emphasis were placed on the following two:

• Certain KILE values are subjects of substantial uncertainty with respect to the levels of values and understanding of the events referred to households and businesses.

• A number of consequences of interruptions are not directly taken into account in calculating the total KILE costs. This is especially true for the effects across different sectors, e.g. transportation: if a power failure interrupts the transport, it leads to losses and delays that are not captured by KILE calculations.

Security of supply

Security of supply (N-1 criteria) is the main purpose of Sima-Samnanger project. In the report, there is ROS-analysis Hordaland (2009) presented. There are three categories of electricity interruptions defined:

- Short power failure – up to 4 hours;
- Medium power failure – from 4 hours to 5 days;
- Long power failure – more than 5 days.

Failures for less than 4 hours have different consequences for the society. Such failures are likely to have no consequences for life and health, but some accidents and fatal cases may occur due to possible lack of mobile coverage and delays of emergency messages. It is known from experience that the probability of assault, burglary and vandalism increases the on streets without light. The food industry is dependent on electricity for both production and storage of refrigerated goods; and even less power cut will lead to the stoppage of all production with consequent large economic losses. For oil and gas production and other process industries power failure can lead to economic consequences that can exceed the amount of NOK 500 million. Fluctuations in pressure and temperature in the processing plant due to power failure, can lead to fires and leaks, and thus have consequences for the lives, health and the environment. The consequences, however, assessed as moderate.

The consequences of medium-long power failures, from 4 hours to 5 days, can be significant in winter period. Especially vulnerable are those living in homes with no other heat source than electricity, which often occurs in cities and towns. A power failure with duration about 12 hours could lead to health effects and deaths for the sick and elderly. Consequences are also connected to results of lack of contact with fire stations, police and healthcare. Because of limited communication possibilities, transport services as aviation, ferry, railways can also be effected. Businesses that use water in production will suffer financial loss. In case of power failure over 5 days, banks have to close and that situation could have serious economic consequences for society.

Nature and environmental impacts

Special attention is paid to socio-economic impacts related to environment and landscape, as it was the main argument against concession line Sima-Samnanger. Each of the six alternatives was evaluated from the perspectives of: landscape, outdoor recreation, cultural heritage and cultural environment, tourism and conservation interests, and intervention-free natural areas. Then alternatives were ranked according to each criterion.

Beautiful landscape and cultural environment are examples of public goods. In estimations of public goods willingness-to-pay or willingness-to-accept should be used. Environmental conflicts around Sima-Samnanger project relates primarily to the aesthetic impact of exposed high voltage wires. The areas affected are mainly interior villages in Hardanger, located in the side arms of the Hardangerfjord and the mountains and forests around them, while the pipeline route in some places will be visible from the Hardangerfjord. The landscape around the side arms of the fjord is a regional public good for those who live and travel in the area. The main arm of the Hardangerfjord is considered as a national symbol and therefore is a public good for the whole population. But the evaluation of environmental goods and natural resources in cost-benefit analysis is a complicated and controversial issue. There are several methods developed to measure WTP for this kind of goods. In the absence of resources to implement custom analysis of a given investment project, it is recommended to use national studies with as close as possible problem. For Sima-Samnanger project, there was found only one comparable Norwegian study: a study of the appreciation of the aesthetic effects of power lines between Namsos and Roan (2009). However, there were grounds to believe that a positive willingness to pay exists.

In the result the economic burden of choosing the most environmentally friendly alternative was estimated for the relevant customer groups. Considering the environment as a national public good, the additional costs of around 3.4 billion were evenly distributed throughout the population and the result was: about NOK 90 per household per year for 35 years. Considering the environment as a regional public good, the additional costs were distributed throughout the residents of Hordaland; the result was: approximately NOK 1000 per household per year for 35 years.

System and technical impacts

System and technical impacts of the project are connected to the time of the project implementation. There are many factors that determine the need for upgrading and/or capacity increase of the network in western Norway, e.g. establishment of production facilities that require a network connection, the network's age structure and other major planned grid investments, such as new power cables to other countries; some political objectives, as the recent agreement with Sweden on the establishment of a common market for green certificates. According to NVE's mapping of the potential for small hydropower plants in Norway, Sogn and Fjordane have the greatest potential for increased small-scale power production. Triggering of this potential is considered to be profitable even without government support, and is highly dependent on investments in the network. Due to these factors, solutions that are realized earlier can provide larger positive impact than projects realized later in time.

Well-functioning power market

Wholesale prices of electricity are determined on the Nordic power exchange NordPool, and these prices are affected by transmission capacity of the network. The Norwegian market has been mainly divided into two geographical areas - south and north, but existing bottlenecks in the network determined changes in this division: there are five price areas today. Because of different transmission capacity between price areas, there are different prices for electricity in these areas; but without such constraints, prices would be the same. Price difference determines distributional consequences and creates competitive disadvantage for businesses in the area with relatively higher prices for electricity. It can be avoided if transmission bottlenecks are eliminated, but it also can have negative consequences as overinvestment and waste of society's resources. That is why measures directed to consumption and production efficiency can be more economically profitable than new infrastructure investments.

Decision criteria used in evaluation

As it was mentioned before not all the impacts were monetized, that is why it was impossible to calculate common criteria as NPV, benefit-cost ratio or IRR. The results of the analysis were presented in the form of comparison of zero-alternative with five others.

The comparison criteria are: calculated investment costs, construction period and two critical impacts: security of supply and environment effects (table 5-3).

Table 5-3 *Comparison of alternatives in Sima-Samnanger project* (Translated from Rapport fra sjøkabelutredningen. Utvalg IV)

Alternative	Investment cost	Construction period (readiness)	Security of supply	Environment
Concession line	1100 mill	2012	Acceptable	Bad
Sea cable	Additional cost 3400 mill + consequential costs	+5 years	Acceptable	Better
Sauda-Aurland (reserve power plant and upgrade)	Additional cost 2-3 mill	+6-10 years	Worse	Better
Sauda-Aurland (gas power and upgrade)	Additional cost 1000 mill + higher costs because gas power is not commercially profitable	+6-8 years	Worse	Better/worse
Sima-Samnanger 3.0	0	+1-2 years	Acceptable	worse/ the same
Sima-Evanger	Additional cost 100 mill	+5-8 years	Acceptable	the same
Sauda-Samnanger	Additional cost 200 mill	+5-8 years	Worse	the same/worse

Concession line and sea cable have the same acceptable level of supply security, but sea cable causes significantly higher investment costs and higher interruption costs, while concession line has negative environmental impact. Due to these facts these two alternatives cannot be ranked without estimation of WTP for environmental goods in considered area. Other evaluated alternatives had worse level of supply security or the same or more negative environmental impacts; however, alternative Sima-Samnanger 3.0 and upgraded Sauda-Aurland were discussed.

The final decision on Sima-Samnanger project has already been made and the most cost efficient alternative (concession line) was chosen, based on the assumption that implicit costs of sea cable solution can be significant.

In the end of the study of appraisal practice in electricity supply we would like to make a remark. In the considered Sima-Samnanger project we do not find a **sensitivity analysis** in its common form because of specificity of the project and its impacts. But on practice it is implemented, e.g. socio-economic analysis of NorNed (600 MW cable connection between

Norway and the Netherlands) included sensitivity analysis based on three critic items: trading income, investment costs and discount rate.

5.3 Case 2: Aviation

Handbook on social analysis in aviation

There is a handbook for social analysis in Norwegian aviation:"Samfunnsmessige analyser innen luftfart. Samfunnsøkonomi og ringvirkninger" (2006), which was developed by Møreforsking Molde AS og Transportøkonomisk Institutt. It consists of two volumes: a methodological guide and a collection of examples. As it stated in the guide, the recommendations on how socio-economic analysis and regional impact assessment should be implemented are linked to the Ministry of Finance guidelines on socio-economic analysis (Veileder i samfunnsøkonomiske analyser. Finansdepartementet, 2005).

The first volume of the handbook contains manuals for how cost-benefit analysis and regional economic assessment (REA) should be implemented for projects within Norwegian Civil Aviation; it consists of the CBA and REA theory, methodology and some important technical issues as factor prices for travel value, noise, emissions, changes in accident risks.

The second volume includes six examples of CBA and REA implementation: three socio-economic analyses of introducing of the instrumental landing system, extension of capacity at Bergen airport and analysis of a regional airport; regional impact assessment of the extension of Bergen airport capacity, airport Gardermoen and catalytic effects of Molde airport.

EXPANSION OF BERGEN AIRPORT FLESLAND

As an example of appraisal practice in Norwegian aviation we took the plan of capacity extension of Bergen Airport, Flesland. Master plan included three parts: investment analysis, socio-economic analysis and regional impact assessment. We studied the document, issued by Møreforskning Molde AS in 2005, "En samfunnsmessig analyse av behovet for videreutvikling av Bergen Lufthavn, Flesland", which presents socio-economic impacts and regional impacts of avoiding capacity shortages at Bergen Airport, Flesland. The example presents an economic analysis of capacity expansion to avoid the limitations on the number of aircraft movements and number of passengers as well as unnecessary delays due to capacity problems in a regular scheduled air space.

Airport in Bergen is Norway's second largest airport in terms of number of passengers. It is expected that traffic growth will create a need for increased capacity in next few decade. The main purpose of the socio-economic analysis is to determine the social costs that can be expected if the capacity of the airport is not increased. These social casts are mainly related to additional costs for users: they will have to change the time of travel or a mode of transport or even refuse from travelling.

To assess this costs the list of travel alternatives was defined.

Table 5-4 *Alternative solutions for Bergen airport capacity extension* (translated from En samfunnsmessig analyse av behovet for videreutvikling av Bergen Lufthavn, Flesland)

Destination	Major alternatives to Bergen airport
Oslo	1. Car, bus or fast boat and flight via Haugesund 2. Car or bus over the mountains 3. Train
Trondheim (also as a hub for other domestic destinations)	1. Car, bus or fast boat and flight via Haugesund
Stavanger	1. Car 2. Fast boat 3. Bus
Kristiansand	1. Car, bus or fast boat and flight via Haugesund
All international flights	1. Car, bus or fast boat and flight via Haugesund

The construction of possible alternatives is based on the assumption that if Bergen airport capacity is not increased, the Haugesund airport will serve as a relief airport. In addition, alternative modes of transport such as cars, trains and fast boats were considered. Transportation costs at the cheapest route were assumed when calculating the additional costs to passengers on different routes.

Appraisal methodology

As it is proposed by the Handbook, appraisal methodology of Avinor is based on CBA and REA. Social analysis of capacity expansion of Bergen airport was conducted exactly according to the recommendations. It includes two independent parts: socio-economic analysis, based on CBA, and regional impact assessment carried out according to one of the proposed methodologies.

Relevant impacts

The most important economic effects of projects within aviation are:

- Changes in generalized travel costs;
- Environmental costs like noise and emissions;
- Effects on safety;
- Investment and operation costs.

As it stated in the Handbook, these economic impacts should be calculated for four effected groups:

1) *Passengers:* costs of alternative transport, no. of passengers deterred, changes in accident risk, costs of delays;
2) *Operators* (airlines): time costs and operating costs, cost of delays, accident costs;
3) *AVINOR*: investment costs, operating costs;
4) *Third parties*: environment costs.

In socio-economic analysis of Bergen airport expansion, relevant impacts were defined as follows:

- Value of avoiding capacity problems (for business travels and other travels);
- Avoided delays (for passengers and operators);
- Accident costs;
- Emissions;
- Investment costs for Avinor.

Methods to monetize/quantify defined impacts

To estimate **additional costs** (as a value of avoiding capacity problems) for passenger, the area around Bergen was divided into 4 zones, which indicate critical start and target points for the area around the airport. Travel costs, costs of delay due to capacity limits and costs of tickets, were calculated from each of these zones to the airport. The total cost of cheapest alternative transportation was calculated for the same start and target points. The difference between these costs is the additional costs that passengers should pay if the capacity of Bergen airport is not extended. Total benefits of capacity extension for passengers were calculated as a product of generalized costs difference and traffic volumes, both for the transferred and deterred traffic.

Important issue in all transport project evaluation is a **travel time** monetization. In this project, the latest international studies were used to put values for business travel time and private travel time. Adjusted to 2005 NOK, it was NOK 242 and 209 correspondingly.

Value of avoided delays was estimated for 5 minutes for 5% of passengers. This loss of time has gained weight 1.5 due to unforeseen time use.

Investment cost, calculated in Master plan, was discounted with rates 10% and also 6%.

Calculation of **emissions** is based on the assumption that there will be fewer aircraft movements from Bergen airport if the planned capacity expansion is not undertaken. It will lead to the increase in movements from and to Haugesund airport and an increase in road transport. The flights from HAU are about the same length as that from BGO, and changes in emission costs from the transferred flights can be disregarded. Using statistics of aircraft movements and number of passengers arrived/gone, the number of additional aircraft movements that are needed to liquidate the rejected and transmitted traffic, was calculated as a basis for calculating the total emissions (CO_2, NO_x and other particles).

Changes in **accident costs** were calculated as the value of avoided accidents by expansion of Bergen airport, because traffic is not transmitted to the road network or other transport with higher accident rate. Number of car accidents (0,19 pr.mill on overage speed 70 km/h) was set as recommended by Norwegian Public Roads Administration Handbook 140. Analysts use an average value per. avoided injury accident at 3.7 million (2005 Kr.).

Avinor’s income was also calculated, although it should not be included in socio-economic analysis, but it gives additional information about project’s benefits. It was estimated as possible loss of income if capacity is not extended.

Decision criteria used in evaluation

Table 5-5 shows the results of cost-benefit analysis and revenue analysis for Avinor. All impacts are discounted for two rates: 6% and 10%.

Table 5-5 *Economic effects of Bergen airport capacity extension* (translated from En samfunnsmessig analyse av behovet for videreutvikling av Bergen Lufthavn, Flesland)

Socio-economic impacts		
Impacts	Discounted values	
	rate 6%	rate 10%
Value of avoiding capacity problems – business travels – - other travels	1472 960 512	2700 1761 939
Avoided delays for passengers and airlines	56	83
Accident Costs	420	780
Emissions to air	- 31	-56
Investment cost for Avinor	-470	-550
Net present value	***1447***	***2957***
Avinor's income		
Income increase	400	800

The main investment criteria, NPV, were calculated to be positive. Benefit-cost ratio or any other criteria were not calculated.

Network effects

As it recommended in the Guidelines, **network effects** to be considered in large projects within aviation are:

- Rearrangements of the airport structure;
- Rearrangement of ATM (Air Traffic Management) services:
  - Changes in travel costs in the air network;
  - Changes in operation costs for NCAA and the airlines;
- Measures affecting other transport modes:
  - Changes in travel costs for other modes.

In the considered analysis network effects were not calculated due to two reasons: airlines' costs are highly uncertain to estimate and these affects can be spread outside the state boundaries.

Regional impacts

The analysis of **regional impacts** is a conducted as a separate part of the appraisal. It examines what is the dependence between change in transportation costs and regional development. There are four groups of affects defined:

- *Direct effects*, related to the airport itself;
- *Indirect effects*, or second-order effects, which captures effects on subcontracting and supporting functions directly connected to air traffic.
- *Induced effects*, or third-order effects, which are related to the activities determined by the direct and indirect effects: local effects, including new establishments.
- *Catalytic effects*, or fourth-order effects, which include effects on industrial activity and public sector related to the airport users, subcontractors, suppliers and other airport services.

The Handbook suggests three methods to evaluate these affects:

- Use of results of other studies;
- Calculation of direct, indirect and induced effects with PANDA, which is marked as preferable;
- Direct mapping of catalytic effects, which is used mainly for large projects, as airport at Gardermoen; in addition it requires calculation of direct, indirect and induced effects.

In regional impact assessment of the considered project analysts used model PANDA (Plan- og Analysemodell for Næring, Demografi og Arbeidsmarked) and empirical data from international and domestic projects to estimate effects on employment and production output in Hordaland region, where airport Flesland is situated. Thorough and detailed description of possible regional impacts was presented.

Robustness of analysis, sensitivity analysis

Even with some limitations in impact assessment, conducted analysis was characterized as robust. However, there are some factors that may affect the calculations. For example, possible increase in operating costs in the transport network, if BGO is not upgraded, was not included. This could increase the benefits further. On the other hand, increase in airplane operation expenses of carrying out master plan (to operate the rejected traffic and traffic transferred to other transport) was not included. If these costs are substantial (and they occur within the country), it could decrease benefits. Sensitivity analysis or scenario analysis were not performed for this project. But it should be mentioned that in common appraisal practice in aviation it is used to assess risk and uncertainty.

5.4 Case 3: Natural gas

Appraisal methodology

There is no handbook for socio-economic analysis of projects in petroleum sector. The only document, that sheds light on the requirements for companies to project appraisal in gas transport infrastructure development is "Guidelines for plan for development and operation of a petroleum deposit (PDO) and plan for installation and operation of facilities for transport and utilization of petroleum (PIO)" (2010). The difference between PIO and PDO is explained in Chapter 2. Both PIO and PDO consist of two parts, the first one is impact assessment (IA) and the second one is development section for PDO and installation section of PIO. Pursuing the purposes of this research we are mainly interested in PIO. Requirements to impact assessment and installation section of PIO provided in the Guidelines give us us common understanding of the appraisal scheme in gas infrastructure development.

In the **installation section** (chapter 4 of Guidelines) mainly includes technical and financial analysis of the project. Although, as it stated in the Guidelines, such issues as: basic decision criteria, with focus on HSE, economy and technology and regional effects, including evaluation of landing and localization, "should be mentioned" in this section. Special attention in technical analysis is given to *tie-in of the development to other fields or facilities* and *possibility of tie-in to the development from other fields and/or pipelines.* This issue is of the main importance for the integration of planning infrastructure to the existing network in the most efficient way.

Cost side of financial analysis consists of investment costs and operation costs. *Investment costs* should be calculated in accordance with NORSOK standard Z-014. Operating costs should include a separate consideration for CO_2 tax and NO_x tax. Cost estimates shall be presented as an expected value, with 90% confidence levels.

Financial analysis should also present sensitivity analyses to reflect the project's range of uncertainty. The methodology of risk assessment is not clearly defined in the Guidelines and is supposed to be chosen by the analysts. The results of financial analysis should be presented as a set of criteria: net present value, a break-even tariff and internal rate of return (calculated before and after tax).

Chapter 3 of the Guidelines provides information about **impact assessment** section of PIO and PDO. “The purpose of the impact assessments is to clarify the effects of a development/installation and the operation of same on the environment, including cultural monuments and cultural milieus, natural resources and the society in general” (Guidelines for PIO and PDO, p. 24).

There is a separation between field-specific impact assessment and regional impact assessment. Together these two studies should fulfil all requirements to IA section of PIO. Regional impact assessment is particularly relevant where multiple developments are planned in the same area. It is supposed to provide a more comprehensive of the environmental effects in the area. But more important is FIA and RIA is required as a background for FIA or in cases where it is really significant for final decision making. FIA in combination with relevant RIA should:

- describe the plans for the installation and the effects they could have on the environment, natural resources and the society;
- discuss the significant positive and negative consequences that are supposed to be caused by facility installation and operation;
- discuss remedial measures, as well as propose any necessary follow-up studies and monitoring programmes.

Before the performing the IA, a study programme should be submitted and discussed with MPE. This study programme is a point of departure for the completing of IA, which actually present assessment of socio-economic effects. Factors that are to be evaluated in FIA can be presented in the list:

- Effect on environmental factors: discharges to sea and soil, emissions to air; material assets, including natural resources and cultural monuments, that may be affected as a consequence of the development; environmental consequences for animal and plant life in the sea areas and along the coastline; significant transboundary environmental effect.

- The volume of energy required and the costs associated with supplying the facility with power.
- Costs of possible reinjecting CO_2 from produced gas, turbines and other facilities. NOx reduction measures should also be considered.
- Expected discharges from ship traffic and affects on fishery industry in connection with the activities on the NCS.
- Regional economic impacts, if they are significant: for business and industry, including planned operations and base services in local and regional scope. Expected employment effects on local, regional and national level, and possible different consequences for women and men should be considered.
- The influence of project implementation on social planning in the local community should be also taking into account.

As we see this, the appraisal process is organized in such a way, that alternative solutions are considered only in installation section. In the IA only a chosen solution is evaluated. We can say that, the part of project appraisal, which mostly includes social impacts, is applied to the already decided solution. In fact, this observation corresponds to the findings in article by Dey (2002) discussed in section 4.3.3 “Gas transport infrastructure impact assessment”. If we look at this practice from the point of view of cost-benefit approach, we can see that benefits of the potential solution are considered only in technical and financial analysis, while impact assessment part mainly presents cost side of socio-economic evaluation. Actually, IA part pursues to find measures to reduce negative impacts of the chosen solution. The shortcoming of this approach is that significant social benefits can be neglected in decision making.

As it was mentioned above, these requirements for project appraisal are given to oil and gas companies, who apply for the license for new petroleum deposit development or facility installation. These companies have primarily financial interest from their activities. Gassco’s role is to present public interest in petroleum industry on the NCS. And actually, that is Gassco’s task to make a proper socio-economic evaluation of the infrastructure development project, and to define what benefits Norwegian society can gain from one particular solution implementation in comparison with another. But as we highlighted before, there is no any established appraisal procedure for Gassco or, at least, a predefined set of impacts that should be taken into consideration. Social impacts that might not be considered by the companies in their PIO and PDO present particular interest. In the next subsection we try to define benefits that might be taken into consideration particularly in Luva project.

LUVA PROJECT

The purpose of this project is to find a solution to connect new fields in the Norwegian Sea to processing facilities (Figure 5-1). The biggest discovered field there is Luva, operated by Statoil, which gas reserves are estimated to be of 40-60 billion standard cubic metres (scm), it is planned to be operated from 2016 (Reuters). Found solution can also provide evacuation of gas from other fields under development, including Linnorm field (renamed from Onyx), operated by Shell. Evaluations conducted by Gassco will be used for investment decision made by an oil and gas company and for the authorities' (MPE, NPD etc.) approval of PIO (Lohne, 2010).

Figure 5-1 *Fields in the Norwegian Sea* (Source: T.O. Lohne on Workshop 17 December, 2010, Molde)

Possible solutions are related to several points. There are three alternative existing gas landing points: Norland, Tjeldbergodden and Nyhamna (Figure 5-2). And there are two existing export pipelines: Åsgard Transport and Langeled (from Nyhamna). There is also possibility of combination of pipeline transport and LNG (liquefied natural gas) solutions. Special consideration was also given to export solutions, because that volume of gas exceeds domestic demand. Solutions should be evaluated from two perspectives: a need for gas evacuation from discoveries and existing fields and general considerations with respect to the optimization of existing infrastructure network and possibility for gas evacuation solutions for future discovered gas resources in the area.

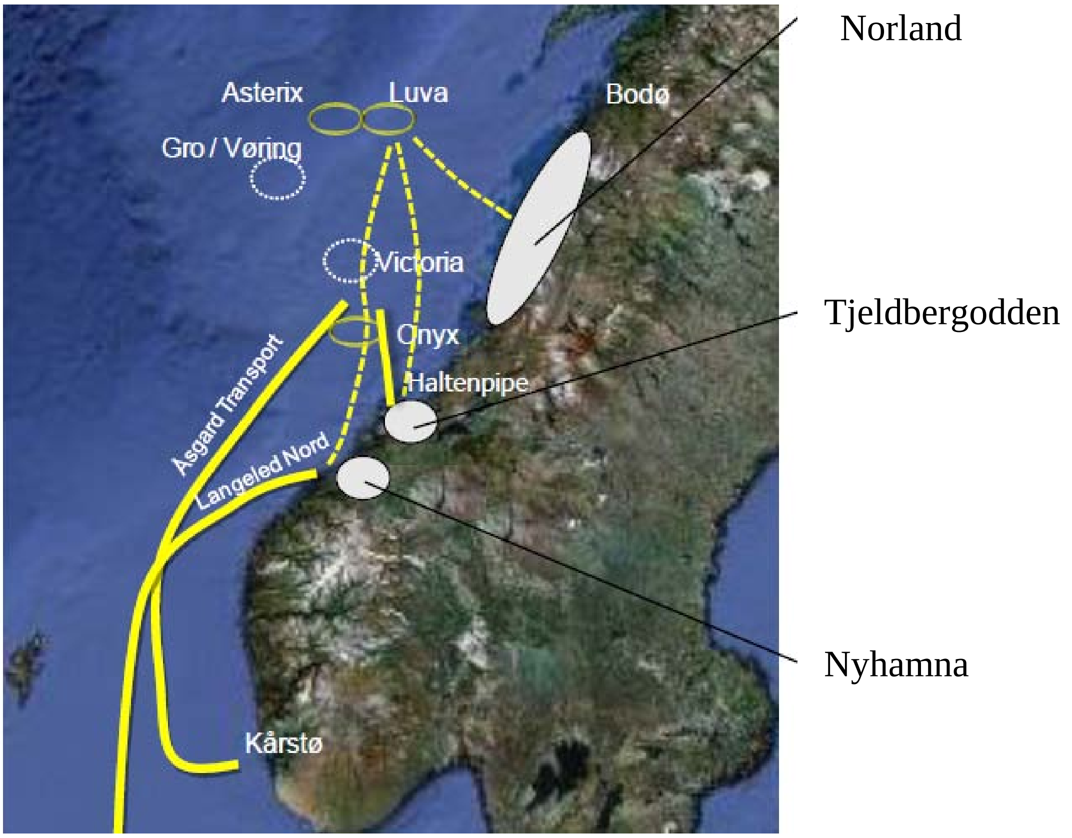

Figure 5-2 *Gas landing points for gas evacuation solutions in the Norwegian Sea* (Source: Lohne, 2010)

Connection of Luva field to the landing point in **Norland** has the major benefit related to close proximity of landing facilities to the operated field. There are two possible landing solutions: LNG or further connection to Nyhamna and transportation to Britain through Langeled. Capital cost of a pipeline to Norland and LNG to markets was estimated 65 bn NOK, for the pipeline to Norland and pipeline to Nyhamna – 25 bn NOK.

The main issue related to the second landing point, **Tjeldbergodden**, is the fact that domestic demand for gas is insufficient to use all evacuated gas. And, even if domestic demand in the area increases, it can be saturated by existing Haltenpipe from Heidrun field. Possible export solutions are the same as for Norland. But in this case direct transport solution to Nyhamna is considered to be more suitable.

Solution with direct pipeline to **Nyhamna** is attractive because of available spare capacity at Nyhamna and Langeled. Estimated capital cost of this solution is 10 bn NOK, and this solution is the most cost efficient. This alternative gives also possibility of a combined solution – connection of Linnorm field to Luva and a tie-in to Åsgard Transport (Figure 5-3). Tie-in to Åsgard Transport has positive aspects as flexibility in capacity utilization and market flexibility.

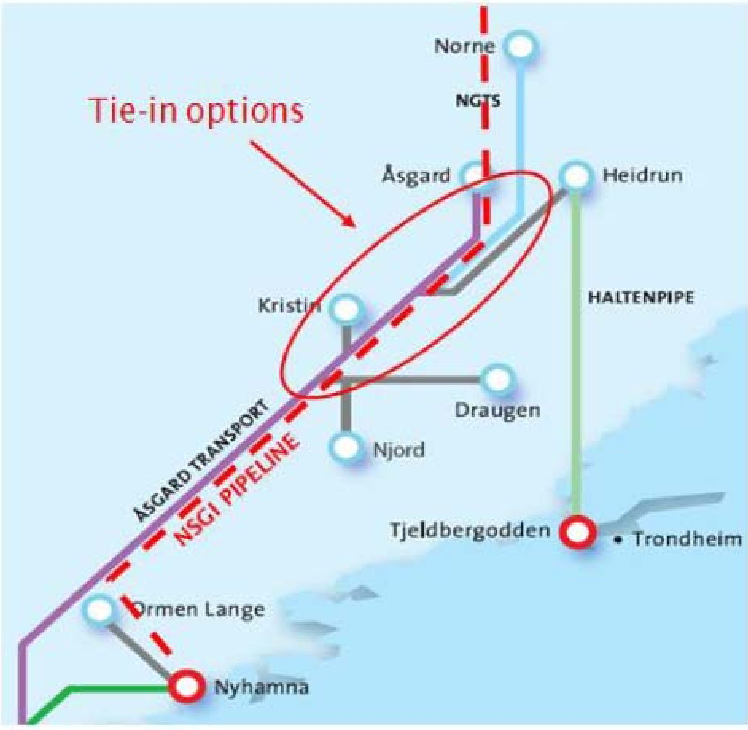

Figure 5-3 *Tie-in options for Luva project* (Source: Lohne, 2010)

Nyhamna solution gives a set of possible benefits both for companies and for Norwegian society and this solution is preferred by Gassco at the moment. We did not found any official documentation on Luva project appraisal. But based on available data from seminars presentations (JazzGass, 20 July 2010, Molde), some communication with Gassco representative (Sten Arve Aide), we developed a set of benefits that might be considered in project evaluation.

Benefits of Nyhamna solution

(1) Integration of two fields, Luva and Linnorm, and its connection to Langeled pipeline system (Langeled North, LLN) can benefit from utilization of existing spare capacity of transport facilities in Langeled. Performed analysis shows that joint development is more efficient that stand alone developments (Gassco, S.A. Aide). Technical plan of this solution is presented on figure 5-4.

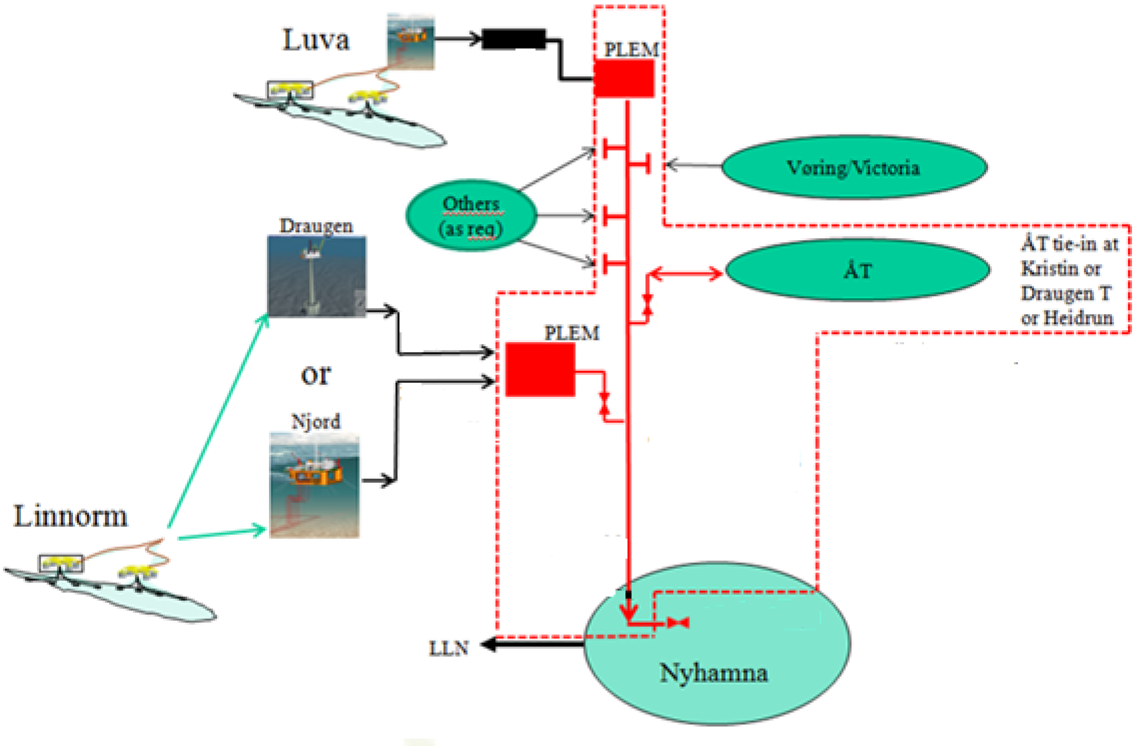

Figure 5-4 *Solution for the Norwegian Sea* (Source: Lohne, 2010)

(2) Investing in a hub can be considered from the point of security of supply. Tie-in of third party gas will improve security of supply from Nyhamna. Going from Nyhamna, further LLN is connected to the Sleipner node which is connected to several exit points in Gassled Area D (Figure 5-5). Therefore, the hub solution will provide significant additional market flexibility.

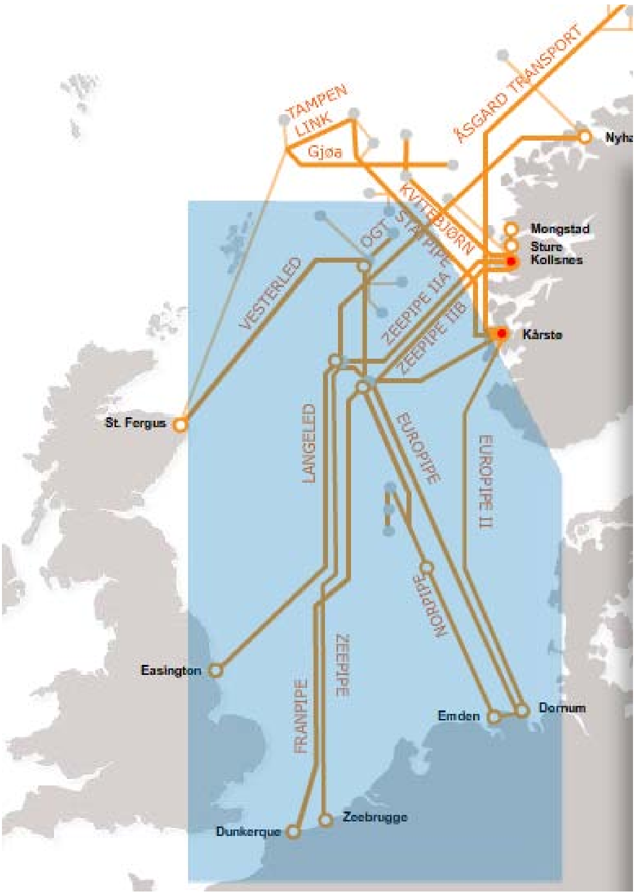

Figure 5-5 *Gassled Area D, Langeled pipeline* (Source: www.gassco.no, Gassled tariff areas)

(3) One more beneficial side of investing in a hub is a possibility to blend gas from different fields in order to achieve required level of CO_2 content and avoid additional investment costs to refinery facilities. This issue was evaluated by Gassco, gas from Linnorm and Zidane can be blended with the gas from Luva/Asterix and Ormen Lange.

Important aspect of gas infrastructure development solutions is specification of its capacity. Capacity and associated economics of scale evaluations is an important part of the scope for the project. Gassco performs evaluations of the volume basis including potential upside volumes; and different pipeline capacities are evaluated in order to find the most optimal capacity that corresponds to the capacity of LLN. Decision to built transport facilities with capacity larger than needed can provide three types of benefits.

(4) A benefit from spare capacity availability is a possibility of more cost efficient connection of new discovered fields in the area to existing transport facilities. Potential upside volumes is the main reason for evaluation possible pre-investments in pipeline capacity. In fact, even the selection of the Nyhamna solution is possible due to the pre-

investment in pipeline capacity in Langeled North (LLN) up to 84 MSm^3/d in combination with the fact that the Ormen Lange field will go off plateau in some years.

(5) One more benefit is that availability of spare capacity means decrease of transportation costs in long run and as a result, increase in total turnover of gas in transport system. It leads to increased income from transport network on the NCS, taxes and in general – benefits for Norwegian society.

(6) Another benefit of a higher pipeline dimension than needed at the time is a reduced need for pressure at the inlet of the pipeline due to the reduced pressure drop in high dimension pipelines.

(7) Alternative solutions for gas transportation should also be evaluated from the perspective of their environmental impacts. Choice of the solution with lower environmental costs (onshore and offshore) can also be seen as a benefit. But on practice, importance of this issue is underweighted and much attention is given to these evaluations.

(8) As it known from practice, infrastructure development can have significant impact on onshore regional development. Regional impact assessment of certain projects can discover additional significant benefits for society. In current project considerations are related to the region where Nyhamna is situated – Møre og Romsdal.

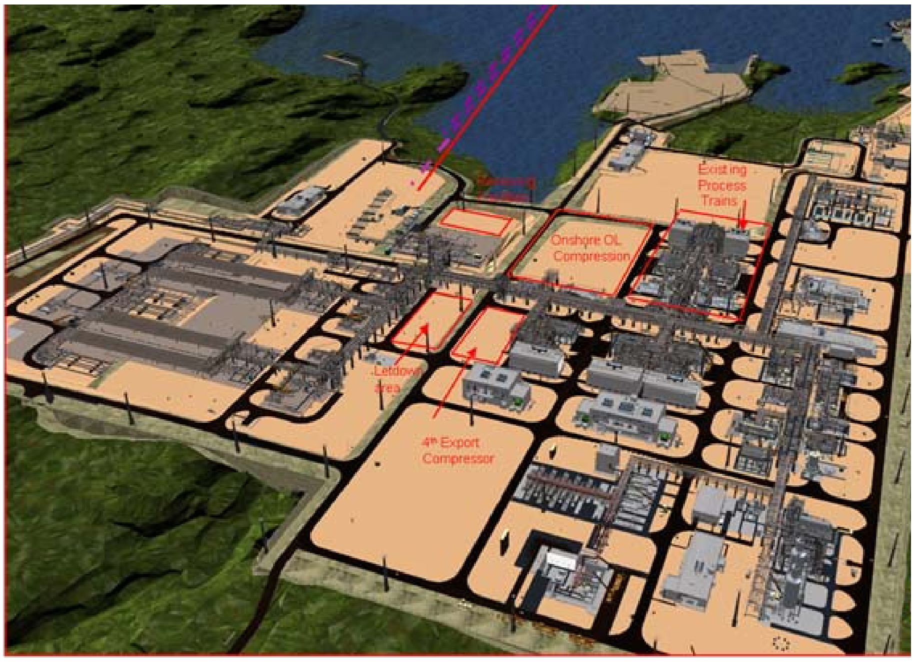

Figure 5-6 *Nyhamna – overview of potential modification* (Source: T.O. Lohne, Workshop, 17.12.2010, Molde)

As it is seen from the figure, implementation of the hub solution assumes modification of Nyhamna and additional investments, which can influence regional economic development through the possible change of employment, use of other infrastructure in the region.

Due to absence of established methodology for socio-economic analysis in gas infrastructure development and lack of comprehensive documental evidence on project appraisal, we cannot make evaluation of the case according to all criteria, developed in case study protocol, as sensitivity analysis, robustness of analysis, decision criteria. But we can make some remarks on these issues. Sensitivity analysis of the projects in natural gas sector can be based on such critical factors as discount rate and price and demand for natural gas. We cannot exactly define what decision criteria is used in the project evaluation, but in general current practice can be defined as cost-efficiency approach.

5.5 Findings and discussion

Chosen research methodology assumes comparison of cases. The basis of the comparison is the set of case study questions, presented in Chapter 3. We discuss these questions in turn, to define commonalities and differences between cases and summarize our findings in the table 5-6. Then we explain the nature of the defined characteristics of appraisal and give some suggestions.

Are there any established or recommended appraisal methods in the sector?

There is a handbook for social analysis in Norwegian aviation: ”Samfunnsmessige analyser innen luftfart. Samfunnsøkonomi og ringvirkninger” (2006), which was developed by Møreforsking Molde AS og Transportøkonomisk Institutt. And there is also a handbook recommended for project evaluation in energy sector: “Samfunnsøkonomisk analyse av energiprosjekter”, developed by the Norwegian Water Resources and Energy Directorate (NVE) in 2003. Both these books are are linked to the Ministry of Finance guidelines on socio-economic analysis (Veileder i samfunnsøkonomiske analyser. Finansdepartementet, 2005).

Methodology proposed in these books is mainly based on cost-benefit analysis, but have some important differences. The scope of NVE handbook is quite wider; it comprises socio-economic analysis in the whole energy sector and provides examples of projects of different nature: production of electricity, power-line network solutions, heating energy,

energy conservation measures etc. While handbook in aviation is more specific and gives more detailed description of social analysis of projects. Important feature of the aviation handbook is description of regional impact assessment and its approaches. These two handbooks are directly used by Statnett and Avinor in their appraisal practices.

Petroleum sector has no such handbook. But there is a set of requirements for project evaluation documented in the Guidelines for PIO and PDO. These Guidelines give only requirements on what should be assessed, but do not recommend any methodological tool. But, in fact, these recommendations are not referred to Gassco; they are relevant only to the companies, who apply for the license for new petroleum deposit development or facility installation.

What appraisal methods are used in economic impact assessment?

According to the requirements of the handbooks, socio-economic analysis of Sima-Samnanger project and expansion of Bergen airport is based on cost-benefit analysis. In the evaluation of the Avinor's project, regional impact assessment was also performed. As there is no established methodology of socio-economic analysis used in gas infrastructure development, there is also no recommended tool. Taking into account nature of the projects in this sector, scope and importance of social impacts of the projects implementation, methodology of CBA is appropriate for the evaluation of gas infrastructure development and can be a good basis for decision making.

What impacts are evaluated?

Statnett. In the NVE book the list of impacts of new transmission facilities are rather short, investment and operating costs and benefits as: annual reduction in interruption costs, annual reduction in the costs of network losses and bottlenecks, residual value of planned construction.

In the Sima-Samnanger project this list was substantially extended. The group of monetized effects includes:

- Investment costs and operating costs of the main solution. Includes all major investments during the life-time of power line;
- Investment costs and operating costs for temporary solutions in a standby / construction period;

- A change in interruption costs, that emerges as a result of investments. It is primarily related to the failure of the various lines in the considered area. Was measured by KILE;
- Transmission losses. Changes in capacity of the lines determine changes in flow and transmission losses in the network as a whole.
- Bottleneck costs. Capacity constraints in the network reduce the potential for imports to the area and export from the area. A new connection reduces bottlenecks and thus reduces the costs.

The list of non-monetized impacts includes:

- Security of supply. Covers the significance of the stability and reliability that is not captured by the monetized effects.
- Nature and environmental impacts. The following dimensions were used: landscape, cultural heritage and cultural environment, recreation, environment, agriculture and forestry, tourism, conservation interests and intervention-free natural areas.
- System and technical impacts. Includes positive and negative effects on power network, which are not taken into account in the numerical calculations or other non-priced effects. For example, flexibility for upgrades in the future or future investments that may be necessary. Consideration of an appropriate future overall network structure is included here.
- Well-functioning power market. It relates to the size of the price areas, the impacts to effective competition etc.

Avinor. The most important economic effects of projects within aviation are: changes in generalized travel costs, environmental costs like noise and emissions, effects on safety, investment and operation costs. In application to the socio-economic analysis of Bergen airport expansion the following relevant impacts were defined:

- Value of avoiding capacity problems (for business travels and other travels);
- Avoided delays (for passengers and operators);
- Accident costs;
- Emissions;
- Investment costs for Avinor.

Feature of this analysis is that effected groups and impacts to them were clearly defined according to the Handbook:

1) *Passengers:* costs of alternative transport, no. of passengers deterred, changes in accident risk, costs of delays;
2) *Operators* (airlines): time costs and operating costs, cost of delays, accident costs;
3) *AVINOR*: investment costs, operating costs;
4) *Third parties*: environment costs.

Gassco. As it was mentioned before, because of the lack of final reports of project evaluation, we composed the approximate list of relevant benefits of Nyhamna solution:

- Utilization of spare capacity due to the integration of two fields, Luva and Linnorm, and its connection to Langeled pipeline system.
- Security of supply. Investing in a hub and a tie-in of third party gas will improve security of supply from Nyhamna.
- Reduction costs of refinery facilities. Gas from Linnorm and Zidane can be blended with the gas from Luva/Asterix and Ormen Lange to achieve required level of CO2 content and avoid additional investment costs to refinery facilities.
- Possibility of more cost efficient connection of new discovered fields in the area to existing transport facilities with pre-invested spare capacity.
- Reduction of transportation costs in long run due to the availability of spare capacity and as a result, increased income from transport network on the NCS.
- Energy cost savings in case of a higher pipeline dimension than needed, as there is a reduced need for pressure at the inlet of the pipeline due to the reduced pressure drop in high dimension pipelines.
- Offshore and onshore environmental impacts: CO_2 and NO_x emissions, negative impacts on fishery, landscape.
- Impact on onshore regional development.

Differences and commonalities

The first and obvious commonality of the considered cases that can be defined is evaluation of investment and operation costs of implemented solution.

Some of the impacts defined to gas infrastructure can be considered in parallel with electricity network. E.g. security of supply is one of the purposes of new infrastructure development in electricity sector. In gas transport sector, usually the main purpose is to ensure gas evacuation from fields, but security of supply and market flexibility is an important benefit. Different level of importance is reflected on that fact that in electricity sector special models and techniques (e.g. KILE) are developed to quantify this impact. While in natural gas sector security of supply or market flexibility is considered as additional benefit of a certain solution, but not a critical factor. In fact, Avinor's purpose of infrastructure development project to avoid capacity problems in some indirect way is also related to "security of supply" considerations, as the goal is to ensure needed services for all airlines and passengers with airport capacity. But it could be more directly associated with "bottleneck costs" calculated in Statnett's project.

Environmental impacts are common to all the three appraisals. This type of impacts is evaluated in each case but in different combinations. Emissions to air, CO_2 and NO_x and noise (specific impact in this sector) are taken into consideration in Avinor's case. There are two groups of environmental impacts relevant to gas transportation: CO_2 and NO_x emissions and negative effect on landscape. There are no emissions to air directly from the pipelines; they are mostly related to gas processing. There is a need for electricity for compressors: power can be supplied from onshore via the main grid, or it can be produced by the gas power plant (Kollsnes, Kårstø). And the letter alternative causes emissions. Negative landscape impacts, in their turn, are directly associated to gas transport solutions. If there are offshore solutions, effects on fishery and shipping routes are considered, while a need for onshore solutions causes the same issues as it is in electricity sector. Statnett focuses on the negative impacts to landscape, recreation and cultural heritage in the area, we see that this point is of high importance also for Gassco evaluations and more attention should be paid to this type of impacts.

Interesting parallel can be done with pricing in these two sectors. There are price/tariff zones both in electricity sector and gas transportation. As it was described in Sima-Samnanger project evaluation prices are dependent on transmission capacity, especially at peak load period. This price difference determines distributional consequences and has its negative impact on market functioning, creating competitive advantages for areas with lower electricity prices. It cannot be directly applied for gas sector, because tariff differentiation on the NCS has another nature. In the electricity market price areas are determined by the market powers: supply and demand. While in gas sector tariff areas are determined in the regulations: tariffs are calculated according to the formula, which is based on long-term marginal costs; therefore tariffs in the areas depend on construction and operation costs of the transport facilities. But anyway, impact called "well-functioning market" in Statnett's case can be in some way associated with the "Reduction of transportation costs in long run due to the availability of spare capacity".

Non-monetized effect "system and technical impacts", e.g. flexibility of future upgrade, in Sima-Samnanger project can be referred to one of the most important considerations in Luva project, when the capacity of pipelines is chosen in order to ensure efficient connection of future discoveries.

There are also specific impacts for the sectors, e.g. interruption costs and transmission losses for electricity sector; thorough calculation of costs of delay based on VOT in Avinor's practice; benefits from utilization of available spare capacity; reduction of costs of refinery facilities in case of hub-investments in Gassco's evaluations.

What decision criteria are used in evaluation?

In Avinor's case, the main investment criteria, NPV, was calculated. In case of Statnett not all the impacts were monetized, that is why it was impossible to calculate common criteria as NPV, benefit-cost ratio or IRR. The results of the analysis were presented in the form of comparison of zero-alternative with five others. The comparison criteria are: calculated investment costs, construction period and two critical impacts: security of supply and environment effects. Because of the lack of established methodology in gas sector we cannot define decision criteria in Gassco's appraisal, but in general we can describe it as cost-efficiency approach.

How network effects are evaluated?

In Sima-Samnanger project evaluation, network effects were included in socio-economic analysis of this project to large extent. Several considered impacts reflected exactly network effects, for example, "well-functioning power market" and "system and technical impacts". In aviation project, network effects were not calculated due to two reasons: airlines' costs are highly uncertain to estimate and these affects can be spread outside the state boundaries. In Gassco appraisal practice this effects are of the highest importance, due to the fact, that one of the main responsibility of the organization is to ensure effective functioning of the whole gas transport network.

Are regional impacts of the projects considered?

Regional impact assessment is not included in the scope of cost-benefit analysis, but regional effects can be significant for large infrastructure projects. In Avinor's case REA was performed with PANDA and presented as a separate part of socio-economic evaluation. In Sima-Samnanger project effects on regional development were not described separately, but were tied into consideration. Specificity of this case is that supply of electricity, or its interruption, directly influence economic activity in the region. In Gassco appraisal practice, impacts to onshore regional economic development can also be substantial in the projects, which assume construction of new facilities onshore.

How the results of applied appraisal methodology are used in final decision making?

As it was stated above, the analysis of social impacts of Bergen airport expansion was conducted as a part of the Master plan and the results of this analysis were used to support a decision-making. From practice it is known that decisions within aviation sector are often based only on financial considerations. Due to the fact that Avinor has financial responsibility and does not receive governmental support, commercial side of projects is often of main importance.

The final decision on Sima-Samnanger project has already been made and the cheapest alternative (concession line) was chosen, based on the assumption that implicit costs of sea cable solution can be significant.

In gas transport industry decision making process is different from electricity and aviation, where Statnett and Avinor make their decisions themselves. Gassco can only recommend solution, which is preferred from the perspective of the integration to the existing network, environmental impacts and Norwegian as a whole. Investment decision is made by oil and gas companies, which, certainly are interested in the most cost-efficient solution. But the final decision is made by Government when they decide whether to approve plan or not.

Table 5-6 *Results of comparative case study*

Questions	Statnett, Sima-Samnanger project	Avinor, Expansion of Bergen airport Flesland	Gassco, Luva project	Comments
***Are there any established or recommended appraisal methods in the sector*?**	”Samfunnsmessige analyser innen luftfart. Samfunnsøkonomi og ringvirkninger” (2006)	“Samfunnsøkonomisk analyse av energiprosjekter” (2003)	No handbook for Gassco, only Guidelines for PDO and PIO for companies in the oil and gas sector	There is a potential need for a handbook on socio-economic analysis in petroleum sector
What appraisal methods are used in economic impact assessment?	Cost-benefit approach	Cost-benefit analysis, regional impact assessment with Panda	Cost efficiency approach	CBA and REA methodologies can be implemented and be useful in decision making in natural gas sector
What impacts are evaluated and how they are monetized or quantified?	Investment costs and operating costs of the main solution and of temporary solutions; Change in interruption costs; Transmission losses; Bottleneck costs; Security of supply; Nature and environmental impacts; System and technical impacts; Well-functioning market	Value of avoiding capacity problems; Avoided delays; Accident costs; Emissions; Investment costs for Avinor.	Benefits: Utilization of spare capacity; Security of supply (market flexibility); Reduction costs of refinery facilities: CO_2 content blending; Pre-investments in efficient connection of new discoveries; Decrease of transportation costs in long run due to the availability of spare capacity; Energy cost savings from lower needed pressure; Offshore and onshore environmental impacts; Impact on onshore regional development.	<u>Commonalities:</u> Investments and operating costs; Security of supply and market flexibility – for Statnett and Gassco to different extent; Bottleneck costs and value of avoiding capacity problems - for Statnett and Avinor; Environmental costs - for all cases but in different combinations: landscape impacts – for Statnett and Gassco; Well-functioning market and decrease of transportation costs in long run- for Statnett and Gassco; System and technical impacts and possibility of future connections – for Statnett and Gassco; <u>Differences:</u> Statnett: interruption costs and transmission losses; Avinor: costs of delay, accident costs;

				Gassco: benefits from utilization of available spare capacity and reduction of costs of refinery facilities in case of hub-investments.
What decision criteria are used in evaluation?	The comparison of alternatives based on criteria: investment costs, construction period, security of supply and environment effects.	Net-present value	Cost efficiency	There are no recommended decision criteria for Gassco evaluation, but on practice cost efficiency considerations are in focus
How network effects are evaluated?	Evaluated in items as "technical and system impacts" and "well-functioning market"	Are not calculated due to two reasons: airlines' costs are highly uncertain to estimate and these affects can be spread outside the state boundaries.	Are taken into consideration, e.g. when possibilities of future tie-ins are evaluated	Are of the highest importance for Gassco, because of the need to ensure effective functioning of the whole gas transport network.
Are regional impacts of the projects considered?	Included in analysis, but not quantified	Evaluated with PANDA, presented as a separate part of socio-economic analysis	No available information for the Luva project	Can be substantial for gas transport sector when project supposes construction of facilities onshore.
How the results of applied appraisal methodology are used in final decision making?	Results of socio-economic evaluations are taken into account by authorities. But in Sima-Samnanger the cheapest alternative was chosen	Results of socio-economic analysis are used to support decision making. But often decisions are based on financial considerations.	Gassco only recommends solutions, but investment decision is made by companies based on financial considerations	Statnett and Avinor make decisions themselves. In gas transportation sector final decision is made by the Government, whether to approve PDO or PIO or not

How the differences in appraisal practices can be explained?

At first glance on our three case studies, we can definitely say that appraisal practices in aviation and electricity sector have much in common; while gas transport infrastructure appraisal differs from them significantly. The first, and the most superficial, reason is the existence of the established methodology of socio-economic analysis for the first two sectors. These methodologies are based on cost-benefit approach, and it makes the practices to look similarly at least by appearance.

If go deeply, we can see that Gassco has conceptual reasons to have appraisal practices different from Statnett and Avinor. The role of these two companies is a mixture of running a business and carrying out the responsibilities of providing public services (Bråthen et al, 1999). While the role of Gassco is of different nature: it presents public interest, does not run a business, but should also present interests of this business.

Both these companies make their investments from governmental funds, directly or indirectly. Their customers are airlines companies in the first case and electricity users in the second case. The owners of the developed infrastructure are Avinor and Statnett, on behalf of the Norwegian government. In gas sector, the situation is different. Investments into transport infrastructure are made by oil and gas companies, who use this infrastructure (or provide for third-party use) and own it. Gassco's role is to evaluate solutions and make recommendations in order to ensure optimal utilization of the whole upstream transport network. Gassco does not make decisions concerning further development of gas pipeline network. This is up to companies, to decide whether to invest or not. And these decisions are, certainly, made based on financial considerations. The only thing that can be done by authorities to take social impacts into account is to reject some particular projects with significant social costs or recommend solutions with higher benefits for the society.

Here we would like to address the proposition, made in the end of Chapter 2, where gas transport infrastructure development is considered as a conflict of interests. We claimed that the difference in goals between oil and gas companies and authorities has it reflection on the appraisal practice. Now we can say that this proposition was right. Actually, evaluation of a project is performed twice: firstly by a company, who initiates the petroleum deposit development or facility installation; and the second evaluation is done by Gassco. Companies have guidelines for PIO and PDO with quite detailed requirements to their assessment. As oil and gas companies' goal is to make their investments profitable and cost efficient, they are mainly interested in financial and technical analysis, where alternatives are compared and analyzed. Impact assessment is required by authorities for the application for a license, but in fact, companies have no incentives to present public interest in their decision making. And their impact assessment has indirect goal just to evaluate negative impacts and propose measures to mitigate them. That is why important social benefits as well as costs can be neglected in the decision making.

Based on these considerations, we derive two main aspects of Gassco's involvement into infrastructure development process:

1. *Gassco ensures the system approach to the gas transport network development.* Oil and companies' goal is to ensure gas evacuation from the fields; and they have no reasons to consider their transport facilities from the perspective of the whole network.
2. *Gassco's responsibility is to conduct a comprehensive socio-economic analysis of the project,* taking into consideration all the related impacts that are neglected in technical and financial analysis made by companies.

Handbook on socio-economic analysis in gas transport infrastructure development

As it was a lot of times mentioned in this study, Gassco has no established methodology for this socio-economic evaluation. After the careful consideration of the appraisal practices of the important Norwegian infrastructure providers, we can state that cost-benefit analysis is the most suitable and reliable tool for the evaluation of gas transport projects. Development of a handbook on socio-economic analysis in gas transport infrastructure development can be useful. One of the most important and challenging issue is to work out a comprehensive set of criteria that should be assessed, which includes the whole range of specific technical factors as possibilities of tie-ins, pre-investment in future fields development, CO_2 content of unprocessed gas; and to define all social costs and benefits, which are not taken into consideration in technical and financial analysis.

Taking as a point of departure handbooks in electricity and aviation, we would like to discuss some basic aspect of handbook development for gas transport infrastructure projects evaluation. It might be based on two methodologies: cost-benefit analysis and regional impact assessment similar to the handbook in aviation.

Based on the example of Avinor’s handbook, we define four groups affected by gas infrastructure projects implementation:

1. ***Owners of the infrastructure***: oil and gas companies;
2. ***Shippers***: companies who use facilities to transport gas, but do not own them;
3. ***Gassco*** as an operator of the infrastructure and a representative of public interest;
4. ***Third parties***: Norwegian society.

The list of defined benefits of Luva project can be modified to obtain a general set of relevant impacts:

- Investment and operation costs (owners of infrastructure);
- Utilization of available spare capacity (Gassco);
- Security of supply (oil and gas companies, who deliver gas to customers);
- Savings on refinery facilities for gas CO_2 content installation (owners of the infrastructure);
- Pre-investments into efficient connection of new discoveries to existing transport facilities (Gassco, oil and gas companies);
- Reduction of transportation costs in long run (shippers, society due to increase of throughput in transport system and increased income);
- Energy cost savings because of a reduced need for pressure in high dimension pipelines (owners and shippers);
- Offshore and onshore environmental impacts: CO_2 and NO_x emissions, negative impacts on fishery, landscape (third parties, society).
- Impact on onshore regional development (third parties, society).

Development of a handbook on socio-economic analysis also assumes elaboration of methods to monetize or quantify impacts and a set of factor prises that can be directly used in project assessment, e.g. emission costs, accident costs. As we saw it in Sima-Samnanger project evaluation, not all the impacts should and can be quantified or monetized; for instance, in gas transport projects, market flexibility might not be quantified. Important aspect of the methodology development is also a definition of the rates for impact discounting. As we introduced regional impact assessment as an important part of the assessment, in addition to CBA, the development of the appropriate technique (like PANDA for Avinor) is needed.

6 CONCLUSIONS AND FURTHER RESEARCH

6.1 Summary and conclusions

Petroleum industry plays a crucial role for the economy of Norway. It generates 22% of Norwegian GDP and 47% of total exports. The share of natural gas in Norwegian petroleum export is steadily growing. Therefore, gas transport infrastructure on the NCS is in constant development: new transport facilities are planned to evacuate gas from fields, new solutions are being worked out to increase efficiency of the existing transport system. Because of significant costs of infrastructure development and its socio-economic consequences, the project evaluation needs to be as accurate and comprehensive as possible and presents an interesting topic for the research.

The purpose of this research was formulated as: *to study appraisal practice in gas transport infrastructure development on the Norwegian continental shelf and suggest possible adjustments of the existing methodology*. Because of complexity of natural gas sector we introduced the first task of this research to study the system of gas infrastructure operation and development in Norway. We thoroughly studied the Norwegian legislation in petroleum sector in order to investigate roles and responsibilities of the main actors; and sequentially described complicated established procedures of gas transport infrastructure development process: from the initiation of transport facility installation to the approval of the plan by Ministry of Petroleum and Energy. As the main responsibility in gas infrastructure appraisal is taken by Gassco, this organization was in particular focus of the research.

Analysis of the current practice and Gassco's activities led us to a conclusion that *infrastructure development is a point, where different goals of gas sector actors come to a conflict*. Three main involved parties can be defined: oil and gas companies, who initiate development of new infrastructure, and invest into new transport facilities; Gassco, who coordinates the process, makes assessments and recommendations; Norwegian government, which regulates all petroleum activities on the NCS. Pipeline owners are interested in making profit from their activities and investments. Goals of authorities and Gassco can be united and formulated as maximization of throughput and the overall capacity of the transport system. Chapter 2 was concluded with the proposition that the defined conflict of interests has a reflection on the infrastructure appraisal practice. This proposition was later confirmed in the research.

The second task was *to assess and compare the state of appraisal practices among Norwegian infrastructure providers and define shortcomings of appraisal practice in natural gas infrastructure development*. To accomplish this task, we described how the methodology of comparative case study can be applied and worked out a case study protocol. The choice of appraisal practices for the case study, Gassco AS, Statnett SF and Avinor, was based on their important common characteristics. All the three companies own or operate a network (main grid, airports, pipeline system), they are owned by the Norwegian government and they have natural monopoly characteristics. Infrastructure development is their responsibility and a point of great importance. To study appraisal practice of the chosen companies we considered recommended methodologies proposed by the handbooks and guidelines and discussed one particular example of project evaluation. As an example of the project evaluation in electricity sector we took Sima-Samnanger power line project, which evaluated alternative lines between Sima and Samnanger. The central argument for a construction of new line between Sima and Samnanger was a security of supply in Bergen area. To analyze appraisal practice of Avinor we selected plan of expansion of Bergen airport Flesland to avoid problems related to capacity limitations. And the third assessment under our consideration was recent project for gas evacuation solution from Luva field in the Norwegian Sea.

Each case was analysed based on the defined set of case study questions. We studied handbooks for socio-economic evaluation in electricity sector and aviation. In gas transportation we analyzed the Guidelines for PIO and PDO, as it is the only document which characterizes appraisal practice in this sector. In the discussion of the particular projects, special attention was paid to the relevant impacts. We defined analogies between the impacts evaluated in different sectors. E.g. security of supply is one of the purposes of new infrastructure development in electricity sector. In gas transport sector, usually the main purpose is to ensure gas evacuation from fields, but security of supply and market flexibility is an important benefit. Environmental impacts are common to all the three appraisals. This type of impacts is evaluated in each case but in different combinations. There are two groups of environmental impacts relevant to gas transportation: CO_2 and NO_x emissions and negative effect on landscape. If there are offshore solutions, effects on fishery and shipping routes are considered, while a need for onshore solutions causes the same issues as it is in electricity sector. Statnett focuses on the negative impacts to landscape, recreation and cultural heritage in the area, we see that this point is of high importance also for Gassco evaluations and more attention should be paid to this type of impacts. Non-monetized effect “system and technical impacts”, e.g. flexibility of future upgrade, in Sima-Samnanger project can be referred to one of the most important considerations in Luva project, when the capacity of pipelines is chosen in order to ensure efficient connection of future discoveries.

The last case study question was *how to explain differences and commonalities between the three cases*. We made a conclusion that Gassco has conceptual reasons to have appraisal practices different from Statnett and Avinor. Both these companies make investments from governmental funds and own developed infrastructure. Their customers are airlines companies and electricity consumers. While Gassco does not make investments to infrastructure development and does not own it, its role is to evaluate solutions and make recommendations in order to ensure optimal utilization of the whole upstream transport network. Investments into transport infrastructure are made by oil and gas companies, who use this infrastructure (or provide for third-party use) and own it. And companies decide whether to invest or not.

Defined in Chapter 2 conflict of interests has its clear reflection on the appraisal practice. Evaluation of the projects is performed twice: once by a company, which initiated facility installation and then, by Gassco. The first evaluation is mainly focused on financial and technical analysis of alternative solutions, and then, impact assessment of the chosen alternative is performed. As companies have no incentives to take into account public interest, their impact assessment aims just to evaluate negative impacts and propose measures to mitigate them. Therefore, important social impacts are neglected in the evaluation.

Based on these considerations, we derive two main aspects of Gassco’s involvement into infrastructure development process: (1) *Gassco ensures the system approach to the gas transport network development.* While oil and companies’ goal is to ensure gas evacuation from the fields; and they have no reasons to consider their transport facilities from the perspective of the whole network. (2) *Gassco’s responsibility is to conduct a comprehensive socio-economic analysis of the project*, taking into consideration all the related impacts that are neglected in technical and financial analysis made by companies.

Considering Luva project, we defined a set of benefits of Nyhamna alternative. By their generalization and based on handbooks for aviation and electricity sector, we defined a list of relevant impacts and affected groups:

- Investment and operation costs (owners of infrastructure);
- Utilization of available spare capacity (Gassco);
- Security of supply (oil and gas companies, who deliver gas to customers);
- Savings on refinery facilities for gas CO_2 content installation (owners of the infrastructure);
- Pre-investment into efficient connection of new discoveries to existing transport facilities (Gassco, oil and gas companies);
- Reduction of transportation costs in long run (shippers, society due to increase of throughput in transport system and increased income);
- Energy cost savings because of a reduced need for pressure in high dimension pipelines (owners and shippers);
- Offshore and onshore environmental impacts: CO_2 and NO_x emissions, negative impacts on fishery, landscape (third parties, society).
- Impact on onshore regional development (third parties, society).

Taking into account practice of the two other considered Norwegian infrastructure providers and the nature of the projects in gas transportation sector, we stated, that cost-benefit analysis is the most suitable and reliable tool for the economic impact assessment and can provide a good basis for decision making. Development of a handbook on socio-economic analysis in gas transport infrastructure development can be useful. It might be based on two methodologies: cost-benefit analysis and regional impact assessment, like the handbook in aviation. It assumes working-out a comprehensive set of impacts, elaboration of methods to monetize or quantify these impacts, definition of discount rates and a set of factor prises that can be directly used in assessment, e.g. emission costs, accident costs.

6.2 Limitations and further research

Limitations of this research are mainly connected to the shortage of data, first of all, related to Gassco's appraisal practice. Information used in the case study was gathered by separate pieces from a plenty of sources: presentations of Gassco representatives, some communication, web-pages. In contrast to Statnett's and Avinor's cases, we do not have final report on Luva project evaluation.

One more issue about this research is a question about the representativeness of the chosen projects. According to the research design literature (e.g. Yin, 2003), a multiple case study can be accepted as valid and reliable if number of replications is around 8-10. In this research we took only one example from the appraisal practices of Statnett, Avinor and Gassco. But our analysis was fastened by the general methodological recommendations for each sector. Extension of the comparative case study by other projects review can be a direction for the further research.

According to the developed case study protocol, we tried to answer nine questions about the appraisal practice to some extent. But not all of them were studied thoroughly enough. The problem of the use of results of socio-economic analysis in final decision making is only touched in this research, but this is an issue if high interest and importance. That is why it is also one of the possible fields of further research.

Certainly, the main topic of further research that comes from this study is a development of a methodology of socio-economic analysis of gas infrastructure development projects, based on CBA. Some methodological issues were discussed in the previous chapter; we tried to define critical benefits of solutions and effected groups.

Also, during this research we found three implications of the incentive problem, which might be interesting to be investigated in relevance to our research. The first implication is touched in empirical part, where we considered benefits of investments in pipeline capacity larger than needed. The pre-investment in spare capacity leads to a set of important positive impacts. But here a natural question arises. Oil and gas companies, who invest into infrastructure development, are certainly interested in investing only in exactly needed capacity. So, the question is what incentives should be implied in order to motivate companies to invest into upside volumes. This question was mentioned in the research by Xu (2010), who proposed the following possible incentives measures: discriminatory tariffs for pipeline owners and other companies without facilities, or different tariffs for new and old pipelines; a higher priority to be awarded as licensees in the area near the pipelines built by the company.

The second implication of the incentive problem arises from the recent information about possible selling of a part of Gassled infrastructure to foreign companies (Aftenposten, 12 April). If a company sells part of its interest in Gassled to some foreign company, this sold infrastructure still remains being a part of Gassled. But there can be an incentive problem for the foreign company to invest in maintenance of infrastructure on the NCS and development of new transport facilities. And if there was a kind of equilibrium in Norwegian gas transport system, it might change significantly.

The third, and the most interesting, side of the incentive problem is related to activities of Gassco itself. As it follows from the Chapter 2, Gassco acts as an Operator of gas transport system on behalf of owners of infrastructure, but it is regulated by the government. From the point of view of agency theory, we can define two principals in Gassco's principal-agency relationships: Norwegian government and oil and gas companies, which own transport infrastructure. According to the literature (Bernheim and Whinston, 1986; Dixit et al., 1999; Peters, 2001; Nielson and Tlerney, 2006) *Gassco can be considered as common agency for two principals.* "A common agency is a situation where several principals have a stake in the actions of a particular agent. In those situations it is natural to expect that each principal will try to influence the agent's actions. The latter will thus face a set of separate contracts, each one being designed in order to align the agent's preferences with those of a specific principal" (Bernard Sinclair-Desgagné, 2001). In this research we figured out which actions of the agent are influenced by the certain principal, and how this influence is organized and regulated. The second point of interest from agency theory perspective is the fact, that Gassco has no purpose to make profit from its activities, which is postulated in regulations.

Common agency situation and absence of commercial interest makes Gassco's incentive system to be very appealing as a topic of research. From the analysis of the roles and responsibilities of Gassco to Norwegian government and oil and gas companies, the possibilities of opportunism and points, where Gassco can pursue its own interest, can be defined. After defining potential of opportunism, implemented incentive scheme can be studied. In particular relevance to this research, it is interesting to investigate how incentives and potentials for opportunism are reflected in gas transport infrastructure development.

REFERENCES

Articles:

Abadie, L.M., Chamorro, J.M. (2009). Monte Carlo valuation of natural gas investments. *Review of Financial Economics* 18: 10–22.

Afgan, N.H., Carvalho, M.G., Pilavachi, P. A., Martins N. (2007). Evaluation of natural gas supply options for south east and central Europe. Part 1: Indicator definitions and single indicator analysis. *Energy Conversion and Management* 48: 2517–2524.

Afshar, K., Ehsan, M., Fotuhi-Firuzabad, M., Amjady, N. (2008). Cost-benefit analysis and MILP for optimal reserve capacity determination in power system. *Applied Mathematics and Computation* 196: 752–761.

Arnott, R., (1997). Transport project appraisal/ cost-benefit analysis. *Journal of Transport Geography* 5 (1): 45.

Au, E. (2002). Impact assessment in the corporate context. Impact assessment, sound business operation, and corporate responsibility for sustainable development, vol. 1. IAIA business and industry series.

Barfod, M.B., Salling, K.B., Leleur, S. (2011) Composite decision support by combining cost-benefit and multi-criteria decision analysis. *Decision Support Systems* 51: 167–175.

Berg, S.V. Tschirhart, J. (1988), Natural Monopoly Regulation: Principles and Practice, Cambridge: Cambridge University Press.

Bernheim, B.D., Whinston, M.D. (1986). Common agency. *Econometrica*, 54: 923-942.

Blome, C., Schoenherr, T., (2011). Supply chain risk management in financial crises —A multiple case study approach. *International Journal of Production Economics*, doi:10.1016/j.ijpe.2011.01.002

Bråthen, S., Hervik, A. (1997). Strait Crossing and Economic Development. Developing economic impact assessment by means of ex post analyses. Transport Policy 4(4): 193-200.

Bråthen, S., Sandberg, K.E., Hjelle, H.M., Killi, M. (1999). Methods for economic appraisal in the Norwegian aviation sector. Working paper, Molde College and Møre Research.

Bristow, A.L., Nellthorp, J. (2000). Transport project appraisal in the European Union. *Transport Policy* 7: 51-60.

Carlton, D. and J. Perloff (2004). Modern Industrial Organization. Fourth Edition, Addison-Wesley.

Carrera-Gómez, G., J. Castanedo-Galán, P. Coto-Millán, V. Inglada, and M. A. Pesquera. (2006). Cost-Benefit Analysis of Investment in High-Speed Train System in Spain. *Transportation Research Record: Journal of the Transportation Research Board* (1960): 135-141.

Damart, S., Roy, B. (2009). The uses of cost-benefit analysis in public transportation decision-making in France. *Transport Policy* 16: 200-212.

Daniel, J.I. (2002). Benefit-cost analysis of airport infrastructure: the case of taxiways. Journal of Air Transport Management 8: 149–164.

Dey, P. K. (2002). An integrated assessment model for cross-country pipelines. *Environmental Impact Assessment Review* 22: 703–721.

Diakoulaki, D., Karangelis, F. (2007). Multi-criteria decision analysis and cost–benefit analysis of alternative scenarios for the power generation sector in Greece. *Renewable and Sustainable Energy Reviews* 11: 716–727.

Dixit, A., Grossman, G., Helpman, E. (1997), Common Agency and Coordination: General Theory and Application to Government Policy Making. *Journal of Political Economy* 105: 752-69.

Dobes, L., Bennett, J. (2009). Multi-Criteria Analysis: "Good Enough" for Government Work? *"Agenda" at the Australian National University* 16 (3): 7-29.

Dobes, L., Bennett, J. (2010). Multi-Criteria Analysis: Ignorance or Negligence? *Australasian Transport Research Forum 2010* Proceedings 29 September – 1 October 2010, Canberra, Australia Publication website: http://www.patrec.org/atrf.aspx

Dolan, P., Edlin, R. (2002). Is it really possible to build a bridge between cost-benefit analysis and cost-effectiveness analysis? *Journal of Health Economics* 21: 827–843.

Economides, N. And D., Encanoua (1996). Special issue on network economics; business conduct and market structure. *International Journal of Industrial Organization* 14.

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review* 14 (4): 532–550.

Eisenhardt, K.M., Graebner, M. (2007). Theory building from cases: opportunities and challenges. *Academy of Management Journal* 50 (1): 25–32.

Ellram, L.M. (1996). The use of the case study method in logistics research. *Journal of Business Logistics* 17 (2): 93–138.

Finch, J.H., Macmillan, F.E., Simpson, G.S. (2002). On the diffusion of probabilistic investment appraisal and decision-making procedures in the UK's upstream oil and gas industry. *Research Policy* 31: 969–988.

Flyvbjerg, B., COWI., (2004). Procedures for Dealing with Optimism Bias in Transport Planning. Guidance Document prepared for the British Department for Transport, UK.

Flyvbjerg, B., Holm, M.S., and S. Buhl, (2002). Underestimating Costs in Public Works Projects: Error or Lie? *Journal of the American Planning Association* 68(3): 279-295.

Fröidh, O. (2008). Perspectives for a future high-speed train in the Swedish domestic travel market. *Journal of Transport Geography* 16: 268-277.

Gamper, C.D., and C. Turcanu. 2007. On the governmental use of multi-criteria analysis. *Ecological Economics* 62: 298-307.

Gasmi, F. and Oviedo, J.D. (2010). Investment in transport infrastructure, regulation, and gas–gas competition. *Energy Economics* 32: 726–736.

Gordon, D.V., Gunsch, K., Pawluk, C.V. (2003). A natural monopoly in natural gas transmission. *Energy Economics* 25: 473–485.

Halldórsson, A., Aastrup, J. (2003) Quality criteria for qualitative inquiries in logistics. *European Journal of Operational Research* 144 (2): 321-332.

Hansen, M., Tsao, J., Huang, A., Wei, W. (1998). Empirical analysis of airport capacity enhancement impacts: a case study of DFW Airport. In: Presented at the 78th Transportation Research Board Annual Meeting, Washington, DC.

Hansen, M., Wei, W. (1998). Multivariate Analysis for the Impacts of NAS Investments: A Case Study of Major Capacity Expansion at DFW. NEXTOR Research Report RR-98-18. University of California, Berkeley.

Hervik, A., Brathaug, A.L., Hagen, K.P. (2011). Sjøkabel eller luftlinje i Hardanger: En samfunnsøkonomist analyse. *Samfunnøkonomen* 3: 30-38.

Hirschhausen, C. von (2008). Infrastructure, regulation, investment and security of supply: A case study of the restructured US natural gas market. *Utilities Policy* 16: 1-10.

Jorge, J.D. and de Rus, G. (2004). Cost–benefit analysis of investments in airport infrastructure: a practical approach. *Journal of Air Transport Management* 10: 311–326.

Joskow, P.L. (2005). Regulation of Natural Monopolies. Center for energy and environmental policy research.

Kern, C. A., Rajkovič, V. (2008). A qualitative model for road investment appraisal. *Transport Policy* 15 (4): 225-231.

Künneke, R.W. (1999). Electricity networks: how 'natural' is the monopoly? *Utilities Policy* 8: 99–108.

Lakshmanan, T.R. (2011). The broader economic consequences of transport infrastructure investments. *Journal of Transport Geography* 19: 1–12.

Lee, G.-J., Heydt, G.T. (2004). An interactive–dynamic mechanism conceptualizing the cost and benefit of electric power quality. *Electric Power Systems Research* 69: 69–75.

Lochner, S. (2011). Identification of congestion and valuation of transport infrastructures in the European natural gas market. *Energy* doi:10.1016/j.energy.2011.01.040.

Mackie, P., Preston, J., (1998). Twenty-one sources of error and bias in transport project appraisal. *Transport Policy* 5 (1), 1–7.

Mentzer, J.T., Kahn, K.B. (1995). A framework of logistics research. *Journal of Business Logistics* 16(1): 231–250.

Mishan, E. J. (1971). Evaluation of Life and Limb: A Theoretical Approach. *Journal of Political* Economy 79: 687-705.

Mohn, K., Misund, B. (2009). Investment and uncertainty in the international oil and gas industry. *Energy Economics* 31: 240–248.

Nakamura, H. (2000). The economic evaluation of transport infrastructure: needs for international comparisons. *Transport Policy* 7: 3-6.

Nash, C. (1991). The case for high speed rail. *Investigaciones Económicas (Segunda época)* XV (2): 337-354.

Navrud, S., Ready, R. C., Magnussen, K. and Bergland, O. (2008). Valuing the social benefits of avoiding landscape degradation from overhead power transmission lines: Do underground cables pass the benefit-cost test? *Landscape Research*, 33(3): 281 — 296.

Nellthorp, J., Mackie, P. J. (2000). The UK Roads Review—a hedonic model of decision making. *Transport Policy* 7 (2): 127-138.

Niekerk, F., and Voogd, H. (1999). Impact assessment for infrastructure planning: Some dutch dilemmas. Environmental Impact Assessment Review 19(1): 21-36.

Nielson, D.L., Tlerney, M.J. (2006). Principals and Interests: Common Agency and Multilateral Development Bank Environmental Lending. International Political Economy Society, Princeton University, November 17-18, 2006.

Nooij, M. de, (2011). Social cost-benefit analysis of electricity interconnector investment: A critical appraisal. *Energy Policy* doi:10.1016/j.enpol.2011.02.049

Nooteboom, S. (2007). Impact assessment procedures for sustainable development: A complexity theory perspective. *Environmental Impact Assessment Review* 27: 645–665.

Nyborg, K. (1996). Some Norwegian politicians' use of cost-benefit analysis. Discussion paper no. 169, Statistics Norway, Research department, Oslo.

Odeck, J. (1996). Ranking of regional road investment in Norway – does socio-economic analysis matter? Transportation 23(2): 123-140.

Pelletier, C., Wortmann, J.C. (2009). A risk analysis for gas transport network planning expansion under regulatory uncertainty in Western Europe. *Energy Policy* 37: 721–732.

Peters, M. (2001). Common agency and the revelation principle. *Economentrica*, 69: 1349-1372.

Phani Kumar, C. V., Basu, D., Maitra, B. (2004). Modeling generalized cost of Travel for rural bus users: a case study. *Journal of Public Transportation* 7 (2): 59-71.

Posner, R.A. (1969). Natural Monopoly and Regulation. *Stanford Law Review* 21: 548-643.

Sáez, C.A., Requena, J.C. (2007). Reconciling sustainability and discounting in Cost–Benefit Analysis: A methodological proposal. *Ecological Economics 60*: 712–725.

Salling, K. B., and Banister, D. (2009). Assessment of large transport infrastructure projects - The CBA-DK model. *Transportation Research Part A* 43: 800-813.

Sen, A. (2000). The Discipline of Cost-Benefit Analysis. *The Journal of Legal Studies* 29: 931-952.

Sinclair-Desgagné, B. (2001). Incentives in Common Agency, CIRANO Working Papers 2001s-66, CIRANO.

Stevens, A. (2004). The application and limitations of cost-benefit assessment (CBA) for intelligent transport systems. *Research in Transportation Economics* 8: 91-111.

Stirling, A. (2001). Science and precaution in the appraisal of electricity supply options. *Journal of Hazardous Materials* 86: 55–75.

Tsamboulas, D. A., Mikroudis, G. (2000). EFECT - evaluation framework of environmental impacts and costs of transport initiatives. *Transportation Research Part D* (5): 283-303.

Tschirhart, J. (1995) Monopsony power and the existence of natural monopoly in energy utilities. *Resource and Energy Economics* 17: 327-340.

Tudela, A., Akiki, N., Cisternas, R. (2006). Comparing the output of cost benefit and multi-criteria analysis - An application to urban transport investments. *Transportation Research Part A* 40: 414-423.

Vickerman, R. (2007). Cost-benefit analysis and large-scale infrastructure projects: state of the art and challenges. *Environment and Planning B: Planning and Design* 34: 598-610.

Voogd, H. (1996). The changing role of evaluation methods in a changing planning environment: Some Dutch experiences. *European Planning Studies 5(2): 257-266.*

Wang, H., Kåresen, R., Hervik, A. and S.O. Thoresen (2001). Mammography screening in Norway: results from the first screening round in four counties and cost-effectiveness of a modelled nationwide screening. *Cancer Causes Control* 12(1):39-45.

Wei, W. (2008). A new approach to quantify the benefit to air travellers resulting from airport capacity expansion*. Journal of Air Transport Management* 14: 47–49.

Wei, W., Hansen, M. (2006). An aggregate demand model for air passenger traffic in the hub-and-spoke network. *Journal of Transportation Research A*: 841–851.

Xu, Y. (2010). A game theoretic analysis of pipeline development under the restructuring of Norwegian natural gas transport system. In *Competition and cooperation – A game theoretic analysis on the development of Norwegian continental shelf.* PhD theses in Logistices 2010:4, Molde.

Xu, Y., Haugen, K. (2008). A game of upstream natural gas pipeline development. *10th IAEE European Conference: Energy, Policies and Technologies for Sustainable Economies*.

Books:

Alf, E. R. (1997). Economic evaluation of vocational rehabilitation programs. *In Social Policy and the Labor Market*, P.R. de Jong and T.R. Marmor(eds.):Volume Two. Aldershot: Ashgate.

Berechman, J. (2009). *The Evaluation of Transportation Investment Projects*. Routledge.

Boardman, A. E., Greenberg, D. H., Vining, A.R., Weimer, D. L. (2006_. *Cost-Benefit Analysis - Concepts and Practice*. 3rd ed. New Jersey: Pearson Prentice Hall.

Bråthen, S. (2001). Essays on the economic appraisal of transport infrastructure. Examples from aviation and fixed fjord links. Dissertation for the degree of Dr.ing. Norwegian University of Science and Technology.

Bryman, A. (2001). *Social Research Methods*. Oxford University Press.

Cooper, H. (1998). *Synthesizing Research*. A Guide for Literature Reviews, Third Edition. London: Sage.

Haezendonck, E. (2007). *Transport Project Evaluation - Extending the Social Cost-Benefit Approach.* Edited by E. Haezendonck. Massachusetts: Edward Elgar Publishing Inc.

Kendall, M.G. (1971). *Cost Benefit Analysis.* A Symposium held in The Hague in July, 1969. The English Universities Press LTD.

Mishan E.J. and Quah E. (2007). *Cost-Benefit Analysis*. 5th edition.TJ Internation Ltd, Padstow, Cornwall.

Nas, T.F. (1996). *Cost-Benefit Analysis - Theory and Application*. Thousand Oaks, CA: Sage Publications Inc.

Niskanen, W.A. (1971). *Bureaucracy and Representative Government*. Aldine Transaction.

Silverman, D. (2001). *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction*. Second Edition. London: Sage.

Silverman, D. (2006). *Qualitative Research: Theory, Method and Practice*. Second Edition. London: Sage.

Walshe, G., Daffern, P. (1990). *Managing Cost-Benefit Analysis*. Macmillan Education LTD.

Weinstein, M.C. (1995). From cost-effectiveness ratios to resource allocation: where to draw the line. In *Valuing health care: costs, benefits, and effectiveness of pharmaceuticals and other medical technologies*, edited By Frank A. Sloan. Cambridge University Press.

Yin, R.K. (2003). *Case Study Research*, Third ed. Sage, Thousand Oaks.

Reports:

Brathen, S., Eriksen, K.S., Hjelle, H.M., Johansen, S., Lillebak, L.M., Lyche, L., Sandvik, E.T., Strand, S. (2006). *Samfunnsmessige Analyser Innen Luftfart.* Del 2: Exempelsamling. Høgskolen i Molde and Møreforskning Molde AS, Rapport 0606b.

Brathen, S., Eriksen, K.S., Johansen, S., Killi,M., Lillebak, L.M., Lyche, L., Sandvik, E.T., Strand, S., Thune-Larsen, H. (2006). *Samfunnsmessige Analyser Innen Luftfart: Samfunnsøkonomi og ringvirkninger*. Del 1: Veileder. Høgskolen i Molde and Møreforskning Molde AS, Rapport 0606a.

Brathen, S., Lillebak, L.M., Sandvik, E.T., Bergem, B.G. (2005). En samfunnsmessig analyse av behovet for videreutvikling av Bergen Lufthavn, Flesland. 2005, Møreforskning Molde AS, Rapport 0505.

EuropeanCommission. 2008. *Guide to Cost-Benefit Analysis of investment projects*. Directorate General Regional Policy. [cited 12.03.2001]. Available from http://ec.europa.eu/regional_policy/sources/docgener/guides/cost/guide2008_en.pdf

Gassco Annual Report, (2009). [cited 15.03.2011]. Available from: http://www.gassco.no/wps/wcm/connect/4fcdef8042421a0ab6b8ff63a6debd44/Gassco_FoU+%C3%A5rsrapport_2009_web.pdf?MOD=AJPERES

Ministry of Petroleum and Energy and Norwegian Petroleum Directorate, (2011). *Facts 2010 - The Norwegian petroleum sector*. [cited 15.04.2011]. Available from http://www.npd.no/en/Publications/Facts/Facts-2010/

Samfunnsøkonomiske virkninger. Rapport fra sjøkabelutredningen. Utvalg iv, 1. februar 2011. [cited 25.03.2011]. Available from: http://www.regjeringen.no/pages/15604222/Utvalg_IV.pdf

Governmental documents:

Finansdepartementet. 2005. *Veileder i samfunnsøkonomiske analyser*. [cited 10.03.2011]. Available from: http://www.regjeringen.no/upload/kilde/fin/reg/2005/0029/ddd/pdfv/266324-veileder_i_samfunnsok_analyse_trykket.pdf

Guidelines for plan for development and operation of a petroleum deposit (PDO) and plan for installation and operation of facilities for transport and utilisation of petroleum (PIO). [cited 9.04.2011]. Available from: http://www.npd.no/Global/Engelsk/5%20-%20Rules%20and%20regulations/Guidelines/PDO-PIO-guidelines_2010.pdf

Meld.nr. 47 (2003-2004) Om innovasjonsverksemda for miljøvennlege gasskraftteknologiar mv. Olje- og energidepartement. [cited 10.03.2011]. Available from: http://www.regjeringen.no/nb/dep/oed/dok/veiledninger_brosjyrer/2004/Stortingsmelding-om-innovasjonsverksemda-for-miljovennlege-gasskraftteknologiar-mv.html?id=88060

NOU. 1997:27. *Nytte-kostnadsanalyser - Prinsipper for lønnsomhetsvurderinger i offentlig sektor*. Norges Offentlige Utredninger (NOU). [cited 10.03.2011]. Available from: http://www.regjeringen.no/nb/dep/fin/dok/nouer/1997/nou-1997-27.html?id=116359

NOU. 1998:16. *Nytte-kostnadsanalyser - Veiledning i bruk av lønnsomhetsvurderinger i offentlig sektor*. Norges Offentlige Utredninger (NOU). [cited 10.03.2011]. Available from: http://www.regjeringen.no/nb/dep/fin/dok/nouer/1998/nou-1998-16.html?id=116515

Petroleum Act: Act relating to petroleum activities (the Petroleum Act), 29 November 1996, No. 72. [cited 9.04.2011]. Available from: http://www.ptil.no/getfile.php/Regelverket/Petroleumsloven_e.pdf

Petroleum Regulations: Regulations to the Act relating to petroleum activities, 27 June 1997, No. 65. [cited 9.04.2011]. Available from: http://www.npd.no/en/Regulations/Regulations/Petroleum-activities/

Regulations relating to stipulation of tariffs, etc. for specific facilities, 20 December 2002, No. 1724. [cited 9.04.2011]. Available from: http://www.npd.no/en/Regulations/Regulations/Stipulation-of-tariffs/

Regulations relating to third party access to facilities, 20 December 2005, No. 162. [cited 9.04.2011]. Available from: http://www.npd.no/en/Regulations/Regulations/Facilities---use-by-others/

Samfunnsøkonomisk analyse av energiprosjekter, NVE, (2003). [cited 19.03.2011]. Available from: http://www.nve.no/Global/Publikasjoner/Publikasjoner%202003/H%C3%A5ndbok%202003/Trykkefil%20h%C3%A5ndbok%201-03.pdf

FOR 1999-03-11 nr 302. *Forskrift om økonomisk og teknisk rapportering, inntektsramme for nettvirksomheten og tariffer*. [cited 17.03.2011]. Available from: http://www.lovdata.no/for/sf/oe/xe-19990311-0302.html

Other sources:

Aftenposten, 12.04.2011. Ønsker å selge ut Norske gassrør. Available from: http://eavis.aftenposten.no/aftenposten/86264/archive/demo/?page=67&query=gassled

Lohne, T.O. (2010). The next decade – a changing environment and challenges for the gas infrastructure. Workshop 17 December, 2010, Molde.

Lohne, T.O. (2010).The Norwegian gas infrastructure –future challenges. JazzGass, 20 July 2010, Molde.

Reuters (2008). *StatoilHydro makes Norwegian Sea gas discovery*. [cited 15.04.2011] Available from: http://uk.reuters.com/article/2008/10/16/sppage023-lg388164-oisbi-idUKLG38816420081016

Samfunnsøkonomi, NorNed, 06.09.2004. [cited 25.03.2011]. Available from: http://www.statnett.no/Documents/Prosjekter/Kabel%20til%20Nederland%20(NorNed)/Dokumentliste/Konsesjonss%C3%B8knad%20og%20konsekvensutredning/Samfunns%C3%B8konomi.pdf

Terms and conditions for transportation of gas in Gassled, (2010). [cited 10.03.2011]. Available from: http://www.gassco.no/wps/wcm/connect/e46545804e169b278437ad80e3f35ee4/Gassled_TermsandConditions01012009.pdf?MOD=AJPERES

UK Department of Environment. (1998). Transport and the Regions [cited 15.04.2011]. Available from: http://www.dft.gov.uk/webtag/documents/index.php