Enhancement of the Life Extension Management Process for ageing Offshore Platforms on the Dutch Continental Shelf

Source: TNO - 2009
Abstract

This research is executed on behalf of State Supervision of Mines (SSM) established at the Haque-Leidscheveen, the Netherlands.

State Supervision of Mines (SSM) is an executive agency of the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I). SSM has several core tasks i.e. supervising compliance with relevant legislation connected with the detection and extraction of minerals and geo-thermal energy. Besides the core tasks of SSM include supervision of storage of substances and supervising compliance with the Gas Act in the field of safety of gas transport networks and making recommendations to the Minister of EL&I. SSM is responsible for the supervision and enforcement of all mining activities. Focused on safety (occupational & process / asset integrity), health, environment and optimal use of mineral resources within the Netherlands (onshore) as well as on the Dutch Continental Shelf (offshore). The minerals which are mined are mainly natural gas, crude oil and salt.

The mission statement of SSM, reflects these responsibilities;

“To ensure that the exploration and production of minerals is carried out in a responsible and socially acceptable manner.” [SSM, 2007 pg 12].

The focus of this thesis will be on the management of the Life Extension process, of the ageing gas production facilities on the Dutch Continental shelf. The result will be a guideline, which will lead to a higher level of control for the upcoming Life Extensions of these facilities. This guideline will be an synthesis of applied Life Cycle Management, Dutch Acts and ISO or API guidelines, which have enumerate, the industry’s best practice. The guideline will be supported by the LEM (Life Extension Management) process diagram, which will serve as the mainframe of the guideline in which the; Lifecycle Phases, products / services and actors are incorporated. Together with the LEM system model it will be possible to quantitatively show how baseline (pre) LEM costs can be assessed and in which extent the result in relation to the overall system cost-effectiveness, may be affected.

The guideline will be applicable to SSM, operators/asset owners, Independent Experts and the industry related companies.

Many offshore production facilities in the Dutch sector of the North Sea are now reaching or have exceeded their original anticipated design life. The industry is dealing with this in an opaque manner. Therefore this research is aiming to find a way to achieve sustainable asset integrity during the Extended Life of the facility by formulating a guideline which will secure the total integrity of the facility by the management of the offshore operators, to ascertain their adequacy in managing ageing structures,

In this context the main research question is stated as:

How to get better grip on the Life Extension Management Process, of the Dutch Offshore Production Facilities?
Providing the required products and services on schedule will require well-tuned management activities for the whole Life Extended period. In this context these activities on high level are:

- a well-managed LEM process;
- defining and executing LEM in a structured way;
- defining the system performance for the Extended Life;
- clear, open and transparent communication.

Performing these activities requires well-equipped and competent actors in a well structured environment. To equip these actors a range of resources are essential, such as competent personnel, infrastructure, material, tools, etc.

Based on the activities described above the elements of the AMC Logistic Process Cycle (LPC) are renamed and redefined in line with the LEM guideline specifications determined in this research on a structured and logical way. Which have lead to the development of a:

1. Process Diagram by structuring the LEM phases;
2. LEM System Model;
3. LEM communication platform.
Enhancement of the Life Extension Management Process for ageing Offshore Platforms on the Dutch Continental Shelf

Thesis Submitted to Hogeschool Zeeland, University of Applied Sciences in Partial Fulfillment of the Requirements for the Degree of Master of Science in Asset Management Control

by

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2011

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1 This Master Thesis contains opinions, findings and conclusions, which are those of the author. They cannot be appointed to those of my employer, State Supervision of Mines (SSM).
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**Thesis Lay-Out**

This section will show the lay-out of the Thesis, the purpose and the way how the research will be performed. The general lay-out of the Thesis is presented in Figure 1.

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*Figure 1 Thesis Lay-Out*
1. Introduction to SSM and the Dutch Gas Production

This Chapter will give an introduction to the research subject, to the Dutch Gas\textsuperscript{(D25)} Production and will present the position of SSM within the industry. State Supervision of Mines (SSM) is an executive agency of the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL\&I), and operates mainly in the field of mining\textsuperscript{(D43)} and extraction of oil and gas. The core tasks of SSM are:

- supervising compliance with legislation connected to the detection and extraction of minerals and geo-thermal energy, underground storage of substances;
- supervising compliance with the Gas Act in the field of safety of gas transport networks;
- making recommendations to the Minister of Economic Affairs, Agriculture and Innovation and other governmental bodies

1.1. The Position of SSM.

The position of SSM within the Dutch Mining\textsuperscript{(D43)} industry is, as regulator on the Health, Safety, Environmental (HSE) and Well Integrity\textsuperscript{(D34)} issues, related to the mining activities onshore as well as offshore. These activities are being performed as executive agency of EL\&I on behalf of the Dutch State [EL\&I, 2007]. The financial interests of the mining activities are being represented by Energy Control Netherlands (ECN), which is fully owned by EL\&I. ECN plays a key role in the exploration, production, transportation and sale of Dutch natural gas\textsuperscript{(D25)}. ECN is also active in oil exploration and production. ECN participates in almost all the gas production ventures in the Netherlands.

ECN is a private limited company with an objective to perform activities designed to implement the Minister of EL\&I policy. All ECN shares are held by the Dutch state, represented by EL\&I. [ECN, 2009].

SSM as well as ECN are both completely independent operating subsidiaries of EL\&I (Figure 2). The contact between both the agency and the company, are merely motivated by SSM to ECN as consultant for recommendation about HSE, well and production facilities integrity issues.
1.2. The specific nature of Mining

Mining\(^{(D43)}\) is an activity that differs in several respects from traditional industrial activities. The most conspicuous differences are [SSM,2007]:

- The extraction site cannot be freely chosen\(^2\), it is tied to the place where the mineral occurs naturally in the subsoil;
- The initial investments in production facilities, to extract the resources are high;
- Mineral extraction could potentially lead to great calamities because high-combustible materials are handled in huge (underground) volumes, which are under high pressure;
- The route of "search-find-win" includes a very wide range of activities, in which widely varying specific expertise is required (from geology to engineering);
- Soil mineral extraction can cause dynamic earth movements (earthquakes).

1.2.1. Risk of Mining

The social importance of the mining\(^{(D43)}\) and gas\(^{(D25)}\) transport and distribution is high. [SSM, 2007] “The annually extracted energy volumes are almost as high as the total energy consumption in the Netherlands, the surplus of the produced gas is exported, therefore the Netherlands is a net exporter.” [ECN, 2009] During the extraction of minerals and the use of pipelines for oil and gas are inherent dangers present when these processes are not properly managed and controlled. These dangers can lead to adverse events. If no appropriate action is taken, this could escalate into major disasters with damage to people, environment and infrastructure, often associated with large financial implications and loss of reputation. Companies in the mining industry are considered to have systems in place, aiming at preventing adverse events and if they do occur to have taken adequate measures to prevent escalation. This all need to lead to a drastic reduction of the likelihood (probability) that such disasters occur.

The risks\(^{(D50)}\) associated with the discovery and extraction of minerals by production facilities are:

- risks to the internal security: besides the ‘usual’ health and safety risks to individual workers, including possible blow-outs, explosions, collisions (offshore) and crashes (helicopters) with fatal consequences for individual or groups of employees;
- risks to the external security: blow-outs, explosions or subsidence over salt caverns or marl pits which can have consequences with fatal ending for residents or transients;
- risks to the environment: blow-outs, explosions and clouds of gas can lead fractures, oil pollution of the soil (including any deterioration\(^{(D11)}\) of the water extraction function if any) of substance;
- risks for damage caused by subsidence or earthquakes associated with the gas or subsidence associated with salt extraction and marl;
- risks for minerals and other occurrences;
- financial economical risks (in 2008 the income from the sale of the produced gas was around € 12 billion).

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\(^2\) By mining at sea as a special feature is used – a platform- with only a very limited area available to the needed equipment, Facilities and accommodation. Moreover, the evacuation of people is considerably more difficult than on the mainland.
1.3. The need for longer Mining

In 2003 the new Mining Act went in force, [EL&I, 2003]. This Act is particularly focused on the efficient extraction (the systematic management) of the Dutch minerals. The extraction of oil and gas occurs only after the Minister of EL&I has approved the mining plan. SSM shall ensure that the mining company is to keep this plan. Moreover, SSM can make recommendations on appropriate measures for the detection and extraction of minerals and the efficient and proactive way to proceed.

1.3.1. Dutch Mineral Production

By January 1, 2006 the Netherlands had 391 discovered occurrences of natural gas, [DG-ET, 2006]. The gas of all currently producing fields, 34 of the expected start-occurrences in the period 2006-2010 and some other occurrences which started production after 2010 is likely, remaining totals 374 billion m$^3$ (excluding Groningen field). The Groningen field has a reserve of 1.136 billion m$^3$. Of about one hundred occurrences its uncertain whether they will ever be developed. This group has potential occurrences, which is heavily dependent on developments in technology (innovation), infrastructure, cost and output price (efficiency). In addition there is an estimate of the potential natural gas to be explored. The range (lower and upper limits) in the territory runs from 60 to 150 billion m$^3$, and on the Continental Shelf from 120 to 290 billion m$^3$. The continental shelf has the biggest potentials for further development, therefore the research will be focused on, securing the future developments on the Dutch Continental Shelf.

1.3.2. Extending the Production Time

“The total gas production of the Netherlands for 2008 is the amount of 76 BillionNm$^3$. The mined volumes can be split in an onshore part (52 billionNm$^3$) and an offshore part (24 billionNm$^3$) The offshore gas reserves represent 31,5% of the total gas revenue, which for 2008 the total was € 13 Billion⁴, [DG-E.T., 2008 pg 23]. The offshore gas generated € 3,8 Billion in 2008, produced by 150 ageing production platforms [SSM, 2007].

As introduced in Chapter 1.3.1, the Dutch mining activities are mainly executed within the Dutch territorial continent (onshore) as well as on the Dutch continental shelf (offshore). Figure 3 shows that the main territorial continent production is supported by numerous smaller fields. The second part of the (natural) gas production is realized on the continental shelf, the continental shelf are an equivalent number of small and medium size fields, but in a multiple quantity compared to the territorial continent.
Figure 3 and 4 show the production historic and forecasts from 1965 till 2040. Figure 3 shows the historic production and forecast, based on the production know profiles of the currently producing gas fields. In figure 4, the futures (prospective resources) non-available or hard to produce gas volumes are added. Producing these extra volumes, might have an effect on the required life of the production facilities, operating on the Dutch Continental Shelf, [ECN, 2009]. The former motivates the focus on the process for Life Extension of the offshore gas production facilities, needed to fulfill the change of the operational need of these assets.

Figure 3 Historic Production and Forecast, [ECN, 2009]

Figure 4 Historic Production and Forecast with On- and Offshore Futures, [ECN, 2009]
Furthermore figures 3 and 4 show the prognoses of the increasing indigenous gas consumption (sloping line) in combination with the rapidly declining gas production, the current production will stop covering the gas need of the Netherlands, in 2018 (figure 3) and (figure 4). The decline in gas production, brings the supply, - and delivery security at risk \((D50)\), \([PRC, 2007]\). To extend the supply and delivery of gas, several measures and inherent decisions need to be taken \([EL&I, 24^{th} of February 2010]\).

**1.4. Production Facilities**

**1.4.1. Future Prospect**

Analyses to determine the future prospects have been performed of the offshore facilities, taking into account the interdependency in relation to the main trunk lines: NGT, NOGAT and WGT, \([ECN, 2010]\). The analyses are based on two scenarios: one that assumes current production forecasts without contingent resources being added, and one that also takes contingent resources into account, see Figure 5. These analyses have been calculated on the basis of current economic parameters and the assumption has been made that abandonment will take place within a year after production ceases, \([ECN, 2010]\).

![Abandonment with current reserves](image1)

*Figure 5 Prospect of the Dutch offshore facilities, [ECN, 2010]*

The largest system in terms of connected facilities, NGT, also shows the greatest imminent abandonment activity. In the scenario assuming current reserves, close to one half of its connected facilities are foreseen to be abandoned within five years. And a comparable number of facilities will be abandoned in the following five years.
In both scenarios, the NOGAT system will experience abandonments of around 15% of its facilities in the next five years. Abandonments in the WGT system in the coming five years are expected to stand between that of the other two trunk lines. At a general level, the number and scale of abandonments in the near future will be significantly affected by whether or not contingent resources are taken in account and the level of success of new techniques to enhance the productivity of the well. Hence these effects are remarkably different for each trunk line. Effects are also driven by the maturity of each individual connected field, the extent of contingent resources and the complexity of the systems themselves.

1.4.2. Extending the facilities life

One of the measures to lengthen the time of the Dutch energy interdependency which needs to be taken, is to ensure that the production continues. The ways to maximize the production is to extend the production of new occurrences and/or the enhance the producibility of the current and future ones. The latter can be done by means of installing new platforms or extending the usage of current platforms. The latter option is the most financially favorable, due to (initial) high capital investment in the production facility. This option results in the challenge to secure the integrity of the production facilities, during the required life. Extended period [SSM, 2010].

Offshore production of gas on the Dutch Continental Shelf started more than 30 years ago, hence the first mining installations were installed in this period:

1. >30 years in service, 13% of platforms on the continental shelf;
2. 20-30 years in service, 31% of platforms on the continental shelf;
3. 10-20 years in service, 35% of platforms on the continental shelf;
4. <10 years in service, 21% of platforms on the continental shelf.

![Age of Offshore Platforms](image)

Illustrating the distribution of the ages of the production facilities on the continental shelf (see, Figure 6), which are divided in four groups, indicating that most of the production facilities are heading towards 10 to 30 years of operation. It has to be noted that the initial design life time of the production facility, typically is for the initial operational period of 20 to 25 years, [ABB, 2008].

A production facility can be technically decomposed in three main installations (see, Figure 7) namely [PSA, 2010]:

1. the foundation (making use of piles), which secure the position of the complete production facility on the seabed;
2. the structure, which is a typically a steel frame to support the topside of production facility;
3. the topside, which a steel structure mounted on top of the structure and houses the installations necessary for producing the gas volumes, safety equipment and production support installations: like power supply, cranes, helicopter deck etc.
Operating after the initial design life\(^{(D36)}\), can only be allowed when a Life Extension assessment\(^{(D39)}\) has been performed. This assessment need to be performed by the Duty Holder and the results of the assessment, to be assayed by an Independent Expert, which will assess the (historical) data and condition of the production platform. The latter is only obligated by its own regulations to assess the integrity\(^{(D34)}\) of the structure, the Dutch Act does not adress measures or guidelines to secure the integrity of the production facilities after their initial design age, \([EL&I, 2003]\). Hence, LE specific assessments need to be made to secure the integrity and safe operation of the foundation, topside and production (support) equipment after the initial design life.

From end 2010 up until 2015 more than 70 L.E assessments need to be executed, \([SSM, 2010]\). Even though the Dutch offshore sector is a mature industry; the former indicates that there is an increased challenge to maintain integrity of the mining installations\(^{(D33)}\), ageing process equipment and decreasing skilled crew to operate them in a safe way \([Nogepa, 2008]\). Which leads to a stronger emphasis on Asset Management\(^{(D05)}\) activities to assure sustainable asset integrity. To administer these measures successfully the availability\(^{(D06)}\), reliability\(^{(D48)}\) and maintainability\(^{(D41)}\) of the complete ageing offshore production facilities, is therefore a major concern of both the Dutch Government and the Duty Holders.

In general the former issues are focusing on the specifics topics such as:

1. no unambiguous endorsements in the Acts are made which will lead in securing the integrity of the production facility during its Extended Life\(^{(D58)}\). The only compulsory evaluation is of the integrity of the structure of the production facility, which is mandatory by the Independent Expert, \([EL&I, 2003]\).
2. no unambiguous Acts or Regulations are in place to secure the integrity and safe further operation of the topside and the installed production (support) equipment, \([EL&I, 2003]\).
3. no guidance has been set-up within the Dutch Offshore industry, to manage the Extended Life of the production facilities.

Following \([SSM, 2008]\) it can be stated:

1. a sense of urgency is felt by all stakeholders;
2. elements of affecting integrity of ageing assets:
   - different SSC, have different design lives;
   - definition of Extended Life;
   - comprehensive safety reviews as basis for securing continued integrity;
   - identification of shortfalls, implementation of improvements;
   - evaluation of ongoing inspection\(^{(D31)}\) and maintenance strategy for its adequacy for Life Extension;
3. focus on occupational safety, lacking focus on process safety.

Taking the former into account, the following question can be asked:

**How can asset integrity also be sustained during the Extended Life?**
2. **Research Approach.**

This Chapter will explain the purpose of the research, formulation of the research question and the method which will are used to perform the research.

2.1. **Purpose of Research**

The research is commissioned by the State Supervision of Mines (present employer of the researcher). As explained in Chapter 1 and in [SSM, 2008] there is no unambiguous endorsement to ensure the Extended Life. Therefore this research is aiming at finding a way to achieve sustainable asset integrity during the Extended Life of the facility. The idea, therefore, is to formulate a guideline that will support:

- getting better control\(^\text{(D09)}\) over the Life Extension Management process;
- recommendations for adapting and improving the current Acts and Regulations;
- the delivery of useful information for the management of the Life Extension\(^\text{(D37)}\) process; and, finally:
  - with aforementioned goals achieving a more substantiated Life Extension assessment\(^\text{(D39)}\).

2.2. **Research Question**

Derived from problem description concerning the need for longer producing with the ageing production facilities. The shortcomings in the management of extending the lives of the ageing production facilities, the research question can be formulated as followed:

**How to get better grip on the Life Extension Management process, of the Dutch Offshore Production Facilities?**

In order to answer the main research question more in-depth research of the problem described in Chapter 1 is required. Therefore the idea is to break down the main research question into sub-questions which should lead to a deeper understanding of the research subject and result in an answer to the formulated main research question.

2.2.1. **Sub-Question 1**

The need for extended mining is described in the introduction. This need results in the wish for an extended operational life of the production facilities. To make it possible to manage this process it will be necessary to define which specific needs should be managed to ensure the safe and effective operation of the facilities beyond their initial life. The above initiates the following sub-question:

**How to determine the main system domain, which will represent the production facilities that need to be assessed by Life Extension Management?**
2.2.2. **Sub-Question 2**

Chapter 1 also explains the concerns about and the need for extending the life of the production facilities. One of the concerns is that there are no clear stated instructions available regarding the total management of the extending the life of production facilities in any of the Acts or Regulations. The answer to this concern is that management principles(s) and/or Regulations(s) need to be researched. This generates the following sub-question:

*Which instruction(s) and/or Regulations(s) could be used for the development of the Life Extension Management process?*

2.2.3. **Sub-Question 3**

Once the structure(s) of the guideline(s) have been defined, the type of management process needs to be determined. The management process needs to be applicable in all phases of the guideline, as described. It should address all actors and stakeholders in relation to their individual tasks (products and services).

*What type of management (support) tools are needed and could be used to support the Life Extension Management process of the offshore production facilities?*
2.3. Research Method

The research will be conducted using an Exploratory Empirical research method as illustrated in Figure 8. The choice to use this type of research will be explained in the following paragraphs.

2.3.1. Research methodology

According to [Routie, 2004] “An exploratory research needs to give insights into and comprehension of an issue or situation. Exploratory research means that hardly anything is known by the researcher about the subject during the outset of the research project”. As the subject of this research is to come up with the “missing” guideline to get control\(^{(009)}\) of the Life Extension Management process of the ageing production facilities the choice of an exploratory study is justified.

The desired approach will be:

- Necessary to rely on secondary research such as reviewing available literature, Acts, Regulations, Standards and earlier publications on this subject. This data will be evaluated during the literature research part of the study.
- The field research will be conducted by means of qualitative approaches such as (in)formal discussions with colleagues (SSM and ECN), foreign supervising authorities (PSA and HSE) and specialized institutes, combined with a more formal approach through in-depth reflection interviews with the actors involved with this topic.
- As part of the research information generated by other initiatives, which were/are run prior and parallel to this study, will be used:
  - The project on Life Extension by SSM, which was started around the middle of 2010, to validate how the Life Extension assessment processes are currently being executed;
  - Projects relating to the Life Extension topic by PSA. PSA initiated its project to determine the boundaries of the re-design qualifications of the production facilities;
  - Projects on the Life Extension topic by HSE. HSE initiated its project in order to propose a roadmap to ensure an unambiguous way of performing Life Extension assessments.

2.4. Research model

The research process will be completed following the research model as shown in Figure 8. This model has the purpose of structuring the study and ensuring consistency in the research.

![Figure 8 Exploratory-Empirical Research model, (Thornhill, Saunders and Lewis, 2006)](image)
The research model is using the following next five consecutive steps:

2.4.1. **Initiation**

The foundation of this research is the fact that I have noted that, when offshore facilities where ageing, some operators of these facilities fail to demonstrate consistently whether their facilities are fit to operate beyond their initial design life. This observation has been reinforced by the needs expressed by SSM in 2008, which also indicate that the management of Life Extension is still not on a level that can guarantee sustainable integrity of the production facility during its Extended Life.

2.4.2. **Theoretical and Practical Foundation**

The first step is the gathering of practical and theoretical data. To define the correct problem, abstraction of the observed data will need to take place. During this process the wide range of information will be reduced to a set of essential information on the research subject.

The second step in the research process is to build a theoretical and practical foundation. The theoretical foundation will be created by literature research on the topic of Life Extension and management processes. The literature research will provide more information and therefore a deeper understanding on the research subject and supply data for solving the initiation problem. Secondly gaining information about Life Extension and the inherent management process will be practiced during the field research of SSM, in order to collect more data and knowledge on how the actors and stakeholder are handling the above processes.

2.4.3. **Problem Definition**

The third phase is describing and substantiating the problem that needs to be researched. The problem will be defined on the basis of the research question. The research question will be broken down into a set of sub-questions, containing the dependent and independent variables of the main question. In the process of defining these sub-questions the design specifications of the guideline and management process will be formulated.

2.4.4. **Experimental Guideline Design**

In the fourth phase the guideline with the corresponding management control functions will be defined and shaped. During this phase the guideline for the management process needs to be finalized to a level where it can be evaluated in practice, and the system boundaries are clearly set (area of control).

2.4.5. **Empirical Research Results**

During the fifth step, the results of the Empirical Research is aiming to provide answers to the research questions. The results phase will need to show and describe the analyzed data that was found. The answer to the research questions will be evaluated with the theoretical and practical information that has been collected during the research.
3. Theoretical and Practical Foundation

3.1. Introduction

This thesis is a continuation of earlier work from a broad field of subjects, aimed at performing and managing an assessment of the Dutch offshore production facilities. The resources used for setting up this work can be divided into the following groups: Firstly the research-based literature that has been produced on Life Extension assessment methods (of offshore production facilities) by field specialists in this subject, specialists like the HSE (UK) and PSA (NO) which are the Oil and Gas mining supervisory bodies of the United Kingdom and Norway respectively. In this part two proven Life Cycle Management (LCM) related methods will be selected and evaluated to determine if they are suitable for use as (starting) point for developing the LE Management guideline. These are the Life Cycle Management principles of the British Standard Institute (BSI) and the Asset Management Control Centre (AMC2). Secondly the globally used Standards and assessment methods, the “industrial best practices”, embedded in ISO and API Regulations and the NORSOK Standards, will be discussed and selected for the guideline if potentially applicable. Thirdly the legal boundaries and endorsements within the Dutch Mining Act and Mining Decree will be studied and discussed for reference purposes where appropriate.

3.2. Literature

According to [Ersdal, 2005], it has only been within the last year that the industry has started focusing on Life Extension of the complete asset (jacket, topside and process equipment). This approach gives a better overview of the technical system (the asset) which needs to be assessed and managed during the Life Extension process.

Most relevant and constructive publications have been collated in Table 3 and Table 4 in pages 91 till 93.

3.3. Guidelines and Assessments

The assessment methods and corresponding subjects in the reviewed literature are building toward a kind of system to support Engineering and Asset Management. The most recent publication by PSA [Sintef Report A15322, May 2010] is a good example of more detailed and in-depth awareness of the complexity of Life Extension of offshore production facilities. This publication compiles and addresses not only the structure of the facility but also the process installations with respect to the threats associated with the ageing of the installations and components.

The publications by [Ersdal et al, 2002 and 2005] have been a fundamental part of the aforementioned report; these publications have highlighted several concerns with respect to the ageing facilities; therefore these publications will be used for reference purposes for the proposed guideline.

To find an answer the main questions of this Thesis a guideline will be developed to control the management of the Life Extension. Aspects for setting up a guideline are:
- production facility seen as a system, ensuring system and cost-effectiveness;
- integrated logistics and Life Cycle Management Control [Ersdal et al., 2005], [Stacey et al. 2008], [Stavenuiter, 2002] and [BSI, 2008].

Furthermore, the introduction of reliability and risk analyses during the management of the LEM process can be determined on a numerical base, the (extra) risks which need to be controlled during the LE assessment. Hence, no production facility has been operated or utilized in the same way [Stacey, 2008], therefore within this research it is assumed that no assessment can be the same on each specific risk level.
The publications of [Kübler, 2006] on applied decision-making in civil engineering have been consulted. The work of the former has been founded on the risk matrix, initiated by the Australian/New Zealand Standardization Organization, under the Standardization norm [AS/NZS 4360 SET Risk Management (D54) Set, 2006], unlike commonly used risk assessment methods (D52) that quantify risks in workshops. This norm embraces a risk decision matrix, which gives a fundamental overview in making high-risk decisions. By applying this structured way of risk decision-making it becomes possible to control this decision-making process, the works of [Kübler, 2006] will be used in a later stage of the research.

3.4. Asset Management Principles

During the literature research two AM methods were looked at, which will be used as the backbone of the Life Extension Management guideline, namely the Asset Management (AM) method as described in the PAS 55 [BMI, 2008] and the Life Cycle Management Systems as described in the AMC base book [Stavenuiter, 2002]. The decision why to study these two Asset Management methods is explained in the next two paragraphs, 3.4.1 and 3.4.2.

3.4.1. PAS-55 [BSI, 2008]

PAS 55-1:2008 strives for the optimal management of physical assets during the entire Life Cycle of the asset, and was established by the British Standards Institution. This PAS provides guidance for good practices in physical Asset Management; typically this is relevant to gas, electricity and water utilities, road, air and rail transport systems, public facilities, process, manufacturing and natural resource industries. The guideline is equally applicable to the public and private sector, and regulated or non-regulated environments [Wikipedia, 2011]. PAS 55 is getting major interest from organizations seeking to demonstrate a high level of professionalism in the whole Life Cycle Management of their physical assets.

The Standard is split into two parts:

- Part 1 - Specification for the optimized management of physical infrastructure assets;
- Part 2 - Guidelines for the application of PAS 55-1.

Figure 9 PAS 55-1 Context and Domain, [BMI, 2008]
Although PAS 55 focuses primarily on physical assets it is not limited to this asset group. PAS55 recognizes that for managing the physical asset it is essential to depend on other asset classes and that they need to contribute to the performance of the managed business context. The model in Figure 9 shows the importance of the interfaces and interdependencies, once again reinforcing the message that a systems integration review is needed.

The shortcoming in this approach is the named “other” asset classes, which are not adherent and integrated in the PAS 55-1:2008 methodology. Other assets are defined as [PAS 55-1:2008]:

- human assets;
- information assets;
- intangible assets;
- financial assets.

There is room for the other classes to provide input for managing the physical asset in the so-called “transition area”. By creating this transition area no synergy between the other asset classes is enforced, so the management and hence the control with regard to the performance of the physical asset can take place without too much influence of the human, information, intangible and financial assets. As for SSM, it is important to have a sustainable Asset Management principle, which will serve as a guideline for the management of the offshore production facilities. PAS 55-1:2008 has no adherent and integrated principle and therefore no impact or performance cooperation principle, which means that the methodology can be applied in a too-wide area of interest of the user, without solid pre-defined control initiators. PAS 55-1:2008 cannot meet the requirements stated in this research and will therefore not be used in this thesis.
3.4.2. **LCM Systems** [Stavenuiter, 2002]

The LCM Systems approach primarily aims to stimulate all logistic actors to fulfill their part in the most cost-effective and effective way by telling them what the result should be and to show them the impact of their contribution to the whole system. The Logistic Process Circle (see Figure 10), is used to establish the system costs-effectiveness. The system process is subdivided into eight process steps. Each step has to be in balance with the preceding and subsequent steps in the cycle, all related to an ILS/LCM analysis.

![Figure 10 The Logistic Process Cycle, [Stavenuiter, 2002]](image)

To manage the asset throughout its Life Cycle, the process circle must be kept in constant balance. As a prerequisite, the process steps must be continuously adapted during the production facility’s initial design life (D36) (about 20-25 years); these steps need to be taken when a production facility changes its initial design criteria, e.g. when it will need to serve beyond its initial design life. The Logistic Process Cycle (LPC) can be used as a backbone for Life Extension Management (LEM). The LPC consists of three dimensions, namely:

- The Operational Environment: where the need or the technical and financial performance of the production facility is defined.
- The Technical System Environment: in reality the technical system is the technical domain, which needs to be managed. In this case it will be the structure and topside of the production facility. When the system boundaries are well defined a system analysis will need to be performed on this created domain [Stavenuiter, 2002].

The third step is to define the logistics process; the logistics process is the support part of the logistics process cycle. The defined steps will name the activities, products, actors and resources, needed to perform Life Extension Management.

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Note: The cost/benefit analysis is not included in the research domain as it is assumed that the responsibilities and/or concerns in respect of revenues and profit should not interfere with asset integrity and therefore the safe operation of the facility. Secondly for setting-up such analyses, can only be performed if reliable data is available, which couldn’t be obtained during this research.
Figure 11 The AMC- LCM system approach, [Staveniute, 2002].

The management of the system plays a crucial role in the Life Extension process, since it converts the requirements into directives and controls the results. According to the AMC approach the management domain (see Figure 11), indicates that this approach is focused on the materiel logistics process which enables the management of the Technical System (the production facility), which in its turn is controlled by an integrated LCM Team (Life Cycle Management Team). The output and input of this domain are initiated by the operational need.

The AMC approach provides clear evidence of sustainable, sound governance to customers, investors, regulators and other stakeholders. Therefore it is a valuable mechanism for ensuring the principles and management of whole Life Cycle planning, risk management\(^{(54)}\), system cost-effectiveness, customer focus, competence and thus sustainability Asset Management, which is also in line with the finding and recommendations of SSM as stated on page 25 [SSM, 2008]. Therefore the AMC approach will be used as starting point in this thesis to formulate a Life Extension Management guideline for the production facility’s Life Extension.
3.5. Standards, Assessments methods and Acts

Until recently, the offshore structural engineering discipline has been focused on the; design, installation, commissioning and operation, of the production facilities [ABB, 2008]. The above indicates that most of the literature, Standards, (recommended) Practices and Acts, were developed mainly for these Life Cycle phases. It can therefore be assumed that assessments of existing production facilities do not have the same level of practical and theoretical experience, which can result in shortcomings in comparison to the former elaborated Life Cycle phases.

The purpose of an assessment of an existing structure for the purpose of Life Extension is to ensure that the likelihood of failure of the structures, production and/or safety equipment is equivalent to a new production facility.

The most generally accepted and used Standard for offshore structures is ISO 19900 “Petroleum and natural gas industries – Offshore Structures – Part 1: General Requirements”. This Standard is a general Standard only; it does not specifically prescribe how to perform Life Extension assessments. The above therefore refers to ISO 19902:2007; this Standard relates specifically to the assessment of an ageing offshore structure for the purpose of Life Extension. This internationally accepted Standard also represents the industry’s best practices. The Norwegian Industry has worked out this Standard in more detail in the NORSOK-N006:2009 Standard. Therefore the NORSOK-N006:2009 Standard will also be researched in this literature study. NORSOK Standards are not internationally (globally) accepted and used, but are commonly applied within Europe. As NORSOK-N006:2009 is based on the internationally accepted ISO19902:2007 the latter will also be used in the research, with reference to the NORSOK Standard where the ISO Standard has shortcomings in comparison to the aforementioned NORSOK Standard.

With this reference method the requirement of the Dutch Mining Act (2003) has been addressed; the Dutch Mining Act (2003) stipulates that the latest state of techniques and knowledge be applied. ISO 19902:2007 will therefore be used as the base reference for the future guideline.

3.5.1. ISO 19902:2007

Specification 19902:2007 from the International Standardization Organization (ISO) specifies requirements and provides recommendations applicable to the following types of fixed steel offshore structures for the petroleum and natural gas industries: caissons, free-standing and braced; jackets; mono-towers; towers. In addition it is applicable to compliant bottom founded structures, steel gravity structures, jack-ups, other bottom founded structures and other structures related to offshore structures (such as underwater oil storage tanks, bridges and connecting structures), to the extent to which its requirements are relevant. It contains requirements for the planning and engineering of the following tasks:

- (re)design, fabrication, transportation and installation of new and existing structures as well as their future removal; in-service Inspection and integrity management of both new and existing structures;
- a detailed assessment procedure for existing structures;
- evaluation of structures for reuse at different locations.

Other Standards, like API RP2A-WSD (API 2000) and API RP2 SIM (API 2010 Under Development) also include procedures for assessment at the same level of detail for existing structures and Structural Integrity Management.
3.5.2. NORSOK Standard N-006:2009

The basic Standard for offshore structures is NORSOK N-001, which especially refers to ISO 19900. This NORSOK Standard provides additional requirements for the assessment of the structural integrity of in-service offshore structures and for Life Extension.

The NORSOK N-006 Standard specifies general principles and guidelines for the assessment of the structural integrity of existing offshore structures as a supplement to NORSOK N-001 and should be used in conjunction with NORSOK N-003, NORSOK N-004 and NORSOK N-005. This NORSOK Standard serves as an alternative to NORSOK N-001 for cases where structures are to be operated beyond their original design requirements and structural resistance is not easily verified through ordinary design calculations, and where use of additional information gained through the life of the structure can be used to demonstrate structural adequacy. The Standard also recognizes the operational state of the facility, namely the facility has to be used for production or will be in hibernation\(^{(26)}\). The disadvantage of the Standards is that this bifurcation is not applied in the decision-making flow diagram.

The general principles of this NORSOK Standard are applicable to all types of offshore structures used in the petroleum activities, including bottom founded structures as well as floating structures. As the majority of ageing\(^{(01)}\) facilities are fixed structures of the jacket type, the detailed recommendations of the Standard are most relevant for this type of structure. These detailed (mathematical) recommendations are the difference between the ISO and API Standards, which gives this Standard added value for the assessment of ageing structures.

Furthermore, the general principles of this NORSOK Standard are applicable to different types of materials used including steel, concrete and aluminum. The general principles of this NORSOK Standard are applicable to the assessment of complete structures including substructures, topside structures, vessel hulls, foundations, marine systems, mooring systems, subsea\(^{(07)}\) facilities and mechanical outfitting that contributes to maintaining the assumed load conditions of the structure.

3.5.3. API RP 2A-WSD

This Recommended Practice (RP) for the Planning, Design and Construction of Fixed Offshore Platforms from the American Petroleum Institute (API) contains engineering design principles and good practices for Work Stress Design (WSD), which have evolved over the development of offshore oil resources. This Standard has been the base for the revision of ISO/NEN19902:2004. Good practice is based on good engineering; therefore, this recommended practice consists essentially of good engineering recommendations. In no case is any specific recommendation included which could not be accomplished by currently available techniques and equipment. Consideration is given in all cases to the safety of personnel, compliance with existing Regulations, and non-pollution of water bodies.

Offshore technology is growing rapidly and in areas where the committee felt that adequate data was available specific and detailed recommendations are therefore provided. In other areas general statements are used to indicate that consideration should be given to those particular points. Designers are encouraged to utilize all research advances available to them. As offshore knowledge continues to grow, this recommended practice will be revised. Hopefully the general statements contained therein will gradually be replaced by detailed recommendations, which will make this Standard for LE assessment more applicable.

In this practice reference is made to the latest edition of the American Institute of Steel Construction (AISC) Specification for the Design, Fabrication and Erection of Structural Steel for Buildings (see Section 2.5.1a). While the use of latest edition of this specification is still endorsed, the use of the new AISC Load & Resistance Factor Design (LRFD), First Edition, is specifically counter-recommended for the design of offshore platforms. The load and resistance factors in this new code are based on calibration with building design practices and are therefore not applicable to offshore platforms. Research work is now in progress to incorporate the strength provisions of the new AISC LRFD code into offshore design practices that can also be used for Life Extension assessments\(^{(39)}\) Evaluations.
3.5.4. API RP2-SIM

The offshore industry is currently developing a new recommended practice (RP) that will focus on the Structural Integrity Management (SIM) of existing offshore structures. The proposed API RP2-SIM will be a significant change to existing practice and provide considerably more in-depth guidance for maintaining existing platforms than is available in the present API RP 2A. The key concept of the proposed RP will be the use of Risk-Based Inspection strategies, which will require the engineer to understand the platform's likelihood of failure and the consequences of such a failure. RP 2SIM will also, for the first time, provide the engineer with fitness-for-purpose acceptance criteria against the platform's ultimate load capacity, measured as the Reserve Strength Ratio (RSR). To take full advantage of the provisions of RP-2SIM the engineer must have knowledge of the likelihood of platform failure, which is best determined through an understanding of the platform's ultimate strength.

The obtained information can also be used to demonstrate fitness-for-purpose and to assess the need for risk reduction and/or mitigation measures. The recommended practice will focus mainly on the structural integrity management, and will make a minor contribution to the assessment of the production facility as a whole. This practice can be considered the counterpart of the widely used and accepted ISO 19902:2007, except all data that is useful with regard to Life Extension assessments is similar, like the general assessment process shown in Figure 12.

![Figure 12](image.png)

*Figure 12 Process to ensure the fit-for-purpose of an offshore structure [ISO 19902, 2007], [API RP2-SIM, 2010]*

- **Data**: managed information for archive and retrieval of SIM data and other pertinent records;
- **Evaluation**: of structural integrity and fitness for purpose, development of remedial actions;
- **Strategy**: overall inspection philosophy & strategy and criteria for in-service Inspections;
- **Program**: detailed work scopes for inspection activities and offshore execution to obtain quality data.
3.5.5. Dutch Mining Act and Decree (2003)

In general the Dutch Mining Acts and/or Decrees are limited to stipulating regulatory measures in respect of Life Extension assessments\(^{(D39)}\) of the production facilities [EL&I et al, 2003].

Regulations currently\(^{4}\) in force:

- Mining Act, Article 7.2;
- Mining Decree, Articles 50 and 53 through 56 & Article 63 (Art. 53a added in June 2007);
- Labor Decree, Article 3.3 par. 1;
- Labor Decree, Article 3.37 k par. 1.

According to Art. MBB.53 the operator must periodically assess the technical integrity of the production facility. Every five years an assessment program needs to be formulated. For each subsequent year the operator describes the components and how they will be inspected.

Paragraph 3 of the article referred to above states that proper arrangements must be made with respect to the content of the assessment program and the annual inspections.

After the installation of the production facility but before the facility is taken into use an Independent Expert (I.E.) must issue a Certificate of Fitness (CoF). This certificate is valid for 5 years, with a maximum number of renewals of the CoF to the end of the design life\(^{(D36)}\) of the production facility

3.5.5.1. Certificate of Fitness (CoF)

The Mining Act and Decree refer to Independent Experts. These Independent Experts are responsible for conducting the statutory certification process as outlined in the explanation of the Mining Decree. The CoF can be used to stipulate the mitigating measures that are necessary to extend the life of the production facility at an acceptable safety level. Such a mitigating measure may be, for example, that the facility is transformed from a manned to an unmanned operation and the level of emergency (evacuation) procedures and equipment are changed. Although these (mitigating) measures are valid for use in the final evaluation of the Life Extension assessment, they are outside the scope of this research.

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\(^{4}\) The Act makes no endorsements with regard to the Life Extension subject. After the design Life the CoF can only be renewed if an Life Extension Assessment of the facility structure has been performed successfully. The LE Assessment by an Independent Expert is mandatory and the validation needs to be performed by an Independent Expert. The I.E. cannot formulate a new 5-yearly Inspection program if the initial design age has passed without verifying the Technical Integrity of the production Facility by means of an I.E Assessment. The I.E. must use the latest knowledge within the industry’s best practices; the CoF provides the I.E. with options for commenting on the production Facility status [EL&I - Article 53, 2003]. As an result of the assessment mitigating measures may be required in respect of the continuation of the supervision and management of the structural integrity of the facility.
3.5.6. **Position of the Dutch (Mining) Act and Decree**

Due to the nature of the Dutch natural gas reserve, the individual sources are scattered. The Dutch natural gas reserves are spread over one huge natural gas field, the Groningen field, and a large number of small fields. This results in the Netherlands having a special position within the EU which may lead to other considerations about the relationship between production and trade and related Acts and Regulations. Those considerations in particular are taken into account in the small fields policy, expressly strengthening the link between production, trade and transport of small gas fields. Figure 13 schematically depicts the perspective of the EU and the Netherlands [PRC, 2007]. The Netherlands has laid down the small fields policy in the Gas Act, which covers both the production and marketing of natural gas.

![Figure 13 Positions of Act, Decree and Regulations, [PRC, 2007]](image)

To be able to manage and generate opportunities for controlling the mining activities within the Netherlands the Mining Act has to be complied with. The Mining Act stipulates how certain activities associated with mining have to be executed. When certain subjects in the Mining Act need to be expanded on in greater detail the Mining Decree is used; the Mining Regulation has the same purpose but rather towards the Mining Decree. The hierarchy between the three is demonstrated in Figure 13, which is applicable to all Dutch Acts. The Mining Act furthermore states that the operator has a so-called “duty” to comply with all Health, Safety and Environmental (HSE) issues. This article directs the operator to the applicable Acts, like Labor Acts, Environmental Acts etc.

This Thesis uses the clauses of direct relevant Acts, Decrees and/or Regulations regarding Life Extension (as explained earlier), although in a later stage of this research Health, Safety and Environment will be incorporated in the System Analyses.
4. Terms of Reference for the Life Extension Management Guideline

4.1. Introduction

In the previous Chapters it has been explained that there is room for improvement when it comes to the Life Extension Management. From a Duty Holder point of view, it could be recommended that the Regulations should be made more explicit and the whole process flow should be more structured and fine-tuned to achieve optimal system and cost effectiveness. Once this has been achieved SSM can then audit and control the validity of the LEM process systematically and consistently among all the actors and stakeholders involved in the LEM process.

This Chapter describes the development of the guideline. In Chapter 3.4.2 the applicability of the AMC approach has been found the most commensurate with the need for a guideline that incorporates the need for Life Extension. The AMC approach can delineate the boundaries within which the LEM control must take place and define the relationships between the actors and stakeholders involved.

For the purpose of establishing the Terms of Reference (ToR) for formulating the Guideline for Life Extension Management, a recognized problem analysis method is proposed [De Leeuw, 1993]. This method is based on the following three steps, which have been elaborated on in Chapters 1 through 3 of this Thesis:

1. problem analysis;
2. problem synthesis;
3. problem specification.

The objective of the problem analysis, synthesis and specification is to obtain a structured and well-defined problem definition, in this case the properly substantiated Terms of Reference. According to De Leeuw, the key elements for analyzing the problem are:

- formulation of the objectives;
- researcher’s perception of the reality;
- Researcher’s perception with relation to reality.
To start with the formulation of the objectives the systematic management approach of de Leeuw [1993] is taken as starting point (figure 14). which is based on three manageable entities, centralized in the set-up, namely:

- the (operational) environment in which the manageable system will need to perform;
- the manageable system, which will need to operate within the operational environment;
- the management system, which will control and direct the operational environment versus the manageable system. These control activities and direct actions are constantly in motion to achieve balance within the operational need and the manageable system performance.

The LCM Systems model of Stavenuiter, as shown in Figure 15, is based on the basic management model of De Leeuw [1993], in which the physical asset has been added - and is therefore better suited for substantiating the LEM guideline. Both Figure 14 and Figure 15 show numerous control and directing actions; these actions will need to be quantified and addressed so that they will achieve their intended effect (D13). To achieve this, Terms of Reference (ToR) will need to be defined for each action, entity and actor/stakeholder. In addition, with regard to the actors involved in the Life Extension Management of the offshore production facilities, Stavenuiter has defined the interaction between these actors, providing a clear view of the interrelationship between the involved actors.

The purpose of the Terms of Reference is to show how the scope will be defined and developed. They should also provide a documented basis for making future decisions and for confirming or developing a common understanding of the scope among the actors and stakeholders. In order to meet these criteria, success factors/risks and restraints, should be fundamental keys.
4.2. Perception of Reality

To get a clear perception of the actual performance of the Duty Holders and the Independent Expert, SSM started a field study on Life Extension parallel to this study. The field study has found that there is no consistent method of performing the Life Extension, by the former mentioned, reference is made to \cite{SSM, 2010}. Therefore this research has been expanded, because it has shown that there is no unambiguous way for guiding the management of the Life Extension. It has been observed during the literature study that the Dutch Mining Acts and Regulations are not designating Life Extension as an action that must be performed.

The field research of SSM has provided greater clarity regarding the marginal directive abilities of the former mentioned, the actors involved in the Life Extension Management have the freedom to determine their own way of performing Life Extension on the ageing production platforms. Hence, it can be concluded that uniformity of performing of Life Extension assessments is missing, a uniform guideline should guarantee, uniformity and quality of the Life Extension Management.

The designation of an Independent Expert in the Dutch mining Acts and Regulations, who validates the Life Extension process performed by the Duty Holder, is aimed at avoiding the above situation. The Independent Experts who are responsible for validating the Life Extension assessments performed by the Duty Holders have been interviewed.

Two of the three Independent Experts were interviewed, namely:

- Bureau Veritas, \cite{SSM, 2010};
- Lloyds Register, \cite{SSM, 2010}.

The third Independent Expert active on the Dutch Continental Shelf, is Det Norske Veritas (DNV) with a small 1.4% share in the Life Extension "market". DNV was not interviewed, since it was not able to fit in with the timeframe of this research. Accordingly, because of their position in this part of the Dutch Offshore market, the interviews focused on Bureau Veritas and Lloyds Register.

The outcome of the interviews during the Life Extension project, \cite{SSM, 2010} are summarized with reference to the two aforementioned Independent Experts. The main (preliminary) conclusions from the two interviews are:

- both Independent Experts have procedures in place that are used as guidelines for performing Life Extension. The procedures are not accredited by the Dutch Accreditation Council (DAC) and are therefore not consistent with regard to design, applicability and managing the validation of the Life Extension assessment\cite{D39}. Hence, the LEM is not controlled in a consistent manner, in view of the differences between the Independent Experts.
- the Duty Holders are not consistent in formulating the Life Extension assessment, with regard to utilizing the latest assessment knowledge, applying the correct history of the facility and the failure to manage the Life Extension assessment in a planned and timely manner.
- both Independent Experts have opinions about the position of SSM. SSM does not interfere with the Life Extension assessment process, which gives the Duty Holders the freedom to perform the Life Extension assessment at their own discretion. Furthermore, a uniform industry wide guidance is missing, which must set a guide for performing and Managing the Life Extension process.
4.3. Relation of the proposed solution with Reality

As it is possible to establish the relation to reality by defining a system model that needs to be controlled and acknowledging the “tangible entities”, according to Stavenuiter [2002] LCM model Figure 15.

Firstly, the physical systems of the production facility determined by functions and installations. The production facility will be broken down, in predefined steps, according to the AMC Functional System Breakdown Technique [Stavenuiter, 2002]. Meeting the applicable Acts and Regulations, this means that the production facility will be broken down into:

- a functional system that represents the production facility;
  - Life Extension Management; pursuant to the Mining Act [EL&I, 2003] the Duty Holder is responsible for the technical and operational management of the production facility.
- operational functions that need to be ensured and guaranteed;
  - Structural Integrity [EL&I, 2003].
  - Health, Safety and Environmental (H.S.E) sustainability [EL&I, 2003], [Labor Act, 2010] and [HSE, 2009].
  - Operational Integrity [EL&I, 2003], [SSM, 2007].
- technical functions; these are the physical functions of the production facility;
  - Jacket; this is the supporting structure of the production facility, [SIS, 2006].
  - Topside; this is the unit that is placed on top of the jacket, which houses the production, safety, lodging and power installations [PSA, 2010].
- installations that need to be taken into account during the assessment [OLF122, 2008].
  - Reference is made to appendix 1, Chapter 1.4, for both the topside and jacket installations.
  - For the safety installations, reference is made to appendix 1, Chapter 1.4.5.

Secondly, the LEM Products and Services needed to ensure the Extended Life period; these responsibilities and Services are defined and clarified in Chapter 5.1.5 and Chapter 5.1.6; a shortlist is given in Table 2.

Related to the (prime) actors and other stakeholders; the installations are considered to be the physical elements for which a logistic actor (or group of actors) is responsible. For this reason a logistic actor is recognized as a significant element in the logistic process, see Figure 33. In this context the (prime)actors are [HSE, 2009]:

- Operator (Prime actor), reference to appendix 1, Chapter 1.5.1;
  - Maintenance Specialists, reference to appendix 1, Chapter 1.5.3;
  - Design Specialist, reference to appendix 1, Chapter 1.5.4;
  - Offshore Installation Manager, reference to appendix 1, Chapter 1.5.6;
- Independent Expert (Prime actor), reference to appendix 1, Chapter 1.5.5;
  - Inspector;
  - Design Specialist;
- SSM (prime actor), reference to appendix 1, Chapter 1.5.7.
4.4. Formulation of the ToR specifications

The objective of the Life Extension Management (LEM) Guideline is to provide clear guidance for the actors and stakeholders who are dealing with Life Extension of the production facilities. The need for transparent and structured information, explained by some by the “gap” within the current Acts, Regulations and Standards, will be a subject for attention; reference is made to appendix 1, paragraph 1.8. In short: the guideline will provide information and define the products and services of the actors involved in consecutive steps that need to be performed to lead the ageing facility into its Extended Life.

Based on the survey results (see Ch. 2 & 3) the ToR ‘objectives’ of a Life Extension Management guideline are defined as follows:

1. the LEM Guideline should consist of a clear overview of LEM principles, which could be realized with a System Modeling Tool and a communication vehicle for all actors involved over the whole LEM period;
2. the System Modeling Tool should be capable of modeling a complete production facility as a system;
3. the LEM principles/requirements should be taken as a baseline reference/norm;
4. the LEM products and services should be adjustable and applicable at all levels of the system model and in all phases of LEM;
5. the model should provide LEM information about: LEM-related system cost-effectiveness during the Extended Life of the production facility. To manage and control these aspects they should be related to the availability, reliability and capability. This in combination with the costs, need and quality per product and actor;
6. management information should be related to the asset (technical system) as well as to the LEM process/organization;
7. the following information should be available per actor: task assignment, resource information accounted for; define, manage and control;
8. the System Modeling Tool should be useable as a monitoring and control tool (comparison of baseline figures with actual figures) as well as a support tool for management improvement by facilitating ‘what if’ analyses;
9. all LEM Guideline elements should be accessible to all logistic actors (on the Internet/Intranet) and should be user-friendly, e.g. through communication supported by a web portal.

From the above it may be derived that for “getting control” of the Life Extension Management of the ageing production facilities it is necessary to use a systematic approach. The systematic approach will affect synergy between products and service of the (prime) actors and the required technical performance of the production facility during its Extended Life. For effective management control systems in general the following prerequisites are derived from the literature [de Leeuw, 1990], [Sol, 1995]:

- realistic objectives;
- relevant control measures;
- knowledge about the effects of control measures on the system to be managed;
- knowledge about the environmental influences on the system;
- knowledge about the actual state of the system;
- sufficient data-processing capacity for the disposal of information relevant to taking the right control actions.
The former mentioned summary list contains the actual control measures needed, which are currently lacking in the execution of the Life Extension assessment processes. The assessments are not performed in a timely manner, the results of the assessments are not consistent and the performance of the production system as a whole is not determined. Hence, the performance and inherently the cost of the production facility during its Extended Life are not determined (ref.: appendix 1, paragraph 1.4). The intended LEM Guideline should give interpretation to the aforementioned and address the tasks and deliverables of the involved actors. Hence, for all actors and stakeholders involved it will be a clear document designed under the supervision of SSM, to offer all products and services required from an industry-wide perspective in a structured and transparent manner, whereby the LEM process will be manageable.

According the AMC approach as described in Chapter 3.4.2 has been used for specifying the ToR, and must include the following items:

- well-specified LEM products and services;
  - by applying System Analyses to the LEM process, Chapter 5.1;
- transparent LEM process structure;
  - by developing a process diagram by structuring the LEM phases, Chapter 5.2;
- key performance indicators;
  - through formulating KPIs for LEM, Chapter 5.3;
- transparent (technical) system breakdown structure;
  - by developing the LEM System Modeling Tool, Chapter 5.4;
- system effectiveness measures;
  - by developing the LEM System Modeling Tool, Chapter 5.4;
- system cost measures during the Extended Life;
  - by developing the LEM System Modeling Tool, Chapter 5.4;
- management control instruments;
  - realizing an LEM communication platform, Chapter 5.5.
5. **LEM Guideline Design**

Based on the elaboration in this Chapter the complex field of Extending the Life of the production platforms and the associated Management of the Life Extension process will be explained. The conceptual design of the LEM principles based on the ToR established in Chapter 4 will be structured on the basis of the following sub-tasks:

1. applying System Analyses to the LEM process;
2. developing a process diagram by structuring the LEM phases;
3. formulating KPIs for LEM;
4. developing the LEM System Modeling Tool;
5. realizing an LEM communication platform.

### 5.1. System Analysis Method

The System Analysis Module (SAM) as developed by Stavenuiter is based on the (integrated) Logistics Process Cycle (LPC) composed of eight defined entities, as illustrated in Figure 16. The definition of the system (D56) and LEM process structure is based on the following reasoning.

As a starting point it is assumed that the LEM process structure is directly related to the installation entities (functional packages). The installations are considered to be the physical elements for which a ‘prime’ actor (or group of actors) is responsible. By this reasoning a prime actor is recognized as a significant element in the LEM process. In this context an actor could be: the asset owner/manager, operator, legal entity but also design department, the workshop, or the specialized contractor if applicable.

Meeting the required installation sustainable (integrity) requires LEM products and services. As systems become more complex, installations become more complicated. This means that more LEM monitoring and control products and services are necessary, as explained in the earlier Chapters.

Furthermore, the offshore gas and oil industry in general can be defined as a “low probability, high risk” industry [HSE, 2009]. According to Kübler [2006], the probability of unwanted events is the result of taking risk (D50) within the decision making (D10) process, which has been a result in most of the cases, that risk is valued and decided upon on within the budgetary constraints. Therefore “Risk” involved during the decision making process, has been added to the LPC entity “Budget”.

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Stavenuiter, 2002 states that providing the required products and services on schedule will require well-tuned LEM activities for the whole LE period. In this context the high level LEM activities are:

- a well-managed LEM process;
- defining and executing LEM in a structured way;
- defining the system performance for the Extended Life;
- clear, open and transparent communication.

Performing these activities requires well-equipped and competent actors. To equip these actors a range of resources are essential, such as competent personnel, infrastructure, material, tools, etc.

Based on the concepts described above the elements of the logistic process are modified in line with the LEM guideline specifications. The need for LE is the driving initiator behind the demand for extended production beyond the initial production facility’s design life.

Figure 16 Modified LPC model for LEM purposes
5.1.1. Life Cycle Phases for SAM

The System Analysis Method (SAM) for LEM is based on the SAM of the AMC principle. The AMC SAM starting point is the Life Cycle phases defined within the AMC methodology (see Figure 17), which are [Stavenuiter, 2002]:

- specify system functionality;
- acquire system functionality;
- achieve (system) and cost effectiveness;
- justify phase-out.

As described in Chapter 5.2 LEM takes place at the end of the initial design life of the facility, which is the phase in which this research, the system and cost effectiveness must be established. The Life Cycle phases for LEM are added to the basic AMC Life Cycle model which are:

- validate and ensure system functionality; the LEM process takes place in this phase;
- achieve and retain (system) cost effectiveness.

As explained earlier, the phase of performing the Life Extension is part of and will need to be performed during the initial design life of the facility, see Figure 19. As explained earlier, before Life Extension it must be determined if the facility’s life can be extended. According to the AMC principle it means that the SAM for LEM is a design analysis, see Figure 16.
Chapter 5.1, will address subject of the activities that need to be performed for a system analysis for LEM. These activities are addressed in detail, including the applicable Acts, Decrees, Regulations and Standards specific to the Dutch Continental Shelf, in Appendix 1.

5.1.2. LEM Needs

Based on the LPC (see Figure 16) an iterative approach has been formulated for determining the operational LE requirements. This means that the analysis phase starts with a rough specification of operational needs to be refined later in two or more LPC rounds. This will provide an adequate set of baseline requirements, translated in the Availability, Reliability and Capability requirements of the facility. These specifications are described in concrete terms so that they can function as a baseline, the concrete terms can serve as KPI's to determine if the facility is meeting its “need” requirements. Further elaboration on defining the KPI’s, reference is made to Chapter 5.3.

The need for Life Extension is initiated by the operator; the operator is responsible for all operational, maintenance and HSE issues throughout the complete Life Cycle of the facility. The operator will therefore need to prepare and submit an application for consent for an Extension of the Life of a facility to the Independent Expert. When the application has been agreed upon the Independent Expert will assess the Life Extension assessment performed by the operator [EL&I, 2003].

The Dutch Government has recognized the value of maintaining existing infrastructure and is developing initiatives to convince the various operators to Extend the Life of their facilities. Facility life can be extended by a two-pronged approach [ECN, 2009]:

- Ensuring cost-effective operations, thereby postponing the moment when it becomes uneconomical to operate a facility;
- Processing more gas (the operational need), with the aim of lowering the unit technical costs of producing the gas, thereby also postponing abandonment of the facility.

For the stakeholders involved, who will be managing the Life Extension, will need to determine the time of which the facility needs to operate beyond its initial life. It is crucial to determine the feasibility of Extending the Life of the facility with respect to the technical and operational performance and expenditures of the facility during the Extended Life.

The in this paragraph indicated approached and the feasibility of Extending the of the facility, will influence the period of which the life of the production facility, will or can be extended.

5.1.3. LEM System Functionality

This paragraph describes the system functionality as part of the technical system of the offshore production facilities. Although system functionality and the performance of the corresponding installations are implicitly linked together, the system functionality and supporting installations will be determined separately. The full support of system functionality is essential to ensure that the operational requirements can be fulfilled, also during the LE phase. The System Functionalities direct influenced by the LEM processes are:

- operational Integrity;
- structural Integrity;
- HSE Sustainability.

It is the responsibility of the LEM team to ensure that it is done in a cost-effective way.

Appendix 1, paragraph 1.3, gives a detailed description of the System Functionality determination approach.
5.1.4. **LEM Installation Performance**

The next step is to determine the installation performance. The following LEM related installations are defined, [PSA, 2010, OLF122, 2008, HSE, 2009]:

- jacket structure;
- topside structure;
- transport pipelines, risers and subsea systems;
- process installation, including back-up process installation;
- auxiliary installations;
- safety installations;
- material handling installations;
- logistic installations;
- marine systems.

During the field research, [SSM, 2010], the industry has indicated that there is a demand for two types of Life Extension for the production facilities namely for:

- hibernation phase ($^{(D26)}$);
- extended operational phase.

The difference in setting-up the guideline is determining the needed installation performance, according to the operational need. Respectively hibernation or extended operation. The differences in assessment have been defined in (Att.01, paragraph 1.9) and Figure 31. Although Life Extension in hibernation ($^{(D26)}$) phase is out of the scope of this research, it will be professed for potential further research on this topic.

For an existing structure it can of course be concluded that it has not failed yet, [SSM, 2010] It has withstood the loads that the structure has been exposed to. The nature of the loads that it has been exposed to, is however not necessarily known in great detail. An existing structure shall be assessed to demonstrate its fitness-for-purpose if one or more of the following conditions (initiators) exist [Ersdal et al, 2005] and [ISO/NEN19902:2007]. In other words, an existing facility, has to be as good as a new one. To ensure that the whole of the production facility is fit for purpose for an Extended Life, it is necessary to manage the LE of the facility as one system, installations and components, [PSA, 2010].

Appendix 1, paragraph 1.4, gives a detailed description with the defined installations based on the role and impact of the installation in the functional system breakdown.
5.1.5. **LEM Products and Activities**

Achieving the installation performance in relation to the LEM objective 'specify the system functionality' means that the physical products and services are based on the specified information from the first two elements. The LEM team is responsible for the quality and completion and for ensuring that it is done in a cost-effective way.

With regard to a (SSM) checklist based on the above results (see Table 2) the main products and services are determined and listed below.

As a minimum the following aspects should be considered [HSE-RR684, 2009], [OLF122, 2008] and [Stavenuiter, 2002]:

- management structure;
- roles and responsibilities;
- SIM activities;
- competency management.

![Life Extension Management Team](image)

*Figure 18 Life Extension Management Team, [Stavenuiter, 2002] & [HSE, 2009];*

The Management of the Life Extension assessment process, plays a crucial role, since it converts the requirements into directives, and controls the results. According to the LCM principle the domain of management is as in Figure 15, which indicates that this approach is focused on the Logistic process, the management of the Technical System (the production facility), controlled by an integrated LCM-Team as per Figure 18.

Appendix 1, paragraph 1.5, gives a detailed description with respect to the products and activities that need to be delivered and performed by the (prime) actors involved in the LEM process.
5.1.6. **LEM Actors and Resources**

The LEM actors are determined by looking not only at the Duty Holder organization but at all stakeholders. Special attention is paid to the resource qualifications, which have been professed in deeper detail in Appendix 1 Chapter 1.5 to 1.6.

5.1.6.1. **Management Structure, by the operator**

As per Mining Act [EL&I, 2003] the operator is responsible for the Life Extension assessment, therefore the Duty Holder should have in place a transparent and effective management structure, with the actors named, which covers the Life Extension items, see Chapter 3.5.

5.1.6.2. **Roles and Responsibilities**

Roles and responsibilities can vary depending on the organizational set-up, complexity, number of structures and other factors. This section does not set-out firm requirements for the various roles, but provides a typical example of roles and responsibilities within a LE process, which has been found to work in practice, [SSM, 2010]. The actual responsibilities for personnel may vary between organizations. However, it is the Duty Holder’s responsibility that a suitable organizational structure is in place.

5.1.6.3. **Maintenance Specialists (MS)**

The maintenance specialist are appointed by the Duty Holder and are responsible for ensuring performance Standards in platform safety case relating to structural and technical integrity are met.

5.1.6.4. **Inspection Contractor (IC)**

The IC is typically contracted and controlled by the MS, the IC supplies trained and specialized personnel and resources to carry out routine surveys and Inspections of the structure of the facility and technical installations.

5.1.6.5. **Design Specialist (DS)**

The DS is responsible for following-up the Life Extension assessment and to define the processes by which the Life Extension objectives are set-out and how to be achieved.

5.1.6.6. **Independent Expert (IE)**

With the introduction of the Safety Case regime and Design and Construction regulations within the Mining Act of 2003, the certification system was replaced by risk based and goal setting activities with independent verification. The IE is appointed and reports to the Duty Holder to provide assurance that the Life Extension assessment is performed correctly. The role of the IE is specified in [EL&I, 2003] and forms part of the whole Life Cycle of the platform Integrity validation process.

The responsibility of the IE is to verify that the Performance Standards for structural safety critical elements have been met in accordance with the Written Scheme of Verification, as per [ISO19902:2007] produced by the IE in agreement with the Duty Holder.
5.1.6.7. **Offshore Installation Manager (OIM)**

As the person responsible for safe operation of the offshore platform, the OIM will have a strong interest in the Life Extension process and will work closely with the operator and others to facilitate the delivery of (historical) information needed to perform the Life Extension assessment.

5.1.6.8. **State Supervision of Mines (SSM)**

SSM is the supervising authority, which has been appointed by the minister of EL&I. The task of SSM is to validate if the Life Extension Management and risk assessment system, set-up and executed by the Duty Holder are lived up to, this way of working is in the light of the goal setting Acts and Regulations endorsed in 2003, [SSM, 2007]. In these Acts no specific tasks are addressed to SSM, for controlling and validating the Life Extension assessment process. The current position of SSM is on a big distance with regards for supervising the overall process, not more than receiving and checking the new CoF is done. The industry has made remarks on the current position of SSM, [SSM, 2010] and therefore the position as in Figure 29 is proposed in this thesis, to integrate SSM in the management of the Life Extension. The manner of inspecting and validating is set in SSM business operation system (2010 version) and strategy program, [SSM, 2007]. The following tasks should be addressed to the responsibilities of SSM:

- **Audit**

The SSM should have in place and maintain an audit program. The audit program should:

1. Determine whether or not the Management of the Life Extension process:
   - is effective in meeting the Life Extension guideline and objectives;
   - is effective in meeting all the Duty Holders legal obligations with respect to LE;
   - effectively manage structural and technical integrity risks, which are forthcoming from the Life Extension assessment;
   - has been properly implemented, maintained and recorded.

2. Review the results of previous audits, reviews and the action taken to rectify non-conformances.

3. Provide information on the results of the audits to the all actors involved.

- **Review**

The SSM should have in place a review process

The objective of the review process is; to review how the Life Extension Management processes can be improved on the basis of in house, external experience and industry best practice.

The review should:

- address findings from the audit program;
- include acquisition of knowledge on new techniques and technologies (including for example Inspection techniques, analysis tools, risk assessment methods and monitoring methods) and practices and these should be evaluated to establish their potential benefit to the Life Extension Management.
5.1.6.9. Competency of the LEM Team

The operator is responsible for performing the Life Extension assessment, which includes competency of its own personnel and a duty of care with respect to the competency of external contractors. It is therefore required that the operator acts as an intelligent customer when purchasing services from external contractors. Competence of personnel relates to the relevance of their education, training and experience to carry out their role within the Management of the Life Extension. The level and area of competence differs between roles.

Guidance is provided in [ISO 19902, 2007 Section 24.8] and [API RP 2SIM, 2005 Section 1.5] on the topic of competence Management for Life Extension.

A more detailed description on the content of paragraphs 5.1.5 and 5.1.6 is given in appendix 1, paragraph 1.6.

5.1.7. Budget and Risks

Although the Analysis Module is not intended for a thorough cost estimation it should be possible to superficially estimate the cost on the insight gained so far. Obviously the accuracy of this will greatly depend on the available expertise. A final cost estimate will become available when all the LEM actors have been modeled in the LEM model, see Figure 23. Final modeling will be described in Chapter 5.3.

Based on the outcome of a financial model decisions will be made, which will be based on risk acceptance criteria and imply that an acceptable risk level is defined in some form, and the exposure level for personnel and environment is compared to this level [Aven, 2003].

The development of these acceptance criteria can differ from the predefined acceptance criteria of regulatory bodies, acceptance criteria developed from cost benefit analysis, or acceptance criteria defined by evaluating the safety level in the industry best practices like ISO, API and the NORSOK-N006 Standards for Live Extension assessments. The ethics in relation to decision making in high-risk situations are detailed further in appendix 1, paragraph 1.7.1 and Appendix 2, paragraphs 2.1 through 2.3.2.
5.2. Developing the Process Diagram by structuring the LEM phases

The LEM phases are be structured by making use of a conceptual process flow diagram, see Figure 19. The diagram sets the phases in which the production facility can be situated during different Life Cycles. Secondly, the various management skills, in combination with the main tasks of the prime actors, will be given. The diagram states the process for one Life Extension for an individual platform. Feedback loops are given to stimulate system thinking according to [Senge, 1990], making use of feedback in an organization, which will strengthen:

- seeing interrelationships rather than a linear sequence of cause and effect; and
- seeing processes of change rather than snapshots.

**Life Cycle Phases:** An offshore production facility typically continues the following technical and operational phases during its Life Cycle, derived from [PRC, 2007]:

- Design; the phase in which the production facility is specified in relation to its production needs and environment. This phase typically involves development costs.
- Construction; in this phase the physical asset is built according to the design. This phase involves cost.
- Installation and commissioning; at this point of the life Cycle the facility is transported offshore from the construction facility and installed and commissioned at the site where the recoverable resources are found. This part of the Life Cycle also involves capital expenditure.
- (Extended) Operation and maintenance; in this phase of the facility’s life it will produce the resources and will be maintained; this phase can be extended in order to meet the changed operational needs. This part of the Life Cycle typically generates revenue but will also include operational and capital expenditures.
- Hibernate or phase-out; at this stage the facility has completed its operational life and is waiting (hibernation) to be re-used or is definitely at the end of its operational life (phase-out). This phase involves cost.
- Disposal; this is most likely the shortest part of the facility’s life. It will be removed from its site and taken to the breaker’s yards to be demolished by an environmentally friendly method. Extensive cost is involved in this phase also.

The process of Extending the Life of the production facility takes place in the operational phase; as can be seen from the above list of phases it is the only phase of the facility that generate revenues, which should cover the OPEX and CAPEX. In order to secure the integrity, technical performance and safety of the facility after its initial design life knowledge regarding the platform’s construction, installation and commissioning are embedded in the maintenance plans, which are used during the maintenance period.

For this purpose a process diagram (Figure 19) has been formulated starting at the initial operational phase and followed by the extended operational and disposal phase. The focus will be on the Life Extension phase, which is part of the initial operational phase. Making use of managerial principles of [De Leeuw, 1993] and [Stavenuiter, 2002], three management aspects have been entered in the diagram namely:

- strategy management; this is the level where the Duty Holder formulates the corporate vision and mission;
- operational management; here the operational actors must operate the facility in the safest and most efficient manner possible. At this level the operational need, and therefore the need/wish for longer operation of the facility, will be revealed.
- Technical management; at this level the technical performance and safety will be realized and the actors involved will also need to determine if and ensure that the facility can operate beyond its initial life.

The prime actors, as defined, will be named and the legal tasks they need to perform will be listed. For the Life Extension Phase, the task will be defined in more detail by making reference to parts of the guideline in the following Chapters.
5.3. Proposed KPI’s for LEM

5.3.1. Introduction

A Key Performance Indicator (KPI) is an industry term for a type of Measure of Performance (MoP). KPIs are commonly used by organizations to evaluate its success or the success of a particular activity for which it needs to be managed [Kaplan and Norton, 1996]. With other words, “what gets measured, gets managed”; in the case of this research, the success of Managing the Life Extension of the ageing offshore production facilities. KPIs are quantifiable measurements, agreed in advance, that reflect the critical success factors of an organization (or department). Many things are measurable, but that does not make them key to the organization’s success. In selecting Key Performance Indicators it is critical to limit them to those factors that are essential to the organization reaching its goals [Stavenuiter, 2002]. This definition indicates that limiting the number of KPIs will keep the actors and stakeholder focused on achieving the KPIs.

5.3.2. Categorization of indicators

Key Performance Indicators define a set of values used to measure against predefined goals and objectives. There are typically two types of key performance indicators. The first type measures real-time performance or predicts future results. These are helpful during long term project to ensure that critical objectives aren’t missed. The second type of KPI measures results of past activity. These indicators are like a report card to see how you did in a particular area. This may be done by monitoring health and performance (Availability, Reliability and Capability), for example, and then correlating the gathered data [HSE-HSG254-2008].

As explained earlier, Measurement of Performance (MoP) is the process whereby an organization establishes the parameters within which the life cycle of the facility is reaching the desired results. This process of measuring performance often requires the use of statistical evidence to determine progress toward specific defined organizational objectives.

![AMC Communication Pyramid, (AMC MSc Course Binder M17, 2010)](image)

Figure 20 AMC Communication Pyramid, [AMC MSc Course Binder M17, 2010]

5 Key Performance Indicators, in practical terms and for strategic development, are objectives to be targeted that will add the most value to the business.
The organizational control mechanisms per management level are given in Figure 20, making use of the AMC communication pyramid. Use of the pyramid clearly shows the subdivision between the management levels, within the whole Asset Management in Control field. In the pyramid it is evident where the management effort needs to be directed (red dotted area), and what the result of the effort will be if performed and managed correctly. The objective of setting the KPIs must be to measure the success of the LEM process. The LEM process has been analyzed as a system (SAM) in the former paragraphs of Chapter 5 and defined in more technical detail in appendix 1 Chapter 1. Here the expected actions and output of the actors has been described together with the definition of the Installation Performance.

5.3.3. Realization of the LEM KPI’s

Making the connection to the measures (KPIs) for LEM the work of [Kravchuk & Schack 1996] has addressed the contents of the KPIs for public agencies (as SSM) and the related industries. Hence, the field of Offshore Gas mining is one of the financial pillars of the Dutch Gross Income, as explained in the introduction to this research.

According to [Kravchuk & Schack 1996], formulating the KPIs for this field the following steps must be made per manageable level:

1. **To Evaluate**

To determine how well a public agency is performing and to evaluate this performance, managers need to determine what an agency is supposed to accomplish, in other words to formulate a clear, coherent mission, strategy, and objective. Then, based on this information, it can be decided how to measure those activities. Evaluation processes consist of two variables: organizational performance data and a benchmark that creates a framework for analyzing that data. For organizational information, focus on the outcomes of the agency’s performance, but also include input/environment/process/output to have a comparative framework for analysis, as per Figure 11.

2. **To Control**

How can managers ensure the actors involved in the LEM process are doing the right thing. Management needs to measure behavior of individual actors and then compare this performance against the requirements to check who has and has not complied. These requirements are described as the LEM guideline. This guideline really consists of requirements and those requirements are designed to control. The measurement of the compliance with these requirements is the control mechanism.

3. **Budgets**

Budgets are crude tools for improving performance. Poor performance may not always change after applying budgets cuts as disciplinary actions. Furthermore, the risk involved in managing on the basis of financial indicators can result in decision-making that can harm the health and safety of the actors, the production facility and the environment.

4. **To Motivate**

Give people significant goals to achieve and then use performance measures - including interim targets - to focus people’s thinking and work, and to provide a periodic sense of accomplishment [Senge, 1999].
5. **To Promote:**

How can public managers convince political superiors, legislators, stakeholders, journalists and citizens that their agency is doing a good job. To convince citizens their agency is doing well, managers need easily understood measures of those aspects of performance about which many citizens personally care.

6. **To Learn:**

Learning is involved with some process of analyzing information provided from the evaluation of the assumptions during LEM and the performance of the facility during the Extended Life. By analyzing that information, the LEM team actors are able to learn from each other, due to the team set-up as modeled in Figure 19 and Figure 34.

**5.3.4. Performance Measurement**

All significant work must be measured in order to be managed, according to [Kravchuk & Schack 1996]:

- Work that is not measured or assessed cannot be managed because there is no objective information to determine its value.
- Unmeasured work should be minimized or eliminated.
- Desired performance outcomes must be established for all measured work.
- Outcomes provide the basis for establishing accountability for results rather than just requiring a level of effort.
- Desired outcomes are necessary for work evaluation and meaningful performance appraisal.
- Defining performance in terms of desired results is how managers and supervisors make their work assignments operational.
- Performance reporting and variance analyses must be accomplished frequently.
- Frequent reporting enables timely corrective action.
- Timely corrective action is needed for effective management control.

To meet the aforementioned point as indicated by [Kravchuk & Schack 1996] and [Stavenuiter, 2002], ensuring that the Extended Life of the production facility is safe and effective, the performance of the installations must be determined according to the Availability, Reliability and Capability as given in Figure 21. These measurable parameters can serve as KPI’s to determine if the performance of the production facility is meeting the requirements as defined or derived from the operational need. These parameters are further defined and explained in appendix 1, Chapter 1.2.1.

![Figure 21 System and Cost Effectiveness breakdown (Stavenuiter, 2002).](image-url)
For determining the system and cost effectiveness the AMICO modeling has been used, for this the operational performance requirement must be determined. The way of using AMICO, has been described in detail by Stavenuiter and therefore reference is given to [Stavenuiter et all, 2002].

The operational performance requirements added to the basic functions are the Capability Requirements that are related to performance of the physical system components (installations) through the installation chain and can be unambiguously tested. When the functional breakdown provides a realistic view of the system all higher operational performance requirements are, by definition, covered [Stavenuiter, 2002].

This systematic approach to determine system and cost effectiveness has been translated, making use of system modeling as described in Chapter 5.4.

To determine the KPIs during the LEM phase, the process model as given in Figure 21 will be used. This model outlines the steps, products and service that need to be taken and delivered during this particular part of the facility’s Life Cycle. The following KPIs are proposed in the following table.

<table>
<thead>
<tr>
<th>Perspective</th>
<th>KPI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic</strong></td>
<td>System Management</td>
</tr>
<tr>
<td></td>
<td>Cost Effectiveness (CE)</td>
</tr>
<tr>
<td></td>
<td>System Effectiveness (SE)</td>
</tr>
<tr>
<td><strong>Technical</strong></td>
<td>System Management</td>
</tr>
<tr>
<td></td>
<td>Function Effectiveness (FE)</td>
</tr>
<tr>
<td></td>
<td>Function Costs</td>
</tr>
<tr>
<td></td>
<td>Installation Management</td>
</tr>
<tr>
<td></td>
<td>Installation Performance (IP)</td>
</tr>
<tr>
<td></td>
<td>Installation Cost</td>
</tr>
<tr>
<td></td>
<td>Cost Effectiveness (CE)</td>
</tr>
<tr>
<td></td>
<td>System Effectiveness Impact (SEI)</td>
</tr>
<tr>
<td></td>
<td>Cost Effectiveness Impact (CEI)</td>
</tr>
<tr>
<td><strong>Operational</strong></td>
<td>Process Management</td>
</tr>
<tr>
<td></td>
<td>Production Performance</td>
</tr>
<tr>
<td></td>
<td>Quality and Safety Performance</td>
</tr>
<tr>
<td></td>
<td>Service Performance</td>
</tr>
</tbody>
</table>

*Table 1 KPIs prescribed by AMC-LEM*
5.4. System Modelling for LEM

5.4.1. Introduction

By applying System Modeling to the LEM process an integrated whole will be created in a structured way, which can be used as a transparent base for structuring, managing and controlling all the Life Cycle phases in relation to all the actors involved. For example: using the LEM model all performance and cost can be integrated and monitored and controlled online. Experience in other fields indicates that to set up an LEM model is a basic management by objectives activity and to use for control purposes is recognized as a typical management by exception activity.

An old saying of Winston Churchill goes: “First we shape our Structures, then our Structures will shape us”. In other words, without a good structure there will not be a good culture. This is confirmed by the findings in the Chapter “perception of the reality”. In the case of the absence of a clear guideline there will be no consistent execution of LEM.

The first step toward consistency is outlined in Chapter 4 and in appendix 1 of this Thesis. The next step is using the results of the LEM SAM to model the production facility and determine the system and cost effectiveness during the Extended Life of the facility.

The results achieved from the system analyses can be modeled in AMICO, which is using three diagram composites to model the functional system. AMICO makes use of the following diagrams [Staveniuter, 2002]:

- Function Diagrams, for modeling the system functionality;
- Installation Diagrams, for modeling the installation block diagram per function;
- Activity Diagrams, for modeling the processes needed to achieve the required installation performances.

5.4.2. Step by step approach

First step: define the different LE phases, which must be in line with the AMICO status categories. Life Extension is part of the initial operational phase of the production facility. Typically a Life Extension process needs to be started 2 years before the initial design life of the facility will end [PSA, 2010]. The Life Extension assessment process is made up of pre-defined phases, which are worked out in Figure 31 and consist of the following consecutive parts [NEN19902, 2007]:

- production facility selection;
- collect and analyze production facility, current and historical data;
- performance required from the production facility during its Extended Life:
  - hibernation, or
  - production.
- determine assessment criteria;
- perform production facilities condition inspections;
- perform Life Extension evaluation assessments re.:
  - current and past condition;
  - structural resistance assessment;
  - current and future Regulation compliance.
- assessment criteria evaluation;
- set up mitigating measures in 5-yearly inspection and maintenance schedule.

Reference to a more detailed work-out of the content of the Life Extension phases is made in Chapters 0 and 5.1.4.
The second step: is used to make an inventory of products, services and actors involved throughout the LE phases:

The products and services of the involved (prime) actors have been explained in detail in Chapter 1.5 of appendix 1; for the cooperation and underlying connections reference is made to Figure 33.

In short the main products and services of the (prime) actors are:

- **Operator (prime actor), reference to Chapter 1.5.1 of appendix 1:**
  - is the initiator of the Life Extension of a facility and manages the Life Extension, communicates directly with the Independent Expert and SSM.

- **maintenance Specialists, reference to Chapter 1.5.3 of appendix 1:**
  - collect and process all relevant facility status data, and organize field inspections of the facility.

- **design Specialist, reference to Chapter 1.5.4 of appendix 1:**
  - performs the Life Extension assessment using data from the Maintenance Specialist.

- **offshore Installation Manager, reference to Chapter 1.5.6 of appendix 1:**
  - supports the Maintenance Specialist with accurate facility structural and installation statuses and performances.

- **Independent Expert (prime actor), reference to Chapter 1.5.5 of appendix 1:**
  - communicates with the operator and needs to validate independently that the Life Extension assessment has been performed according to the agreed rules, regulations and Standards.

- **inspector:**
  - validates the (field) data used in the Life Extension process, produced by the operator.

- **design Specialist:**
  - validates the complete assessment, including structural calculations.

- **SSM (prime actor), reference to Chapter 1.5.7 of appendix 1:**
  - audits the LEM process in several stages, executed by the operator, taking into account the remarks made by the Independent Expert;
  - if there is any doubt about the independence of the Independent Expert, the Independent Expert and operator can be challenged.
Third step: set up a system breakdown structure (system – functions - functional packages/installations) that is most suitable for the LEM purpose of assess, manage and control. The system breakdown will be set up according to the principles of [De Leeuw, 1993] and [Stavenuiter, 2002]. The breakdown, underlying functions and installations are given in Chapter 5.1 and on greater detail in Appendix 1. The conceptual breakdown of the production facilities LEM structure is visualized in Figure 22:

![Conceptual System Breakdown](image)

Figure 22 Conceptual System Breakdown

In the fourth step: the relations and impact of the product/actor combinations on the system elements will be determined. The relations between the prime actors are defined by the Mining Act of 2003 [EL&I, 2003], see also Figure 33. The Impact Factor (IF) can be defined as the impact the services, products and related actor can have on a related actor or installation. It has to be noted that the operator is responsible for the adequate performing of the Life Extension process and management of this process, therefore the Impact Factor (IF) of all actions, products and services can be set at 100%. The Independent Expert validates the products of the operator and therefore the IF between these two prime actors must be 100%. SSM has only direct supervisory authority over the operator. The actions that SSM can take against the operator will have a 100% impact. The relation with the Independent Expert is a facilitating one only. SSM can comment on the work and performance of the Independent Expert, but the Independent Expert is free to acknowledge these comments. On the other hand, steps can be taken to question the independence of the Independent Expert. It is therefore suggested that this IF is set at 70%.
5.4.3. The Function Diagram

The function diagram (see Figure 23) is based on a number of predefined steps and based on the SAM for LEM. The prerequisite of the SAM for LEM is outlined in the previous Chapter 5.1 and been worked out in Appendix.1. First of all, the operational functions must be defined through the proposed SAM for LEM; these functions are the functions that are derived from the need assessment. Hence, these are the functions that the mining operator will pay for and that the facility must therefore “deliver” during its Extended Life. These requirements are listed in the first step “operational need”. These functions are then logically subdivided until the final so-called technical base functions are reached. These are the functions that have an unambiguous relationship with one or more installations. The operational and technical functions, including the installations, are derived from Chapter 5.1.3 and appendix 1- paragraph 1.3.

![Figure 23 Functional breakdown offshore production facility](image-url)
5.4.4. The Installation Diagrams

Installation diagrams provide the necessary insights into the relationships between installations and their order of precedence.
A functional block diagram is prepared for each base function. This is used in combination with the Function Diagram, to enter the entire facility into a model, which can then be used to perform calculations that will provide an insight into the effects of insufficiently acting installations at a higher level, both performance-wise and cost-wise.
To achieve these insights for LEM it will be necessary to determine the availability, reliability and capability of the installations/functions, in a slightly modified way as outlined in the SAM, see appendix 1, paragraph 1.2.1.

The Installation Diagrams, which can be derived from the operational functions, are:

- structural integrity;
- operational integrity;
- H.S.E sustainability;
  - production safety installation,
  - facility safety installation.

To determine the performance of the production facility installation the underlying technical installation must be modeled; these technical functions are:

- L.E.M Control;
- jacket functionality:
  - jacket structure;
  - facility foundation;
  - riser installation;
- topside functionality:
  - topside structure;
  - production installation;
  - auxiliary installation;
  - logistic installation;
  - hoisting installation.

Installation diagrams can relate installations to each other. AMICO makes it possible to model five significant types of circuits. A circuit is the modeled relation between the installations from “begin” to “end”. The five types of circuits are:
1. single circuits: used when just one installation is supporting the basic function;
2. serial circuits: used when the basic function is dependent on the performance of two or more installations, when the performance of an installation has a direct impact on the subsequent installation;
3. parallel circuits: can be used when two or more installations that are independent of each other have a certain impact on the basic function.
4. redundant circuits: can be used when an installation will never fail whatever the outcome of the installation performance;
5. a combination of the above circuit types.

For the underlying theories and mathematical underpinning of the modeling technique reference is made to [Stavenuiter et al, 2002].
The following installations\textsuperscript{(D33)} can be modeled:

5.4.4.1. \textit{Jacket Installation Diagram}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{jacket_diagram}
\caption{Installation Diagram “Jacket”}
\end{figure}

5.4.4.2. \textit{Topside Installation Diagram}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{topside_diagram}
\caption{Installation Diagram “Topside”}
\end{figure}
5.4.4.3. **HSE Sustainability Diagram**

The system as a whole produces failures when all individual barrier weaknesses align, permitting "a trajectory of accident opportunity", so that a hazard passes through all of the holes in all of the defenses, resulting in a failure [Reason, 1977].

The set of safety installations is therefore modeled as in below given model:

![Figure 26 Installation diagram H.S.E Sustainability](image)

5.4.4.4. **LEM Control Diagram**

LEM control has been modeled as an installation. By applying one installation for management purposes there will be a direct impact of the performance of the LEM team, without interfering with the supposed performance of the technical systems as modeled in the former paragraphs.

![Figure 27 Installation Diagram LEM Control](image)
5.4.5. Activity Diagrams

For modeling the activities per installation an activity diagram must be modeled in which the activity per installation is set. The modeling uses basic IDEF0 blocks as described in Figure 28.

The control function is considered a management or engineering product. The need for control activities depends on the terms and level of actor competence.

The need for support depends on the situation and/or need of the client-actor. Figure 31 gives an example of the activity diagram of the LEM Control Team which is a translation of Figure 29 including the appointment of the responsible actor (the Duty Holder).

For the remaining models relating to the aforementioned installations and functions, reference is given to the AMICO model supporting this Chapter. The remaining models are set up for baseline purposes, whereas the point of interest within this Thesis is the management of the Life Extension as a whole.

IDEF0, is a technique in which a process is schematically proposed. IDEF0 great advantage is that it shows in an action plan, material flows and information flows. Furthermore it is also clear how the dependencies are related in a process.
5.5. Information Management

Information management is the process by which all relevant historical and operational documents, data and information are collected, communicated, stored and made available to those who need it. Structural integrity management has the potential to produce large amounts of information, which needs to be collected, communicated and stored in an efficient and accessible manner. Ease of information access, clarity in presentation, information interrogation, trending and others are aspects of data management that have a pronounced effect on the overall effectiveness and efficiency of SIM. To this effect Duty Holders typically have computerized systems in place. As with any database system, the reliability and accuracy of the data stored is largely dependent on the quality and format of the data input in the system.

There are three primary elements of information which answer the questions [Griffiths, 2006];

- What is needed? – relevance
- When is it required? – timeliness
- How is it required? – accuracy

5.5.1. Relevance

The Duty Holder must ensure that information which describes the key elements of the SIM system and their interaction and also provides direction to related documentation is established and maintained in a suitable form.

Records of the following items are retained for the duration of the platform life and available to the other Life Extension [D37] actors [ISO19902, 2007], [HSE-RR685, 2009] and [PSA, 2010]:

- general platform characteristic data, e.g. original or subsequent owners, original or subsequent function, location and orientation, water depth, corrosion protection systems etc.;
- original design analyses, e.g. design contractor, date of design, design drawings, material specifications, design codes used, environmental criteria etc;
- structural assessments, including computerized numerical models of the structure;
- fabrication details, including as-built drawings;
- installation reports;
- in-service maintenance [D42],
- engineering evaluations;
- in-service Inspection condition monitoring including current condition and presence of anomalies including photographic records;
- repairs [D45] and structural modifications;
- risk and performance analyses of the facility;
- mitigating actions;
- records of accidents and incidents;
- competence records of specialists who have been involved with the facility during the useful life [D40] of the asset.
Historical information on the below mentioned topics must be retained. Additionally, the Duty Holder should endeavor to identify and recover any relevant information not directly held by the Duty Holder, such as that held by the Independent Expert under the certification regime [ISO19902, 2007].

The following databases should be kept as a minimum:

- as-built drawings;
- current and historical Inspection results;
- maintenance activities and modifications;
- drawing register (not required if the drawing database is easily searchable);
- environmental data;
- anomalies register, including criticality rating;
- damage register;
- completed and outstanding inspections.

5.5.2. **Accuracy**

Control procedures are in place to ensure that [Griffiths, 2006]:

- Documents, data and information are easily located and accessible to authorized personnel.
- Documents, data and information are periodically revised to incorporate any changes.
- Current versions of relevant documents, data and information are available at all sites where asset related tasks are performed.
- Obsolete documents, data and information are promptly removed from all points of use, and replaced by their replacement document.
- Archival documents, data and information retained for legal or knowledge preservation purposes are suitably identified.
- Documents, data and information are suitably secure dependent on the level of sensitivity involved, and if in electronic form are adequately backed up and recoverable.
- Any data which has become obsolete is removed, archived or flagged as ‘obsolete’ to avoid cluttering the data base.

Data should be stored in such a way as to aid trend spotting where possible. This is of particular value for Inspection data, which can be used to establish trends between consecutive Inspections, and between assets. Inspection data should be stored in a way that allows ready interrogation of critical anomalies. Inspection and maintenance data should be stored in a way that allows easy collation of information on any backlog of Inspection / maintenance activities.

5.5.3. **Portal Information Sharing**

The multi-disciplinary and international nature of Life Extension Management projects requires powerful managerial and communicative tools to ensure the transmission of information to the end-users. One of the objectives of Life Extension Management must be to provide a dedicated communication system as the central source of information of the offshore production facility and traceability for the prime actors, in addition to traditional ways of communicating to the (prime) actors, through peer-reviewed publications, reports, e-mail and conversations. Web tools have become a major information channel [Vermeulen et al., 2006], and offer alternative avenues of communication.
This part of the thesis explores the web tools used as a communication vehicle offered to the (prime) actors involved in the Life Extension project to communicate internally. One tool have been built: a web based portal. Particular emphasis was placed on the efficiency, relevance and accessibility of the information on the website as well as the use of the collaborative utilities, the rationale of web space design as well as integration. Perspectives, methods of communication and management in respect of the use of web tools in the Life Extension projects will be discussed in Chapter 5.5.4. These new methods are ideally suited to be applied to large multi-disciplinary research projects.

The objective of the use of web based portals is to manage a large, international project and to effectively disseminate the results. The resulting information and communication system has to address the following goals:

- To develop and exploit a communication and dissemination system that will be the focus of Life Extension Management information.
- Become the prime and secure source of internal communication and project information for the (prime) actors.
- It must reduce the need for multi-recipient emails.
- It must obviate the need to email large documents.
- It must improve the ability of the management team to communicate effectively.
- It must be able to store the files that are generated in the project.

The challenges to be addressed include providing tools for communication, a central storage facility for common documents, restricted work areas to protect intellectual property, methods for populating the website, whilst promoting integration within the project. Therefore it would be advisable that the Duty Holder is charged with the task of acting as the host of the portal and locating the contributions of the (prime) actors on the share point of the portal after reviewing the contribution on validly to the Life Extension project. This can result in reduced reliance on a single person and slower updating of the information but would avoid pollution of the portal.

In an interdisciplinary project involving several dozen participants from different institutes through Europe, the main challenge for the Life Extension Project Team is to ensure the communication between the actors (engineers, maintenance specialists, design specialists, etc), who have their own personality, culture or experience. In addition to the conventional methods for the communication between the (prime) actors (e.g. telephone, meetings, reports), there are now many new tools available to help the project management. The portal should have a centralized point for communication to facilitate the exchange of information between participants, to encourage them to collaborate and to manage the project in real time [Vermeulen et al., 2006].

The information which will be generated during LEM and to be shared among the (prime) actors, will be derived from the SAM for LEM. The LEM portal has been designed to address these information element in a structured way, so they can be placed, found and used by the entitled (prime) actors.
5.5.4. Portal Communications

The portal is typically a secure site and is accessible to the project members directly via the web. It is managed by the webmaster in close collaboration with the project team of the Duty Holder.

According to [Vermeulen et al., 2006]. The portal includes, at the minimum, the following: “Announcement” and “events” ($D_{14}$) items see also appendix 3, Chapter 3.1, displayed in the central frame of the homepage, together with the main data of the production facility. They crucially inform all the partners about the project management and announce the scheduled meetings and deadlines of the project. To be sure that all the partners are well informed an automatic alert e-mail should notify each of them when an announcement is made or an event ($D_{14}$) entered. Meetings held for the Life Extension project team, and the work packages, are displayed in an “events” section. Each event can be linked to a workspace dedicated to providing information about the attendees, the agenda, the presentations, the report and any document concerning the event. Each workspace is managed by the meeting organizer and access is restricted to members of the relevant group.

The common documents produced in the frame of the Life Extension project by each workgroup/ (prime) actor are stored under the topic “documents”. A short description displayed at the top of the library explains the content and the access rights to the user.

The subtopic “documents” is dedicated to documents needed to perform the Life Extension of the production facility like relevant Acts, Standards, (inspection) reports etc. The “lists” topic is dedicated to collecting information about each (prime) actor. In the subtopic “Contacts”, each partner can add and update its own information (address, function, role in the project, etc.). This information is only used for the management inside the Life Extension project.

The section “Planned deliverables” allows everyone to follow the status and the progress of each deliverable. Each actor has the responsibility to update the status of their deliverables. The different views quickly give an overview of the tasks, the tasks due, the active tasks or the tasks assigned to other actors. The section “Completed deliverables” includes the final documents regarding the official deliverables of the project. Figure 30 shows the proposed set-up of the Life Extension Management Portal.

![Figure 30 Start Page of LEM Portal](image-url)
6. **Conclusions and Recommendations**

6.1. **Conclusions**

In this Chapter the results obtained during the assessment stage, the theory development stage and the design and case study stage are discussed and evaluated. Conclusions are drawn with respect to the research objectives as stated in Chapter 2 and the ToR as has been set-up in Chapter 4. Secondly recommendations for further research are given:

- During the field research it became clear that the Dutch Acts, Decrees and/or Regulation do not stipulate unambiguous Life Extension requirements and/or address the risks which can occur during the Extended Life.

- The field research of SSM has provided greater clarity regarding the marginal directive abilities of the above mentioned, the actors involved in the Life Extension Management have the freedom to determine their own way of performing Life Extension on the ageing production platforms. Hence, from these observations it can be concluded that uniformity of performing of Life Extension assessments is missing, where as an result the outcomes of these Life Extension assessments are hard to audit and weight on validly.

- PAS-55 is not suitable for the use as an Asset Management principle/guideline. This principle merely states points of attention on a high level and doesn’t address the interaction between the involved actors and the corresponding products and activities to administer a sound manner of Asset Management.

- It has been discussed whether the AMC-LCM principle is the Life Cycle Management approach which has been implemented for LEM of the ageing offshore structures. Therefore the principle has been altered to AMC for LEM in Chapter 4.

- The boundaries of the domain of Life Extension, has been outlined specifically for LEM in Chapter 4, by formulating the ToR on the basis of De Leeuw and Stavenuiter. To fulfill the ToR, a SAM for LEM has been performed according to the AMC approach, which have been detailed further in appendix 1. By performing the SAM the system boundaries have been set and therefore, sub-question 1 has been fully answered.

- The applied and adapted AMC Asset Management approach has an embedded process to manage assets and their management teams. Which has supported the objectives stated for the ToR in Chapter 4.4.

- The topic H.S.E sustainability is not embedded as an separate entity in the applied AM approach. To address this topic, because it is one of the major subjects on which SSM is supervising on, the topic has been integrated in “LEM Installation Performance”. As show in the system breakdown of Figure 23 the influences on the Extended Life of the production facility, can be modeled and therefore recognized.

- Although the Mining Act(2003), has stipulated that operation of the production facilities has to be risk based, it has been observed that that more attention need to be made to the risk involved in Extending the Life of the production facility. Hence, by adding risk to the LPC for LEM, risk has added to the LEM process.
• Furthermore the risks that may be involved in Extending the Life of the production facility have been addressed in the introduction. Addressing risk in decision making has been achieved by applying the risk management model as in appendix 2 has been used; further in this appendix risks and decision were detailed to the level of ethics involved within the process of decision making under risk. In fact managing risks, is one of control measures, which have been integrated in the LPC for LEM under the entity “Budget, which is part of the guideline for LEM.

• It has been observed that interdisciplinary projects share lot of information and involve collaborative work amongst institutes from many countries with different experience [SSM, 2010]. Due to the amount and way of communicating information related for LEM, the timely process of LEM is negatively influenced. Therefore an web based communication vehicle has been developed, to enhance the communication between the LEM (prime) actors. This improvement will need to lead to a higher LE assessment and a better controllable LEM.

• Projects like LEM, require specific tools to communicate between partners inside the project and to disseminate results to and outside the project management team. To show how the management process of the production facility will need to be performed in time, a process diagram has been developed, to address the communication lines and name the products and services within LEM.

• Secondly for communication purposes, the modeling tool AMICO has been utilized. AMICO goes hand-in-hand with the LEM-SAM and has the ability to run several scenarios with different impact ratios between the installations and actors, and variables for the Reliability, Availability and Capability of the installations, which are in fact the system and cost effectiveness measures (KPI’s) as stated in the ToR.

• With respect to the communication between partners and (prime) actors, web based portal has been to set-up a dedicated communication vehicle for LEM. The communication vehicle has been classed in such a way, that all relevant LEM information and documentation can be shared among the (prime) actors and stakeholders involved, so that quality and time can controlled and monitored on an effective manner. Therefore it may be concluded that sub-question 3 has been fully addressed and the specification on this topic within the ToR.

• Using the LCM-AMC approach, together with the ToR, which have been addressed during the research. Therefore it can be concluded that the guideline which has been developed in Chapter 4 and 5, could have added value to gain a more substantiated Life Extension Management.
6.2. Recommendations

Recommendations based on the findings during this research can be summarized in the following points:

- It would be advisable to make further use of the system modeling tool AMICO in a real life situation, including H.S.E sustainability. It would be certainly useful to adapt AMICO to the field of Offshore oil and gas, so that performance and risks can be derived from the outcomes.; further research on this topic will be necessary.

- Due to lacking of available data to support the model. It was not possible to determine the system cost and effectiveness figures on validated data. It would be advised to validate the complete model on system cost and effectiveness.

- During the field research, it has been learned that a facility can be in hibernation during the Life Extension period. Therefore it is recommended that LEM for hibernation, will be studied on a deeper detail then where this research has gone.

- As described in Chapter 6, improving the communication concerning LE by applying a web based portal could be a solution for the long lead times of the current LE processes. It is recommended that this topic is researched further and, if possible, that the designated communication vehicle is used in a real life environment.

- It has been noticed during the research that the Dutch Acts and Regulations do not address Life Extension Management. It would be useful if more duty-specific formulations of obligations were included in the Mining Act. In this way a guideline as proposed in this Thesis can be applied in a more timely and detailed manner.

- It is advisable to test the complete developed guideline in a real life situation. This guideline will need to be supported with developed tools during this research as the portal communication vehicle and the system model in AMICO.

- At last: by applying the guideline also the management of risk needs to be evaluated, in such a way if the ethics within decision making are being lived up to. The pitfall in making decisions within LEM, can be that; as the industry is looking for longer and effective mining making use of ageing production facilities, the risks which can occur during the extended life will need to be noted and addressed, and so the decision on using a facility for a extended period, cannot only be based on financial influences.
1.1. Introduction

The explanation of the system- and logistic process structure is based on the following reasoning, [Stavenuiter, 2002];

It is assumed that the logistic process structure is directly related to the installation entities, the operational and technical packages. The installations are considered to be the physical elements for which a logistic actor (or group of actors) is responsible. For this reason a logistic actor is recognized as a significant element in the logistic process. In this context the (support) actors, designers and specialist are, [HSE, 2009];

1. Operator
   - Maintenance Specialists
   - Design Specialist
2. Independent Expert
   - Inspector
   - Design Specialist
3. SSM

To meet the required installation performance during the Life Extended period of the facility, which has been derived from the from the operational need. It will be required that the logistic products and services when assessing the facility for Life Extension are; Re-appraisal of the structures and technical installations, in some cases modified for enhanced production techniques and adjusted maintenance strategy.

With the logistic actors in place, it is possible to perform logistic activities, these activities will need to provide the former mentioned product and services to achieve the required installation performance. The former will be derived from the system breakdown structure, see Figure 23 in which the operational need will be met, through the functionality of the system.

The dimension time is the dominator for an production facility. In case of an offshore production facility for both the initial design life(D10) and the Extended Life. The timeframe for the Life Extension assessment has not been determined and is depended of the complexity of the production facility, an period necessary of performing an extensive assessment of two years has been stated by, [PSA,2010]. The former will be performed parallel of the operational phase of the production facility, which can give frictions when in the Life Extension assessment, operational futures are taken into account.

A summarization of all LPC entities has been given in the shortlist, which has been set-up in Table 2.
### LEM Check List; Specify/Secure L.E. System Functionality

#### Remarks

<table>
<thead>
<tr>
<th>Operational need:</th>
</tr>
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<tbody>
<tr>
<td>• Safety, Health and Environmental demands;</td>
</tr>
<tr>
<td>• assumed quantity of product to be extracted;</td>
</tr>
<tr>
<td>• stable E&amp;P indigenous market;</td>
</tr>
<tr>
<td>• skilled and competent workforce;</td>
</tr>
<tr>
<td>• applicability of new mining techniques.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System functionality:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• system definition;</td>
</tr>
<tr>
<td>• functional decomposition;</td>
</tr>
<tr>
<td>• functional interfaces;</td>
</tr>
<tr>
<td>• Safety, Health and Environmental conditions;</td>
</tr>
<tr>
<td>• 5-yearly maintenance plan, approved by Independent Expert;</td>
</tr>
<tr>
<td>• system characteristics;</td>
</tr>
<tr>
<td>• performance characteristics;</td>
</tr>
<tr>
<td>• physical characteristics;</td>
</tr>
<tr>
<td>• effectiveness requirements.</td>
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</table>

<table>
<thead>
<tr>
<th>Installation performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Installation the following list of information can be composed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Installation definition:</th>
</tr>
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<tbody>
<tr>
<td>• general description;</td>
</tr>
<tr>
<td>• specific operational requirement;</td>
</tr>
<tr>
<td>• material/component breakdown;</td>
</tr>
<tr>
<td>• functional interfaces and criteria;</td>
</tr>
<tr>
<td>• environmental conditions.</td>
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<tr>
<th>Product influences on installations:</th>
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</thead>
<tbody>
<tr>
<td>• maintenance concept;</td>
</tr>
<tr>
<td>• time to obsolescence (D046);</td>
</tr>
<tr>
<td>• installation characteristics;</td>
</tr>
<tr>
<td>• performance characteristics;</td>
</tr>
<tr>
<td>• physical characteristics;</td>
</tr>
<tr>
<td>• Capability, Reliability and Availability (D066);</td>
</tr>
<tr>
<td>• test and survivability;</td>
</tr>
<tr>
<td>• maintainability (D041);</td>
</tr>
<tr>
<td>• risk to Health, Safety and Environment;</td>
</tr>
<tr>
<td>• energy efficiency;</td>
</tr>
<tr>
<td>• recyclability.</td>
</tr>
<tr>
<td>LPC Check List; Specify/Secure L.E. System Functionality</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Logistic products:</strong></td>
</tr>
<tr>
<td>- technical and operational system Life Extension realization planning (strategy management);</td>
</tr>
<tr>
<td>- determine operational and system requirements;</td>
</tr>
<tr>
<td>- consult and validate system history database;</td>
</tr>
<tr>
<td>- analyze systems specifications;</td>
</tr>
<tr>
<td>- functional and technical installation specifications;</td>
</tr>
<tr>
<td>- technical and operational system design/breakdown;</td>
</tr>
<tr>
<td>- technical and operational inspection report reviews;</td>
</tr>
<tr>
<td>- structural performance (fatigue) assessment reports;</td>
</tr>
<tr>
<td>- technical and operational system risk reviews;</td>
</tr>
<tr>
<td>- contractor competence assurance;</td>
</tr>
<tr>
<td>- test, inspections and validation plan;</td>
</tr>
<tr>
<td>- acceptance of Standards, Acts and Regulations;</td>
</tr>
<tr>
<td>- gap analyses between acceptance Standards and design Standards;</td>
</tr>
<tr>
<td>- reliability, availability and maintainability plan;</td>
</tr>
<tr>
<td>- system retirements plan(s);</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Logistic services:</th>
<th>Reference is made to Figure 19 and Chapters 1.5 and 1.6 of appendix 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- operational need and feasibility analyses;</td>
<td></td>
</tr>
<tr>
<td>- execute Life Extension assessment;</td>
<td></td>
</tr>
<tr>
<td>- auditing and reviewing Life Extension Management of Duty Holder;</td>
<td></td>
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<tr>
<td>- validate independency of IE;</td>
<td></td>
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<tr>
<td>- evaluate and verification of the Life Extension assessment of the Duty Holder.</td>
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</tbody>
</table>

<table>
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<tr>
<th>Logistic activities:</th>
<th>Reference is made to Figure 19 and Chapters 1.5 and 1.6 of appendix 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- resource planning and control;</td>
<td></td>
</tr>
<tr>
<td>- project management;</td>
<td></td>
</tr>
<tr>
<td>- consult and apply design documents (f.e.ISO 19902:2007/NORSOK N006:2009);</td>
<td></td>
</tr>
<tr>
<td>- performing installation and structural inspections;</td>
<td></td>
</tr>
<tr>
<td>- performing Life Extension installation integrity assessment;</td>
<td></td>
</tr>
<tr>
<td>- utilization and feedback of produced (inspection) reports and LE assessments;</td>
<td></td>
</tr>
<tr>
<td>- information management;</td>
<td></td>
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<tr>
<td>- document management;</td>
<td></td>
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<tr>
<td>- quality and risk determination;</td>
<td></td>
</tr>
<tr>
<td>- Health, Safety and Environmental management and provisions;</td>
<td></td>
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<tr>
<td>- workforce policy/management;</td>
<td></td>
</tr>
<tr>
<td>- cost calculations;</td>
<td></td>
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<tr>
<td>- risk management[^OS4]</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Logistic actors:</th>
<th>Reference is made to Figure 33 and Chapters 1.5 and 1.6 of appendix 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following logistic actors, should be involved in the Life Extension process:</td>
<td></td>
</tr>
<tr>
<td>- Mining Company as operator of the production facility.</td>
<td></td>
</tr>
<tr>
<td>- Mining Company as maintainer of the production facility.</td>
<td></td>
</tr>
<tr>
<td>- Mining Company as designer/inspector of the production facility.</td>
<td></td>
</tr>
<tr>
<td>- Independent Expert as evaluator of Production facility status.</td>
<td></td>
</tr>
<tr>
<td>- Independent Expert as inspector of the facility.</td>
<td></td>
</tr>
<tr>
<td>- SSM as Life Extension process supervisor.</td>
<td></td>
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</tbody>
</table>

[^OS4]: Table 2, LEM short list Specify and Secure System Functionality, [based on Stavenuiter, 2002]
1.2. LEM Needs

Summarizing the “need” drivers for extending the gas production and therefore the life of the production facilities:

- Stable political E&P climate, which need to consist in supporting and applying the small field policy. For further development of difficult and existing smaller fields, detection and development of unconventional gas.
- Fallow acreage covenant to stimulate E&P activities in inactive parts of offshore production licenses. Implementation of this covenant will further stimulate the mining of extra gas, within the so called sleeping fields.
- New technologies which enable field Life Extension e.g:
  - deliquification system, which enables to lift c.q. mine the gas at low pressure wells. This group of techniques also include preventing the well to suffocate in most likely process water, the so called liquid loading.

1.2.1. Ageing threats

The ageing process includes not just a general degradation of SSC’s but also includes the change of demands on the system posed by evolving requirements and circumstances, hence to make it economically feasible to Extend the Life of the facility, which can include the following [PRC, 2007]:

- Changing production demands:
  - reservoir fluid variations;
  - water cut increase (may change from approximately 0% to 90%);
  - reservoir fluid variations;
  - production fluid temperatures rise;
  - additional cooling requirements for production purposes.

As described in this part, the ageing of the topside and it’s equipment is an issue to ensure safe operations especially for facilities, which Life will be Extended. Therefore it can be recommended, that the same steps for LE of the Structure (Figure 31) will be used for the assessment of the topside to cover the primary steps namely:

- consideration of whether assessment type is needed and executable;
- information and history review, see [ISO/NEN19902:2007, Chapter A24.6.1];
- screening of SSC state, [NORSOK-N006:2009]; (major damages, major changes, exceeded wear and deviations from design);
- analysis of the structure and SSC’s (design analysis), see [NORSOK-N006:2009];
- decision making (acceptable as is, modification needed or disposal).

The above will be supplemented with the information gained by the individual SSC’s survey’s. The former can be submitted in the earlier recommended assessment plan, in order to achieve a complete overview of the status of the production facility. By creating this complete overview, it is possible to assess the production facility as an integrated system of operational- and technical function with the associated technical installations.
To meet the operational (need) demands, the answers of the technical need by applying a Life Extension assessment are:

1. structural; and operational integrity; these functions are demanded by Act, Regulations and Standards;
2. health, safety and environmental sustainability; this function is endorsed by the Dutch labor and mining Act;
3. LEM; In the Mining Decree, the co-operation between the operator, Independent Expert and authorities has been described. Furthermore in the ISO/NEN 19902:2007 and the preliminary API SIM Standard, requires a L.E. management team.

To achieve these insights for LEM, it will be necessary to determine, the availability, reliability and capability of the installations/functions. As can be derived from the SAM, reference is made to Chapter 5 of this research. These three variables are depending on the outcome of the assessments performed by the Duty Holder. Hence, these variables will determine the installation performance (IP) of the production facility. The IP can be written as $IP_f = f(A \ast R \ast C)$, [Stavenuiter, 2002].

1.2.1.1. Availability, Logistic

The probability (%) that an item of equipment is in an operable and committable state, without unsettled repairs, when called for an unknown (random) time, [Stavenuiter, 2002].

1.2.1.2. Reliability, Logistic

Is the probability that a system or component will perform its intended function for a specified period under stated conditions. Reliability is usually expressed in terms of probability of performance of an asset without failure. The performance can be expressed as mean time between failures (MTBF) can be expressed in hours or as the number of failures in a given period of time, [Blanchard, 1998].

1.2.1.3. Capability, Logistic

Is a measure in (%), of the extent to which the installation is qualitatively capable of meeting the requirements. To make the performance indicator (PI) applicable in practice, the following margin conditions will need to be established:

- the figures will be expressed in terms of probability as percentages between 0% and 100%, in relation with the modeled year-period;
- the concrete term for $A$ is defined as: (active time – down time); where the down time is the element of active time during which an installation (or SSC) is unable to perform its required functions, due to failure (will need to be defined by the LEM team);
- the concrete term for $R$, represents the reliability during the Extended Life, based on behavior of random failures, [Jones, 1995], which can be expressed as:

$$R(x) = e^{-\lambda t}$$

where:

- $R(x)$ = probability of success;
- $\lambda$ = failure rate (1/MTBF);
- $t$ = duration of the mission time, e.g. time between inspection intervals.

the concrete term for the baseline $C_1$ is by definition 100%.
The actual C can be assessed by testing the suitability and quality of an installation, by testing and evaluating the tests. In this context the suitability is defined as a measurement (%) of the extent to which the installation is physically capable of meeting the requirements.

1.3. LEM System Functionality

In this paragraph, the system functionality as part of the technical system of the offshore production facilities will be described. Although system functionality and the performance of the corresponding installations, are implicit linked together, the system functionality and supporting installations will be determined separately, [Stavenuiter, 2002].

Defining the boundaries of the technical system, is not more than defining the technical span which need to be controlled. For this thesis the focus is set on the gas production facilities, typically the facilities consist out of two parts, the jacket (the lower part) and the topside (the upper part).

The functions which need to be controlled are, [PSA, 2010], [OLF122, 2008] and [NORSOK-N006:2009] for detailed functions and performances reference is made to Table 4 and Table 5:

- LEM control;
- structural integrity;
- operational integrity;
- H.S.E sustainability;
- topside functionality;
- jacket functionality.

1.3.1. Jacket functionality

The jacket functionality is defined as subsystems composed of several installations. It is in most cases erected through a composition of steel frames, beams and upstream transport pipes the so called “risers”. The main functions of the jacket are, [PSA, 2010];

- support, accommodate and to discharge the developed structural forces of the topside;
- withstand the mechanical and environmental, static and dynamic loads;
- assurance personnel onboard can abandon the facility safely;
- lodge the riser installations.
1.3.2. **Topside functionality**

The structure which is called “topside” has as main function to house the process; and auxiliary equipment, safely lodging of the facilities staff and supporting the functions of hoisting and transport installations. Also these are defined as subsystems composed out of several installations.

The main installations on the topside of the facility are, [PSA, 2010] and [NORSOK-N006:2009];

- topside structure;
- transport pipelines, Risers and subsea systems;
- process Installation, including back-up process installation;
- auxiliary installations;
- safety installations, structural as well as operational;
- material handling installations;
- logistic installations;
- marine systems.

1.4. **LEM Installation Performance**

During the field research, [SSM, 2010], the industry has indicated that there is a demand for two types of Life Extension for the production facilities namely for:

- hibernation phase;
- extended operational phase.

The difference in setting-up the guideline is determining the needed installation performance, according to the operational need, respectively hibernation or extended operation. The differences in assessment have been defined in (Att.01, paragraph 1.9). Although Life Extension in hibernation phase is out of the scope of this research, it has been professed for potential further research on this topic. An existing structure shall be assessed to demonstrate its fitness-for-purpose if one or more of the following conditions (initiators) exist [Ersdal et al, 2005] and [ISO/NEN19902:2007]. In other words, an existing facility, has to be as good as a new one. To ensure that the whole of the production facility is fit for purpose for an Extended Life, it is necessary to manage the LE of the facility as one system, installations and components, [PSA, 2010].
1.4.1. Guides for Assessments

For determining if the performance of the structure, still satisfies the requirements which are demanded by Act, ISO and/or API Standards, an assessment need to be performed to determine the level of remaining structural performance.

To indicate that assessment of the integrity of the facility is not only reserved for Life Extension purposes, initiators outside Life Extension are given in the summary of point 1. These analyses and evaluations, can already have been carried out for one of the specific purposes. Such analyses and evaluations shall be part of the L.E assessment process [ISO19902:2007] and [NORSOK-N006:2009];

1. Changes from the original design or previous assessment basis, including:
   - addition of personnel or Facilities such that the platform exposure level is changed to a more onerous level;
   - modification to the facilities such that the magnitude or disposition of the permanent, variable or environmental actions on a structure are more onerous;
   - more onerous environmental conditions and/or criteria;
   - more onerous component or foundation resistance data and/or criteria;
   - physical changes to the structure’s design basis, e.g. excessive scour or subsidence, and inadequate deck height, such that waves associated with previous or new criteria will impact the deck, and provided such action was not previously considered;
   - damage or deterioration of a primary structural component: minor structural damage can be assessed by appropriate local analysis without performing a full assessment;
   - however, cumulative effects of multiple damage shall be documented and included in a full assessment, where appropriate.

2. Exceedance of design service life, and if degradation of the structure due to corrosion is present, or is likely to occur, within the required Extended Life.

1.4.2. Assessment of Structures

In Figure 31 the decision flow diagram for assessing the former two phases are mentioned and stated in two separate main assessment criteria flows:

- Life Extension for hibernation;
- Life Extension for production:
  - topside;
  - jacket.

This flow diagram is a composition of the decision assessment diagram drawn-up by [ISO 19902:2007-figure 24.2.2], and the assessment procedure diagram of [Ersdal, 2005-figure 2-1].

---

7 In the ISO 19902:2007 and API RP 2A-WSD guidelines, it is stated that; At all times an Extension of the design service Life can be accepted without a full Assessment if Inspection of the structure shows that time-dependent degradation (i.e. fatigue and corrosion) has not become significant and that there have been no changes to the design criteria. Within the miningAct or decree no limitation for applying this clause has been submitted. Though for the labour decree Article 3.3 lid.01 it is mandatory, that in ever which Lifecycle status (see Chapter 4), the Facility is an proven state of integrity, that it is safe to enter and be worked upon.
The description is the basis for the LE assessment, it should be a clear and consistent. In this description, the following aspects should be included [Stavenuiter, 2002]:

- the capability Requirement for the basic functions\(^{(D20)}\) (installation chain) which need to be assessed;
- what are the underlying technical system assessment methods;
- what is the added (safety) value in relation to the assessment need in terms of operational requirements;
- success criteria for the Life Extension assessment, safety, technical and financial.

*Critical notes for the proposed assessment scheme are:*

- feasibility (technical / economic / time);
- system; and cost effectiveness;
- reproducibility / verifiability;
- Act and Standards consist ability.

When deciding whether a full assessment is necessary, the following factors shall, as a minimum, be considered:

- the significance of the initiator triggering the assessment with respect to the structural system’s reliability\(^{(D48)}\);
- the platform’s exposure level;
- the recorded historical performance of the structure, topside and production equipment, including fabrication and installation records.
Collect and Analyse Production Facility (D13) current and historical LTE for Hibernation or Production

LE for Hibernation

Determine and Assay acceptance criteria for Facility Hibernation

Perform Condition Assessment

Hibernation Analyses,
- Evaluate Condition Assessment,
- Action Assessment,
- Structural Resistance Assessment,
- Perform design level analysis,
- Ultimate Strength analysis
And/or
- Assessment by comparison,
- Assessment by probabilities of Failure
- Assessment based on prior experience,

Pass Criteria?

Yes

Intervention;
- Repair,
- Removal (end of Loop)

fit for Hibernation and Removal

Disposal Phase

No

Disposal

Hibernation disposal

Periodical Inspection and survey’s

LE for Production

Determine and Assay acceptance criteria Topside

Perform Condition Assessment Topside

Topside Analyses;
- Evaluate Condition Assessment,
- Installation Performance Assessment,
- Environmental regulations Assessment,
- Safety mitigation Assessment,
- Assessment by comparison.
- Qualifications of Actor and Stakeholder Assessment.
- Assessment by comparison
- Assessment based on prior experience,

Pass Criteria?

Yes

Intervention;
- Repair,
- Upgrade,
- Disposal

fit for purpose - further production

No

Periodical Inspection survey’s and

Platform Selection and LE need Assessment

Determine and Assay acceptance criteria Structure

Perform Condition Assessment Structure

Structural Analyses;
- Evaluate Condition Assessment,
- Action Assessment,
- Structural Resistance Assessment,
- Perform design level analysis,
- Ultimate Strength analysis
And/or
- Assessment by comparison,
- Assessment by probabilities of Failure
- Assessment based on prior experience,

Pass Criteria?

Yes

Yes

fit for Hibernation and Removal

Disposal

Hibernation disposal

Periodical Inspection and survey’s

Figure 31 Proposed Flow diagram for Dutch LE Assessment
For an existing structure it can of course be concluded that it has not failed yet. It has withstood the loads that the structure has been exposed to. The nature of the loads that it has been exposed to, is however not necessarily known in great detail. Data from Inspection\(^\text{[SIS, 2006]}\) can show the fatigue cracking, subsidence and marine growth and other parameters that are important for the loading on the structure. Information from the actual material certificates and welding certificates may give information about the steel quality and welding quality. Further, there may have been performed simultaneous measurements of waves and current and the corresponding stresses and motions in the structure, although this level of condition monitoring is not common on the facilities operating on the Dutch Continental Shelf. These types of condition monitoring, can be applied for facilities, where the historical knowledge is minimum or to be applied as mitigating measurement [SSM, 2010].

Finally, for existing structures it is often economically favorable to perform more detailed analysis, new inspections, tests and measurements rather than redesigning and increasing the steel weight, reconfiguring the structural and production parts or replace the existing structure with a new structure. In contrast, in the design of a new structure, detailed analysis often costs more than a structural change early in the design phase. The later need to be performed by Independent Experts, to ensure that the LE assessment is performed on actual and trustworthy information. The validation of the information gathered, initially by the operator will be submitted for validation to the Independent Expert. Although the Independent Experts, perform the validation of the information and the checks of these information in case of doubt. The actual validation will be performed outside the Netherlands, this can be in worldwide [SSM, 2010]. The decentralization of the assessment validation “team”, can give the advantage that the validation will be performed subjectively. On the other hand, no direct supervision on the validation process can be performed. It can be recommended that a list of competence of the actors, who will actually perform the L.E assessment will be added to the assessment plan.

The assessment of the structure for production and for hibernation, are in principle the same. The assessment needs to prove that the integrity of the structure is capable to withstands the loads where it is exposed to, which in both phases are basically the same.

Generally the assessment of existing structures (except topside en production equipment) is based on the reviewed Standards and recommendations of Chapter 3. It can be recommended that this information, will be submitted to the Independent Expert and the Supervising Authority as an assessment plan, prior of commencement of the actual L.E. assessment process:

- consideration of whether assessment type is needed and executable, [NORSOK N006, 2009];
- information and history review, see [ISO/NEN19902:2007, Chapter A24.6.1];
- screening of structural state, [NORSOK-N006:2009]; (major damages, major changes, deviations from design);
- analysis of the structure, [NORSOK-N006:2009]; (design analysis, ultimate strength analysis or probabilistic analysis);
- decision making (acceptable as is, modification needed or disposal).

The general form of these procedures is also presented as a flowchart, as shown Figure 31, [ISO/NEN 19902,2007 – API RP2-SIM, 2010].

The purpose of the assessment of an existing structure is to ensure that the structure has an acceptable level of personnel and environmental safety. With reasonability it can be stated that a existing structure has to be operationally and integrity safe as an new one, [PSA, 2010].

In order to ensure this, a method of evaluating the safety of the structure has to be established. Possible ways of evaluating the structural safety is by proof-loading or by an analysis that estimates this safety. However, proof-loading will not be performed on offshore structures because it is hard to perform and the safety issues of the tests are bigger than the structural integrity of the structure itself , leaving analysis as the main option, [SSM, 2010].
The purpose of a structural analysis is to determine if the structure of the facility is sufficiently safe. Methods of designing structures have developed from “trial and error” to linear elastic design by load and strength calculations and code check. The development of linear elastic design has to some extent been a process of “trial and error”. The design against new failure modes have been introduced into the code checks as more experience on incidents and accidents has been collected.

Important aspects of this development are the understanding of structural behavior aspects. Linear elastic design and the codes used today for offshore structures are relatively mature. Failures are relatively rare for structures in operation on a field. However, it should be noted that very few offshore structures have been exposed to any loading comparable with the design loading. During the field research, very few failures have been noted and the failures that have been seen are rather due to errors in design, fabrication or installation. The “failures” in design can be appointed to the lower knowledge of strength an forces on the structure at the time of design. The current knowledge and designing models are more sophisticated and heavier metrological essay criteria.

That the main outcome of the structure which are currently assed (build from 1975 to 1990, [SSM, 2010]), indicate that some of the structures are to rigged and need to be adjusted in flexibility, to avoid cracking of members [SSM, 2010]. Hence, the permission of the amount of extending the operational years, will be limited by these measures, otherwise the structural safety factor has gone up. One of the main concerns during installation is the condition and stability of the seabed, which has to prove itself during the years that the facility is installed, and if installment of the foundation columns have been according the foundation plan. This information is in most times lacking, these abnormalities are not drawn-up at the facilities installation report. But the information is of great importance, for the history of the (equal) load of the facilities structure, [SSM, 2010].

When designing new structures, the most used method for ensuring safe structures is the use of linear elastic analysis and component checks by Standardized formulas. The members and joints are checked for overload (ultimate limit state), fatigue (fatigue limit state) and for accidental load situations such as explosion, fire, boat collisions and environmental conditions (accidental limit state). Most recognized Standards and recommended practices will include the relevant failure modes, but the local circumstances of the facility need to be added to these assessment descriptions, like changed environmental criteria (significant wave height), the support vessels have enlarged during the period from design to LE (increasing of the tonnage by impact) and by extracting the reserves from the well the pressure drops in the well and can result in lowering of the seabed (which initiate lowering of the height of the facility against the seawater level.), [SSM, 2010].

It has been observed that there is a significant difference in the knowledge about an existing facility and the facility when in design phase. It is important to account for this fact when evaluating the safety of existing facilities. If the SSC’s is well managed and maintained, the knowledge about the SSC’s may be significantly increased, [SSM, 2010]. This increased knowledge on construction and operational data needs to be used to increase the accuracy of the analysis of the structure, topside and operational equipment, this will reduce the uncertainty about the extended performance and safety.

---

1 [Ersdal, 2005] “When designing new and untested concepts, a more thorough analysis of possible failure modes may be necessary and Standards and recommended practices may not be fully sufficient. A fundamental requirement in structural analysis is that the calculations should be on the conservative side. According to the lower bound theorem of plasticity, an external load in equilibrium with the distribution of internal stresses, which nowhere exceeds the acceptable plastic stresses in material, is less or equal to the collapse load, if ductility is acceptable. Normally this is checked by using a linear elastic analysis, giving statically admissible forces, followed by a component check of stresses according to accepted Standards, and the use of ductile material. A method typically used for collapse analysis (also called pushover analysis), including geometric stiffness and plastic hinges, will also give a solution according to the lower bound theorem. This solution is theoretically closer to the lower bound solution than the linear elastic solution. The established safety factors are developed based on linear analysis methods, and these safety factors cannot necessarily be directly adapted to non-linear solutions without some adjustment, if the goal is the same level of safety.”
Structural design codes have to be practiced, slightly on the safe side in order to take care of uncertainties (material selection, fabrication methods, etc) at the design stage. This conservatism may be excluded to some extent in an assessment of an existing structure in form of reduced safety margins, if such uncertainties are reduced. However, it is also likely that information about an existing structure is difficult or impossible to find, e.g. due to a poor data management systems. This will increase the uncertainty about the structure as compared to the design case. For the operation/maintenance phase of the facility the maintenance personnel needs to have sufficient knowledge of the design assumptions, operational conditions etc. to be able to make such an assessment. Hence, considerable penalties in form of larger safety margins should be required, if this knowledge is not available or applied, [Ersdal, 2005], [PSA, 2010] and [SSM, 2010].

1.4.3. Hibernation and Structural Assessment

The definition for hibernation according to ISO/NEN 19902:2007 is:
A structure which has been totally decommissioned (e.g. an unmanned platform with inactive flow lines and all wells plugged and abandoned), or a structure in the process of being removed (e.g. wells being plugged and abandoned) generally does not need to be subjected to the assessment process. The latter, is not applicable due to the Dutch labour Act and legislation, which obligate that the facility is periodically inspected and assessed to ensure safe working environment and conditions, [Labour Decree Article 3.3 and 3.37k, 2010]. The overall requirement of assessing the integrity of the structure and proving that its fit-for-purpose is imbedded in, [EL&I, Mining Decree Article 53, 2003]. The types of analyses which can be applied after determining the acceptance criteria, according to NEN/ISO 19902:2007 Chapter 24, are noted in f, further elaboration of these acceptance criteria, reference is made to, [NORSOK-N006:2009].

In general an assessment of the structure will start with collecting sufficient data for an engineering assessment of the platform’s overall structural integrity. Information of the platform’s structural condition and facilities, with particular attention to data that cannot be explicitly verified (e.g. pile penetration), should be collected. General Inspections of topside, underwater, splash zone and foundation should be performed, and decision on whether more detailed Inspections and possible soil borings is necessary, should be performed based on engineering judgement, [Ersdal, 2005]. The assessment stipulated by ISO, is set-up by a set of pre-defined levels, which increase in the weight of scrutiny per level. Steps variation from the possibility, to assess by comparison with a similar nearby structure. When sufficient similarity can be demonstrated and the structure used for comparison is found fit for purpose.

To the highest and heaviest level of Assessment is the structural reliability analysis (SRA), this type of assessment is applied the most in the Netherlands, [SSM, 2010]. When applying SRA, ISO 19902 states the following:

- “The use of SRA requires extreme care and there is insufficient knowledge of the statistics to enable requirements or recommendations to be included in a Standard. Acceptance is highly dependent on the knowledge and skill of the analyst and the data upon which the analysis is based. It is recommended that thorough validation of the techniques and application of those techniques be undertaken, that acceptance criteria be agreed upon between the regulator (where one exists) and the owner, recognizing the scope for over optimism in determining the RSR, and that the results of the SRA be combined with consideration of the costs and benefits of strengthening or other remedial measures”, [NEN/ISO 19902:2007, Chapter A24.9.3].

The decision criteria as described in the ISO Standards, are not elaborated in the Dutch Acts and Regulations. Furthermore it has to be stated that no validation as described in the former, has been submitted for approval to the regulator (SSM), during executed LE assessments, [SSM, 2010]. It further subscribes the need for introducing an assessment plan as described in Chapter 4.
1.4.4. **Topside Assessment**

For LE assessment of the topside, in the mining Acts and Decree no specific Chapters have been dedicated to this part of the facility. The only Decree which can be applicable to endorse good maintenance (D42) of the topside and the process equipment can be found in [Labour Decree Article 3.3 and 3.37k, 2010], which oblige that the facility is periodically inspected and assessed to ensure safe working environment and conditions. The [ISO 19902:2007, Chapter 24.6.2] states that; “Data relating to the current state of the topside (D58) structure shall be considered. Where data are not available, are ambiguous or thought to be inaccurate, additional walk-around surveys of the topside (D58) structure and facilities shall collect the necessary information”, it has been observed during the field research, that in several cases “walk-around” surveys have been performed, [SSM, 2010].

At this moment for the topside and production equipment, the rules stated in the Labour; Acts and Regulations are to be applied, to ensure safe operation of the process equipment. Even though not all SSC’s are covered, it is merely a summary of rough guides, which does not secure long term maintenance (D42) program visions of the topside as system.

The maintenance is now merely based on Dutch industries best practice guidelines, which are supported by the operators. An example of this supported guidelines is for lifting gear, which are tested according to TCVT guidelines.

Pressure equipment is on the otherhand compelled to be tested every year by an Independent Expert, in this case Lloyd’s (who is as only IE, certified to perform these inspections).

The process system can be separated in the main hydrocarbon system and utility systems [PSA, 2010]. PSA refers to the decomposition of installations in NORSOK Standard P-100 “Process systems” which contains a list of actual installations, NORSOK Standard P-100 contains a detailed description of the equipments belonging to the different installations (not repeated in this document).

1.4.5. **H.S.E Sustainability**

In the system model, the installations are modelled as described in Chapter 5.4.4.3. The function of the safety installation, needs have a deeper clarification, because this is lacking in the described ISO and API Standards as well as in the, [OLF122, 2008]. To clarify the function of the safety installations, the hypotheses of Reason will be used, to compose the H.S.E installation diagram.

![Swiss Cheese model](Reason 1977)
The hypothesis states, that most accidents can be traced to one or more of four levels of failure:

1. organizational influences;
2. unsafe supervision;
3. preconditions for unsafe activities;
4. and the unsafe activities themselves.

In this example the model (Figure 32), an operational set of defenses against failure are modeled as a series of barriers, with individual system weaknesses in individual parts of the system, and are continually varying in size and position.

1.5. LEM Products and Activities

In this part the logistic process will be defined, according to the logistic process cycle, see Figure 16. The logistic process is the support part of the logistic process cycle. The steps defined in the LPC, will name the activities, products, actors and resources which needs to be involved and in which relationship to manage the Life Extension process.

![Figure 33 Life Extension Management Team, (Stavenuiter, 2002) & (HSE, 2009);](image)

The Management of the Life Extension assessment process, plays a crucial role, since it converts the requirements into directives, and controls the results. According to the AMC principle the domain of management is as in Figure 15, which indicates that this approach is focused on the Logistic process, the management of the Technical System (the production facility), controlled by an integrated LCM-Team. The output of this domain is initiated by the operational need. As the time and knowledge for executing Life Extension is determined and specialized, it can be recommended that a dedicated team will perform the Life Extension assessment, which is also stated in, [NORSOK N-006, 2009].

Due to the above mentioned it can be reasoned that for the Management of the Life Extension, an dedicated (LE) management team will be formed. The proposal is to set-up the management team as per Stavenuiter LCM-team, as per Figure 33.
Managing the Life Extension process requires the parties involved to put in place an appropriate organizational structure and have defined management processes. The objective of these is to define responsibilities of individuals and to clearly set out their activities, interactions, lines of communication and interfaces. Typically, these would be recorded in the Duty Holders Life Extension guideline. The following aspects should be considered as a minimum, [HSE-RR684, 2009], [OLF122, 2008] and [Stovenuiter, 2002]:

- management structure;
- roles and responsibilities;
- SIM activities;
- competency management.

1.5.1. **Management Structure, by the operator**

As per Mining Act [EL&I, 2003] the operator is responsible for the Life Extension assessment, therefore the Duty Holder should have in place a transparent and effective management structure, with the actors named, which covers the Life Extension items, see Chapter 3.5.

The management systems should:

- clearly identify the procedure for risk assessment and acceptance;
- identify technical and budgetary responsibilities. This should be an integral part of the Life Extension strategy and be clearly communicated so that all personnel are aware of and accept their responsibilities and reporting structure;
- identify reporting lines for all personnel;
- comply with Acts, Rules, Regulations and Standards;
- cover the role of and management of external suppliers;
- competency management of its personnel and external contractors.

Typically, the interactions and interfaces between the parties are included in the Life Extension strategy document in the form of a flowchart.
1.5.2. Roles and Responsibilities

Roles and responsibilities can vary depending on the organizational set-up, complexity, number of structures and other factors. This section does not set-out firm requirements for the various roles, but provides a typical example of roles and responsibilities within a LE process, which has been found to work in practice. The actual responsibilities for personnel may vary between organizations. However, it is the Duty Holder’s responsibility that a suitable organizational structure is in place.

1.5.3. Maintenance Specialists (MS)

The maintenance specialists are appointed by the Duty Holder and are responsible for ensuring performance Standards in platform safety case relating to structural and technical integrity are met. This is typically achieved by:

- setting the maintenance policy in line with corporate policy, business plan and Life Extension assessment plan;
- meeting the objectives set in the policy and plans;
- ensuring the required resources are available to allow the Life Extension assessment plan to be executed;
- appointment and management of the Independent Expert, Supervising Authority (SSM) and other parties involved in delivering Life Extension information;
- providing access to information resources for all parties involved in the Life Extension assessment of the involved facility;
- appointment of the risk to the technical, operational and structural integrity of the platform and the inherent expected cost during the Extended Life. Address these finding to all actors involved.

1.5.3.1. Inspection Contractor (IC)

The IC is typically contracted and controlled by the MS, the IC supplies trained and specialized personnel and resources to carry out routine surveys and Inspections of the structure of the facility and technical installations. The IC is typically a specialist contractor, with its own Inspection and quality procedures, which will need to be reviewed for consistency with the Life Extension guideline Standards, best practices and Acts. Responsibilities of the IC typically include:

- generation of detailed Inspection work scopes in line with the requirements set out in the structural and technical inspection scope;
- ensuring competency and qualifications of Inspection personnel;
- carrying out Inspections in line with the work scopes;
- providing detailed reporting on Inspection findings.
1.5.4. **Design Specialist (DS)**

The DS is responsible for following-up the Life Extension assessment and to define the processes by which the Life Extension objectives are set-out and how to be achieved. Responsibilities of the DS typically include \[HSE-RR684,2009\] and \[PSA, 2010\]:

- Assessment of integrity issues and ensuring visibility of these issues and associated risks to the operator, as per Figure 12;
- develop and maintain Life Extension strategies around safety critical elements and risks;
- validate structural and technical inspection finding and make recommendations;
- validate weight control procedures and complete the weight database;
- maintain analysis models of structure and perform structural assessments as required by ISO19902:2007;
- include planned modifications and operational upgrades in Life Extension assessment;
- validate if the facility is capable to handle the environmental load (airgap, tilt and met ocean data);
- produce a report of integrity and technical issues;
- review Inspection and maintenance work scopes;
- evaluate and make recommendations for change management.

1.5.5. **Independent Expert (IE)**

With the introduction of the Safety Case regime and Design and Construction regulations within the Mining Act of 2003, the certification system was replaced by risk based and goal setting activities with independent verification. The IE is appointed and reports to the Duty Holder to provide assurance that the Life Extension assessment is performed correctly. The role of the IE is specified in \[EL&I, 2003\] and forms part of the whole Life Cycle of the platform Integrity validation process.

The responsibility of the IE is to verify that the Performance Standards for structural safety critical elements have been met in accordance with the Written Scheme of Verification, as per \[ISO19902:2007\] produced by the IE in agreement with the Duty Holder.

Aspects that would typically be covered by the IE include, \[SSM, 2010\]:

- review of any impairments or maintenance issues with respect to Structural Critical Elements;
- verification of any significant structural modifications;
- verification of the Life Extension assessment processes;
- independently verifying the data produced by the Duty Holder design specialist;
- submitting an Life Extension report, with measures to be taken to ensure the integrity of the facility;
- when the Life Extension assessment has been performed and judged positively, submitting a new CoF;
- competency management of its personnel and external contractors.

The IE should be involved with general integrity related activities such as analysis reviews and modification reviews, and have free access to any relevant information and the remit and resources to carry out their duties as required by the Dutch Act, \[EL&I, 2003\]. The IE should be informed of any significant structural issues and should be given the opportunity to provide comments.
1.5.6. **Offshore Installation Manager (OIM)**

As the person responsible for safe operation of the offshore platform, the OIM will have a strong interest in the Life Extension process and will work closely with the operator and others to facilitate the delivery of (historical) information needed to perform the Life Extension assessment.

1.5.7. **State Supervision of Mines (SSM)**

SSM is the supervising authority, which has been appointed by the minister of economic affairs. The task of SSM is to validate if the Life Extension Management and risk assessment system, set-up and executed by the Duty Holder are lived up to, this way of working is in the light of the goal setting Acts and Regulations endorsed in 2003, *SSM, 2007*. In these Acts no specific tasks are addressed to SSM, for controlling and validating the Life Extension assessment process. The current position of SSM is on a big distance with regards for supervising the overall process, not more than receiving and checking the new CoF is done. The industry has made remarks on the current position of SSM, *SSM, 2010* and therefore the position as in Figure 29 is proposed in this thesis, to integrate SSM in the management of the Life Extension assessment process, *Stavenuiter, 2002*. The manner of inspecting and validating is set in SSM business operation system (2010 version) and strategy program, *SSM, 2007*. The following tasks should be addressed to the responsibilities of SSM;

Audit and review are an integral part of the tasks of SSM and should be applied on the LPC loop as indicated in Figure 10. These are the processes whereby the supervisor interrogates the Duty Holder on their Life Extension management process to ensure that operations are taking place as intended, and that these continue to be effective and appropriate. These processes consist largely of interviewing personnel and review of records. To this effect, the following sections include questions that Duty Holders should be considering as part of the audits executed by SSM.

1.5.7.1. **Audit**

The SSM should have in place and maintain an audit program. The audit program should:

4. Determine whether or not the management of the Life Extension process:
   - is effective in meeting the Life Extension guideline and objectives;
   - is effective in meeting all the Duty Holders legal obligations with respect to LE;
   - effectively manage structural and technical integrity risks, which are forthcoming from the Life Extension assessment;
   - has been properly implemented, maintained and recorded.

5. Review the results of previous audits, reviews and the action taken to rectify non-conformances.
6. Provide information on the results of the audits to the all actors involved.

The audit program should be based on the results of risk assessment of the Life Extension processes, in service incidents or unexpected structural performance and the results of previous audits and reviews, *ISO19902, 2007*. Particular attention should be given to new or modified systems which have been implemented during the last certification period and in duty during the Extended Life of the facility, *OLF122, 2008*. 
1.5.7.2. Review

The SSM should have in place a review process

The objective of the review process is; to review how the Life Extension Management processes can be improved on the basis of in house, external experience and industry best practice.

The review should:

- address findings from the audit program;
- include acquisition of knowledge on new techniques and technologies (including for example Inspection techniques, analysis tools, risk assessment methods and monitoring methods) and practices and these should be evaluated to establish their potential benefit to the Life Extension assessment processes.

1.6. LEM Actors and Resources

The actors which are involved in the Life Extension process, together with the products which they need to produce are named in the former Chapter 1.5. In the former Chapter also the mutual cooperation has been elaborated, what will be described in this Chapter, is the competency of the actors which they need to be met and how the information which will be necessary to perform the Life Extension be systematical guaranteed and available for the Life Extension team members.

1.6.1. Competency of the LEM Team

The operator is responsible for performing the Life Extension assessment, which includes competency of its own personnel and a duty of care with respect to the competency of external contractors. It is therefore required that the operator acts as an intelligent customer when purchasing services from external contractors. Competence of personnel relates to the relevance of their education, training and experience to carry out their role within the management of the Life Extension assessment process. The level and area of competence differs between roles.

Guidance is provided in [ISO 19902, 2007 Section 24.8] and [API RP 2SIM, 2005 Section 1.5] on the topic of competence management for Life Extension. The specialists involved with Life Extension should be, [HSE-RR684, 2009]:

- familiar with relevant information about the specific platform(s) under consideration;
- allocation and calculation of the risk and inherent cost of the Extended Life of the facility;
- proven track record, within the actors field of experience;
- awareness of the difference between design and assessment engineering;
- knowledgeable and certified where appropriate in the use of Inspection tools and techniques;
- aware of general Inspection issues in the offshore industry.

Details on specific requirements for evaluation and Inspection, data collection and update and Inspection program are given in the ISO Standard, but are from a higher quality in, [NORSOK-N006:2009].
Competency management can be aided by putting in place a suitable policy for recruitment, retention and succession planning of operator, Independent Expert and SSM staff and any contractor staff to provide continuity of personnel. This provides some clear technical benefits, but also encourages development of a safety focused culture, [Staveniuer, 2002]. In many instances, competency management extends to external suppliers who may have a direct effect on Life Extension of offshore production facilities.

1.7. Budget

Assessing and evaluation of the assessment, is an essential part of managerial decision making criteria. Decision taking is being executed during all Life stages of the production facility, in which the decisions during the Life Extension assessment and evaluation, are of critical influence on the safe and continues further operation of the production facility.

The budgetary part of the LPC is in this case not to determine whether the cost of the Life Extension assessment are effective and to be justified against the future revenue and operational costs. The former should already be performed, and being weight in the decision making strategy to determine, if further operations are economical feasible with the intended facility. During the Life Extension process, a number of risks will need to be addressed, these need to be controlled during the Extended Life. These risks are the variables of e.g the competence of the workforce, or failure of topside equipment which is not part of the technical Life Extension assessment. These risks, when occur, will inherently have a financial impact on the financial performance of the production facility during the Extended Life, [Emblemsvåg, 2003].

To avoid these risks or to quantify the impact of these risks if they occur, classification and thus decisions towards these risks need to be made. Typically decision theory is classified into descriptive and prescriptive decision theory. Descriptive decision theory aims to describe and understand decisions made in reality by real persons which also sometimes behave irrationally. The prescriptive decision theory - also called normative decision theory with provides a basis for rational decision-making, choosing the optimal alternative and supporting decision makers. Moreover, decision theory can distinguish between decision-making by an individual or a group, [Kübler, 2006]. Regarding decision-making by a group, the whole group can be treated in decision theory as an individual, provided that the group members have unitary preferences. Decision-making can also be studied in the case when the decision process involves a rationally acting opponent, [Senge, 1999]. Following [Luce and Raiffa, 1957], decision theory can also be divided into decision-making under:

- certainty;
- risk or;
- uncertainty.

In the case of extended operational time of an asset, an unwanted events (risks of structural or a technical failure, with damage to man or environment), are probably there if the wrong decisions are taken during the Life Extension assessment. Hence, to outcome of the Life Extension assessments and the consequent decisions which are taken, are taken under uncertainty.
Decisions based on risk acceptance criteria imply that an acceptable risk level is defined in some form, and the exposure level for personnel and environment is compared to this level, [Aven, 2003]. The development of these acceptance criteria can differ from predefined acceptance criteria from regulatory bodies, acceptance criteria developed from cost benefit analysis, or acceptance criteria defined by evaluating the safety level in the industry best practices f.e ISO and API Standards for Live Extension assessments, [Ersdal, 2005]. The Dutch Mining Acts and Regulations are goal setting for the offshore industry those Regulations can be seen as an example of using such risk acceptance criteria. The use of risk acceptance criteria is a mechanical decision tool, the risk is either less than the acceptance criterion or it is not.

This method of decision making will in principle be deontological, in so far as they have the form of clear rules and obligations. A zero risk exposure could be seen as the fulfillment of the deontological ethics. In practice a low risk level is usually used.

1.7.1. The ALARP principle

The ALARP principle (As Low As Reasonably Practicable) requires an identification and consideration of a range of potential measures for further risk reduction, [HSE, 2003]. According to the principle, risk shall be reduced to a level that is as low as reasonably practicable. The principle should provide a motivation for seeking continuous improvement.

The ALARP approach can be interpreted to have a deontological element as its purpose is to achieve as low as possible risk exposure. However, the focus on “reasonably practicable” means a reference to the consequences, and would thus also include an element of consequentialism, [Ersdal, 2005]. An ALARP evaluation may be performed with focus on these consequence elements within a Life Extension approach. Hence, the ALARP principle seems primarily linked to deontological theories.


### 1.8. Principle for Gap Analyses

In general, gap analysis is a tool that helps a company or project team to compare its actual performance with its potential performance. At its core are two questions: “Where are we?” (the Ist situation) and “Where do we want to be?”, (the Soll situation). The goal of gap analysis is to identify the gap between the optimized allocation and integration of the inputs, and the current level of allocation. This helps provide the company with insight into areas which could be improved. The gap analysis process involves determining, documenting and approving the variance between the need requirements and current capabilities.

In the case of LE assessment, the regulatory issues identified in Chapter 3.2, 3.5 and 3.5.5, together with the organizational issues. An overview can be made of possible deviations (gaps) between:

1. The required state of the facility (Structure and Topside), according to the current requirements and the and the future operational needs.
2. The anticipated performance of the facility during the Life Extended period.

It will be important to define the gaps, between the diversity of mentioned Acts, and the applied Standards for design and L.E. assessment. Analyses must then be carried out to see how these gaps can be closed, the [OLF 122, 2008] describes a methodology for performing the gap analysis; dividing the process of performing the gap analysis into five different phases, see Figure 34:

1. Working meeting and reports;
2. Gaps assessment;
3. Reporting and follow-up of the gaps;
4. Implementation and follow-up of status;
5. Closing the gaps.

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*Figure 34 Proposal of Gap analysis, [OLF 122, 2008]*

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The gaps may be deviations from regulations or can be identified gaps e.g. from the companies separate requirements. It is recommended that the gaps identified are assessed for criticality in order to ensure the right priority is given to the implementation measures. The main factor for the criticality should be the risk associated with the gap, and it is expected that the gap with the highest risk has the highest priority, i.e. according to the ALARP method.
The gap can be closed through technical, operational or organisational changes or a combination of these. Risk reducing measures will include:

- technical measures: e.g. replacement or upgrading for equipment, (for obsolescence) challenges/new regulations);
- introduce operational limitations; (equipment is not upgraded for future production/operational conditions);
- increased training/education (challenges related to human resources).

It can be assumed that it will be challenge to identify the broad spectrum of compensating measures for the various gaps, as the basis for a system- and cost effectiveness analysis. The time needed for the implementation of the measure and the time until full effect of the measures is achieved, are also important parameters. Therefore, it is important to also take the time perspective into account during the evaluation of the compensating measures, [OLF 122, 2008]

### 1.9. L.E.M Standards and Literature

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Table 3 Literature Information Summary
List the main relevant Standards, regulations, requirements, guidelines, codes etc. for Life Extension.

<table>
<thead>
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<th>#</th>
<th>Reference.</th>
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<td>API RP 2-SIM Recommended Practice for the Structural Integrity Management of Fixed Offshore Structures (under development)</td>
<td>Main focus on fixed steel, but covers all structural forms</td>
<td>- Inspection&lt;sup&gt;(2011)&lt;/sup&gt; - SIM</td>
</tr>
<tr>
<td>06</td>
<td>BS 7980</td>
<td>BS 7910 Assessment of facts in metallic structures</td>
<td>Structural and process equipment and welded components</td>
<td>- Fitness-for-service and remnant life assessment</td>
</tr>
<tr>
<td>07</td>
<td>DnV RP F101</td>
<td>DnV RP F101 Assessment of corroded pipelines</td>
<td>Structural, process equipment and welded components</td>
<td>- Fitness-for-service and remnant life assessment</td>
</tr>
<tr>
<td>08</td>
<td>DnV RPC203</td>
<td>DnV RPC203 Fatigue Strength Analysis of Offshore Steel Structures</td>
<td>Structures</td>
<td>- Fatigue Assessment (incl. a section on Extended Fatigue Life)</td>
</tr>
<tr>
<td>09</td>
<td>ISO 13822</td>
<td>ISO 13822 Assessment of existing structures (2001)</td>
<td>All types of existing structures</td>
<td>- General framework for assessment e.g. ISO19902</td>
</tr>
<tr>
<td>10</td>
<td>ISO 19900</td>
<td>ISO 19900 (series) Petroleum and Natural Gas Industries – General Requirements for Offshore Structures (2002)</td>
<td>- ISO 19900 lists exceeding of the original design Life as an initiator for platform assessment.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>NORSOK N-005</td>
<td>NORSOK N-005 Condition monitoring of load bearing Structures (1997)</td>
<td>Addresses all types of structures (fixed, steel, concrete, floating) but with little detail.</td>
<td>- Overall principles for CM to maintain structural integrity</td>
</tr>
<tr>
<td>15</td>
<td>OLF 2008a</td>
<td>Recommended guidelines for the Assessment and documentation of service Life Extension of Facilities.</td>
<td>- HSE and technical integrity and conditions - Gap analysis regulations - Assessment of LE</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Regulation Information Summary, [PSA, 2010]
In addition to former Table 4, the following NORSOK Standards can be used [PSA, 2010] for the system decomposition, [Stavenuiter, 2002].

<table>
<thead>
<tr>
<th>NORSOK Standards</th>
<th>System Decomposition Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-001</td>
<td>Living quarters area</td>
</tr>
<tr>
<td>C-002</td>
<td>Architectural components and equipment</td>
</tr>
<tr>
<td>D-001</td>
<td>Drilling installations</td>
</tr>
<tr>
<td>D-010</td>
<td>Well integrity in drilling and well operations</td>
</tr>
<tr>
<td>H-001</td>
<td>HVAC 184</td>
</tr>
<tr>
<td>L-001</td>
<td>Piping and valves</td>
</tr>
<tr>
<td>L-002</td>
<td>Piping design, layout and stress analysis</td>
</tr>
<tr>
<td>M-001</td>
<td>Material Selection</td>
</tr>
<tr>
<td>M-501</td>
<td>Surface preparation and protective coating</td>
</tr>
<tr>
<td>N-001</td>
<td>Structural design</td>
</tr>
<tr>
<td>N-003</td>
<td>Actions and action effects</td>
</tr>
<tr>
<td>P-001</td>
<td>Process design</td>
</tr>
<tr>
<td>P-100</td>
<td>Process systems</td>
</tr>
<tr>
<td>R-001</td>
<td>Mechanical equipment</td>
</tr>
<tr>
<td>R-002</td>
<td>Lifting equipment</td>
</tr>
<tr>
<td>R-003</td>
<td>Safe use of lifting equipment</td>
</tr>
<tr>
<td>R-004</td>
<td>Piping and equipment insulation</td>
</tr>
<tr>
<td>S-001</td>
<td>Technical safety</td>
</tr>
<tr>
<td>Z-008</td>
<td>Risk based maintenance &amp; consequence classification</td>
</tr>
<tr>
<td>Z-013</td>
<td>Risk and emergency preparedness analysis</td>
</tr>
</tbody>
</table>

Table 5 NORSOK Installation Performance, Inspection and Design Guidelines, [Sintef, 2010]
Appendix.2. System Modeling

2.1. Multi attribute analysis with managerial decision and ethical theories

The focus of the risk analysis with uncertainty is to produce good alternatives with respect to safety, economy and other attributes. It includes risk reduction without acceptance criteria, and includes an element of deontology. It also includes cost benefit analysis, [Emblemsvåg, 2003]. The decision process is, however, not mechanical on the basis of the risk analyses and these decision analyses. The decision process can be seen as a process of evaluating and weighing the different stakeholder interests. The stakeholders may to some extent have different means, and hence different agendas for the decision-making. However, by including these views and presenting them clearly, the decision making process would be open and finally end in a discourse that can be audited by the stakeholders. A critic to this way of thinking may ask whether anything is acceptable within the multi attribute analysis with managerial decision, as long as the decision makers find discourse. The answer is obviously "No". The decision makers should take into account the relevant goals, criteria and preferences by the stakeholders and actors within the Life Extension team, but the acceptance should not be based on direct use of risk acceptance criteria. The interests of the stakeholders would in most cases be that the safety is at least in accordance with normal practice, which means that the decision process should be able to account for some indications of a reasonable risk. It can be assumed that decision methods seem to have a reasonable basis in sound ethical theories. There is no clear guidance on which ethical theory that is preferable to others. Hence it is difficult to use the ethical theory as a guiding principle to choose between the decision methods. However, it seems to be a rational logical link between the decision methods available and the major ethical theories available.

2.2. Managing Risks under Uncertainty

Risk management is the process which focuses on efficient and effective management of potential opportunities and adverse hazards, [Emblemsvåg, 2003]. Risk management involves all aspects of risk assessment and it can be structured into a generic format which is illustrated in Figure 35. It is emphasized that this format is independent of a considered industry or branch thereof. Therefore, it can be seen as an overall decision and management framework. Figure 35, which is taken from AS/NZS 4360:2006, shows the required steps for risk management. Definition of the context is the most important step. The strategic and organizational context needs to be identified or defined. For instance, answers need to be found to questions such as: How is the Life Extension team coming to a decision? And which other parties are affected by the implementation of possible actions? In addition, the system has to be identified.
A further crucial part of the first step is the choice of the acceptance criteria to be used. The analyzed risk can then be assessed/evaluated, whether it is acceptable or not. In case it is not acceptable, appropriate risk treatments can be incorporated such as risk mitigation, reduction or transfer. The review and monitoring of the individual steps accompany the whole risk management process as well as communication with the decision makers in the Life Extension team and related stakeholders.

Figure 35 Risk management process according to [AS/NZS 4360:2004]

Today’s decision-making under risk is based on, rational decision theory and Bayes’ theorem. Three possible decision analyses can be distinguished, namely prior, posterior and pre-posterior decision analysis, [Kübler, 2006]. Whereas prior decision analysis considers only information which is already available, the posterior decision analysis is able to account for new information; and using the pre-posterior decision analysis it is possible to identify an optimal strategy to perform experiments, e.g. inspections and subsequent actions before the experiments are actually carried out.
Today, pre-posterior decision analysis is a crucial tool for the assessment of existing structures and risk-based inspection and maintenance planning. Only if the objective of decision-making is clearly identified, is it able to serve the decision maker to allocate his or her resources beneficially. Using investment criteria beneficial projects or actions are identified. For instance, cost comparison is a simple and often utilized criterion. However, it fails to take into account the revenues as well as the time-variant structure of costs and revenues. Comparing costs and revenues occurring at different points in time is only possible by using the concept of discounting, [Kübler, 2006].

The predominant investment criterion utilized in economics is the net present value (NPV) that discounts costs and revenues to obtain the present value. The net present value is simply the sum of all present valued costs and revenues which are associated with the investment, such as a civil engineering facility. If costs and revenues are uncertain, the project with the maximum expected net present value is preferred. Risk is a measure of a hazard. Mathematically formulated, it is the expected value of all consequences and this highlights its closeness to decision theory, expresses in Net Present Value (NPV). Risk assessment and management is today’s framework for decision-making in civil engineering and thus needs to be part of the management issues during the Life Extension assessment.

2.3. Decision Analyses

In optimizing the safety of a risk exposed system, all failure modes and uncertainties associated to these failure modes should in principle be addressed. As this in practical design is an impossible task, the following fundamental principle should be applied: The risk model is sufficiently accurate when any improvement to the risk model to make it more accurate should not lead to a change in the conclusions made, [Aven, 2003].

2.3.1. Simplified Decision Analysis

Following [Kübler, 2005], optimal design in structural engineering may be seen and formulated as a decision problem within the framework of Bayesian decision analysis, [Aven, 2003]. In short, the decision problem may be formulated as an optimization problem, where the expected Life Cycle benefit of the structure is determined by setting the boundaries within the Life Extension Management. Due to the fact that income and costs of risk with uncertainty can occur at different times, the expected benefit is capitalized (by means of its net present value) to the point in time when the decision is made.

When searching for the optimal use Life of a system, it should be taken into account that the system or parts may fail in the future and that it may be rebuild if feasible. This will, again strongly depends on the future potential income / revenue.

Figure 36 A Simple Event Tree, [Ersdal, 2005]
Following [Ersdal, 2005] the decision/event tree shown in Figure 36, illustrates the pursued approach. The first node in Figure 36 represents the system (production facility), which is evaluated for Life Extension. At this time the reliability and capability of the system is determined. After the system is passing into its Extended Life, in principle two events may happen.

The system may survive (event $E_1$) or it may fail. If the system fails, there are again two possibilities. Either it is economically feasible to reconstruct the system or it is not (event $E_2$). If economically feasible, the system is reconstructed and thereafter again two events may follow. Either the system fails before the anticipated design life (event $E_4$) or the structure survives (event $E_3$). Hence, in the presented case, only the expected costs of risk with uncertainty up until the time of the first failure will be taken into account.

2.3.2. Ethics within Decision Making

The ethics within decision making will in principle be deontological, in so far as they have the form of clear rules and obligations. [Rawls, 1971] could be used to argue for such a decision method. Based on the Kantian ethics argued by Rawls, one could argue that a person should not be exposed to a higher risk in order to benefit other persons, a company or the society. A zero risk exposure could be seen as the fulfillment of the deontological ethics. In practice a low risk level is usually used (ALARP).

The deontological theory presented here by Rawls, is supported by the theories of (Kant, Jonas, and Habermas) all clearly focused on the individuals right with respect to risk exposure. Jonas, (1993) is also clearly including the environmental concerns into the ethical basis for decisions. A zero accident philosophy would in many aspects be the right philosophy based on deontological thinking. However, in practice it is impossible to obtain a zero risk as anything more than a vision when facing uncertain future events and consequences. This would lead to more pragmatic implementations of the deontological ethics in practical decision making.

Elliott and Taig [2003] develop the practical pragmatic implementation of the deontological ethics starting by stating that “No person or organization has a moral right to expose another to risk.” This is the starting deontological principle, as mentioned earlier. They go on and state some reasonable exceptions to this statement. First it is argued that “It is morally acceptable to expose another person to risk if the purpose of the action is to reduce the net risk for this person”. It is recognized that the manager of a risk in such situations has a moral obligation to explain the risk to the actor(s) who will face it and secure informed consent before starting out. The next Extension of this exception would be “It is morally acceptable to take moderate risk in order to reduce risk for others”. The final Extension that is formulated by Elliot and Taig [2003] is that “It is morally acceptable to ask someone to take a modest health or safety risk in order to accrue other, non-health or safety benefits for others”. This is exemplified by people working in hazardous jobs, as working on offshore production facilities. This will however, require that those at risk should where possible give their own consent and that those creating or managing risks should be competent in minimizing them within reason.

The general principles for responsibility of organizations that should apply in such situations are as follows [Elliot and Taig, 2003] and [Kübler, 2006]:

- ensure openness and transparency about risks and how they are controlled;
- continually search for ways to reduce risk, unless they compromise other desirable outcomes;
- involve people in decisions that affect them as far as practicable;
- work across the spectrum of areas for which the organization is responsible, those for which it shares responsibility with others, and those it can influence but not control.

The use of e.g. risk acceptance criteria and the cautionary principle (in face of uncertainty, cautionary should be the ruling principle) would be such pragmatic ways of deontological thinking.
Appendix.3. Information Management

3.1. Portal lay-out

To build the communication portal, which will need to serve and enhance LEM, the guides as described in Chapter 5.5 need to be inserted. To do so, a so called “Relation Matrix” has been set-up which will elucidate the content per page on the communication vehicle. The matrix (Table 6) has to be reading, as one is peeling an union, layer by layer, the Portal will guide you towards a higher level of required information on LEM and the production facility involved.

The portal can be accessed by the Internet on, [http://portal.amicoservices.nl/SSM-LEM-GLP/default.aspx](http://portal.amicoservices.nl/SSM-LEM-GLP/default.aspx). As visitor the portal can be accessed through the demo account:

- username: demo@amicoservices.nl;
- password: demo.

<table>
<thead>
<tr>
<th>Portal Page Structure</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Page</td>
<td>Portal LEM Purpose</td>
</tr>
<tr>
<td></td>
<td>LEM Actors Relationship</td>
</tr>
<tr>
<td></td>
<td>Stakeholder and Actors</td>
</tr>
<tr>
<td></td>
<td>Team (Actor)</td>
</tr>
<tr>
<td></td>
<td>Overview/Structure</td>
</tr>
<tr>
<td></td>
<td>LIST: Documents</td>
</tr>
<tr>
<td></td>
<td>Guideline for LEM</td>
</tr>
<tr>
<td></td>
<td>Data Control</td>
</tr>
<tr>
<td></td>
<td>Process Control</td>
</tr>
<tr>
<td></td>
<td>Asset Control</td>
</tr>
<tr>
<td></td>
<td>Site Contact</td>
</tr>
<tr>
<td></td>
<td>Announcements</td>
</tr>
<tr>
<td></td>
<td>Links</td>
</tr>
<tr>
<td>Actors</td>
<td>LIST: Production Facilities</td>
</tr>
<tr>
<td></td>
<td>LEM Contact</td>
</tr>
<tr>
<td>Facility Info</td>
<td>System Lay-out</td>
</tr>
<tr>
<td></td>
<td>LIST: Documents</td>
</tr>
<tr>
<td></td>
<td>LIST: Deliverables</td>
</tr>
<tr>
<td></td>
<td>LIST: Certificates</td>
</tr>
<tr>
<td></td>
<td>LEM Team</td>
</tr>
<tr>
<td></td>
<td>Process Management</td>
</tr>
<tr>
<td></td>
<td>AMICO [AC]</td>
</tr>
<tr>
<td>LEM</td>
<td>Calendar</td>
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<tr>
<td></td>
<td>Tasks</td>
</tr>
<tr>
<td></td>
<td>Contacts</td>
</tr>
<tr>
<td></td>
<td>Announcements</td>
</tr>
<tr>
<td></td>
<td>Discussion Board</td>
</tr>
</tbody>
</table>

Table 6 LEM Portal Relation Matrix
Definitions

In this Master Thesis, the following definitions are used;

D01. **Ageing**

– General process in which the characteristics of a system, structure or component gradually change with time or use, [Stavenuiter, 2004].
– A process of degradation related to the progression of time and/or the use of the facility and the systems related to the facility, [PSA, 2010].

D02. **Ageing management**

– Ensuring the availability of required safety functions with account taken of changes that occur with time and use. This requires addressing both physical ageing of SSC, resulting in degradation of their performance characteristics, obsolescence of SSC’s, i.e. their becoming out of date in comparison with current knowledge, Standards and regulations, and technology, and organizational ageing, [PSA, 2010 slightly edited].

D03. **Ageing effects**

– Net changes in the characteristics of an SSC that occur with time or use, and are due to ageing mechanisms. For examples of negative effects, see ageing degradation, [Galbraith, 2005].

D04. **ALARP**

– As Low As Reasonable Practicable, a methodology used for quantitative and qualitative assessment of the risk and risk reduction measures and the benefits of implementation of these. ALARP evaluation is only valid if the risk levels identified are lower the upper acceptance criteria, [HSE, 2003].

D05. **Asset Management Control (AMC)**

– Asset Management is the set of processes, tools, performance measures and shared understanding that connects the system, structures, components or activities of and around an asset together, [Stavenuiter, 2002].

D06. **Availability, Logistic (A_l)**

– The probability (%) that an item of equipment is in an operable and committable state, without unsettled repairs, when called for an unknown (random) time.
In equation: (active time – not available time)/active time, [LCM- systems, 2002].

**Availability, Operational (A_o)**

– The measure of degree to which an object or item is in an operable an committable state when called for an unknown (random) time, [Stavenuiter, 2002].

D07. **Barrier**

– Defences that prevent a vulnerable target from being exposed to hazardous energy in an accident event, [Galbraith, 2005].
D08. **Barrier system**

-The technological, human or organizational system that is ensure that the barrier(function) is fulfilled, [Ersdal, 2005].

D09. **Control**

- An existing process, policy, device, practice or other action that acts to minimize negative risk or enhance positive opportunities, [AS/NZS 4360:2004].

**NOTE:** The word 'control' may also be applied to a process designed to provide reasonable assurance regarding the achievement of objectives.

D10. **Decision making**

-Can be regarded as the mental processes (cognitive process) resulting in the selection of a course of action among several alternatives. Every decision making process produces a final choice. The output can be an action or an opinion of choice, [Kübler, 2006].

D11. **Deterioration**

- Is a process that adversely affects the structural performance, including reliability over time due to, [SIS, 2006];
  - naturally occurring chemical, physical or biological actions,
  - repeated actions such as those causing fatigue,
  - normal or severe environmental influences,
  - wear due to use, or
  - improper operation and maintenance of the structure.

D12. **Design Life**

-See Life (design), D36

D13. **Effect**

-Is an event or circumstance that occurs as a result of facts and/or events,[Kübler, 2006].

D14. **Event**

-Occurrence of a particular set of circumstances, [AS/NZS 4360:2004].

**NOTE 1:** The event can be certain or uncertain.

**NOTE 2:** The event can be a single occurrence or a series of occurrences.

D15. **Facility**

-A fixed gas or oil production installation installed on the Dutch Continental Shelf that is not defined as a mobile installation [Ondracek, 2009].
D16. Fallow blocks

- Are those where the initial term (normally 6 years) has expired with no drilling, dedicated seismic or other significant activity for a period of 3 years [EL&I, 2010].

D17. Fallow discovery

- Is a discovery which the current licensees are unable to progress towards activity due to misalignment within the partnership, a failure to meet economic criteria, other commercial barriers, or a combination of these, [EL&I, 2010].

D18. Failure

- The termination of the ability of an entity to perform a required function, [Ersdal, 2005].

Ageing failure is a failure whose probability of occurrence increases with the passage of time (independent of the operating time), [Ersdal, 2005].

D19. Fitness for Service (FFS)

- Quantitative or qualitative engineering evaluation of the structural integrity of a component containing a fact or damage, carried out to a published procedure. Also known as “Fitness for Purpose (FFP) assessment” or “Engineering Critical assessment”, [PSA, 2010].

D20. Functions (basic)

- The lowest level of the functional breakdown. These are technical functions which have an unambiguous relationship with an installation chain, [Stavenuiter, 2002].

D21. Functions (sub)

- Functions of the main functions can be realized. Examples of main function ‘mine hunting’: detect, classify, identify, etc, [Stavenuiter, 2002].

D22. Functions (operational)

- Functions which the system was purchased to meet operational performance, [Stavenuiter, 2002].

D23. Gap

- An identified difference between systems in place and facilities design and a recognized and accepted Standard e.g. the Standards referred to the facilities Regulations, [OLF122, 2008].

D24. Gap analyses

- An systematic evaluation of the systems in place and the facilities design against the requirements in a recognized and accepted Standard e.g. the Standards in and referred to the facilities regulations and design Standards, [OLF122, 2008].
D25. **Gas**
- Quantities of dry natural gas, measured after purification and extraction of natural gas liquids and sulphur. Production includes only marketable production, and excludes any quantities re-injected, vented and flared, and any extraction losses, [ECN, 2008].

D26. **Hibernation**
- Is a state of inactivity of the production facilities prior total abandonment of the facility. Which it is assumed that during the period the facility in hibernation the anticipated maintenance measures remain in place, [PRC, 2007].

D27. **Indicator of ageing**
- A sign or evidence that some damage has already or is about to occur, and can be thought of as symptoms of ageing damage, [PSA, 2010].

D28. **Import of (crude) Oil**
- Imported crude oil divided by countries of origin, EU-27 is counted without imports inside the EU, [PRC, 2007].

D29. **Import of (natural) gas**
- Imported natural gas divided by countries of origin, EU-27 is counted without imports inside the EU, [PRC, 2007].

D30. **Import dependency**
- Net imports of a country or region divided by the sum of the gross inland consumption and bunkers. Within a carrier, [PRC, 2007].

D31. **Inspection (General)**
- A careful and critical scrutiny of the item or equipment for determining its condition, the purpose of which is to discover facts that can give rise to danger. Inspections can include non-destructive testing, as well as visual surveys, replication of a surface, and materials sampling to determine the physical and metallurgical condition of the equipment, [Ersdal, 2005].

D32. **Inspection (Risk Based)**
- A methodology which aims at establishing an inspection programme based on the aspects of probability and consequence of a failure, [PSA, 2010].

D33. **Installation**
- A set of devices (system/equipment components) which supports one or more (technical) basic functions as independently as possible and with a minimum of interactive effects on other installations, [LCM systems, 2002].

D34. **Integrity (structural)**
- Ability of a structure not to be damaged by events like fire, explosions, impact or consequences of human errors, to an extent disproportionate to the original cause, [ABB, 2009].
D35. **Integrity (Asset Sustainability)**

-An asset has integrity\(^{(D34)}\) when it meets design performance Standards for effective control of risks and failure and when the Asset Management systems effectively support those Standards, [SSM, 2008].

D36. **Life (design)**

-Assumed period for which a structure is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary, [NORSOK N006, 2009].

D37. **Life Extension**

-The methods/process to obtain, secure an acceptable technical and operational integrity throughout the extended service life\(^{(D38)}\), [Ersdal, 2005].

D38. **Life Extended**

-Assumed period beyond the service life\(^{(D36)}\) for which a facility is to operate and still obtain an acceptable technical and operational integrity [PSA, 2010].

D39. **Life Extension Assessment**

-The process to evaluate if Life Extension\(^{(D29)}\) of a facility and its SSC is acceptable, [HSE, 2009].

D40. **Life (Useful)**

-Under given conditions, the time interval beginning at a given instant of time, and ending when the failure intensity becomes unacceptable or when the item is considered non repairable as a result of a fault, [PSA, 2010].

D41. **Maintainability (M)**

- Is the characteristic of design and installation indicating the measure of ease and rapidity with which equipment can be retained at a specified level of performance. Maintainability is expressed as the probability that asset will conform to specified conditions within a given period of time when maintenance\(^{(D42)}\) action is performed in accordance with prescribed procedures and resources [Blanchard, 1998].

D42. **Maintenance**

- Set of activities performed during the working life\(^{(D40)}\) of the structure in order to enable it to fulfil the requirements for reliability\(^{(D48)}\), [Blanchard, 1998].

- Combination of all technical, administrative and managerial actions during the Life Cycle of an item intended to retain it in, or restore it to, a state which it can perform the required function, [Blanchard, 1998].

D43. **Mining**

- Is the extraction of (valuable) minerals or other geological materials from the earth, [PRC, 2007].
D44. Mitigation
- Plan covering the need for upgrading (repair/replacement), monitoring, inspection and testing, [PSA, 2010].

D45. Non-conformity
- An identified difference between the physical condition and/or Standard on the facility and the requirements in the applicable regulations, [SSM, 2007].

D46. Obsolescence
- SSC becoming out of date in comparison with current knowledge, Standards, technology and needs, [NEN 19902, 2007].

D47. Redundancy
- The existence of more than one mean at a given instant of time for performing a required function, [OLF 122, 2008].

D48. Reliability (R)
- Is the probability that a system or component will perform its intended function for a specified period under stated conditions. Reliability is usually expressed in terms of probability of performance of an asset without failure. The performance can be expressed as mean time between failures (MTBF) can be expressed in hours or as the number of failures in a given period of time, [ Blanchard, 1998].
  (note; the number of failures is a given period, defined as the “Failure Rate”, [Jones, 1994].

D49. Repair
- Activities performed to preserve or to restore the function of a structure that fall outside the definition of maintenance, [PSA, 2010].
- Physical action taken to restore the required function of a faulty item, [Blanchard, 1998].

D50. Risk
- The chance of something happening that will have an impact on objectives, [AS/NZS 4360:2004].

NOTE 1: Risk is often specified in terms of an event or circumstance and the consequences that may flow from it.
NOTE 2: Risk is measured in terms of a combination of the consequences of an event and their likelihood.
NOTE 3: Risk may have a positive or negative impact.

D51. Risk Analyses
- Systematic process to understand the nature of and to deduce the level of risk, [AS/NZS 4360:2004].

NOTE 1: Provides the basis for risk evaluation and decisions about risk treatment.
D52. Risk Assessment

- The overall process of risk identification, risk analysis and risk evaluation, refer to Figure 35, [AS/NZS 4360:2004].

D53. Risk Criteria

- Terms of reference by which the significance of risk is assessed, [AS/NZS 4360:2004].

NOTE: Risk criteria can include associated cost and benefits, legal and statutory requirements, socioeconomic and environmental aspects, the concerns of stakeholders and actors, priorities and other inputs to the assessment.

D54. Risk Management

- The culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects, [AS/NZS 4360:2004].

D55. Risk Management Process

- The systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analyzing, evaluating, treating, monitoring and reviewing risk, [Kübler, 2006]

D56. System

- A system is an integrated composite of people, products, installations and processes that provide a capability to satisfy a stated need or objective, [Staveniuter, 2002].

D57. Subsea

- Structures and equipment for offshore oil and gas production and transportation located below the sea level or on the seabed, [PSA, 2010].

D58. Topside

- Those parts of an entire offshore installation which are not part of the substructure and includes modular support frames and decks where their removal would not endanger the structural stability of the substructure, [NEN19902, 2007].

D59. Uncertainty

- It applies to predictions of future events, to physical measurements already made, or to the unknown, [Kübler, 2006].
### Abbreviations and Acronyms

Below the list of abbreviations and acronyms which will be found in this report:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALARP</td>
<td>As Low As Reasonable Possible;</td>
</tr>
<tr>
<td>AMICO</td>
<td>Asset Management Information &amp; Communication;</td>
</tr>
<tr>
<td>AM</td>
<td>Asset Management;</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute;</td>
</tr>
<tr>
<td>AISC</td>
<td>American Institute of Steel Construction;</td>
</tr>
<tr>
<td>BSI</td>
<td>British Standardization Institute;</td>
</tr>
<tr>
<td>CAPEX</td>
<td>Capital Expenditure;</td>
</tr>
<tr>
<td>CoF</td>
<td>Certificate of Fitness;</td>
</tr>
<tr>
<td>DG-E.T.</td>
<td>Directorate General for Energy and Telecom - Ministry of Economic Affairs. (Present EL&amp;I);</td>
</tr>
<tr>
<td>EBN</td>
<td>Energie Beheer Nederland (Dutch);</td>
</tr>
<tr>
<td>ECN</td>
<td>Energy Control Netherlands;</td>
</tr>
<tr>
<td>EL&amp;I</td>
<td>Ministry of Economic Affairs, Agriculture and Innovation (former Ministry of Economic Affairs);</td>
</tr>
<tr>
<td>EU-27</td>
<td>The 27 countries (members) forming the European Union;</td>
</tr>
<tr>
<td>Et al.</td>
<td>when referring to a number of people;</td>
</tr>
<tr>
<td>G.I.I.P</td>
<td>Gas Initial In Place;</td>
</tr>
<tr>
<td>HSE</td>
<td>Health and Safety Executive (United Kingdom);</td>
</tr>
<tr>
<td>IF</td>
<td>Impact Factor;</td>
</tr>
<tr>
<td>ILS</td>
<td>Integrated Logistic Support;</td>
</tr>
<tr>
<td>IP</td>
<td>Installation Performance;</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization;</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator;</td>
</tr>
<tr>
<td>LCM</td>
<td>Life Cycle Management;</td>
</tr>
<tr>
<td>LE</td>
<td>Life Extension;</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>LEM</td>
<td>Life Extension Management;</td>
</tr>
<tr>
<td>LPC</td>
<td>Logistic Process Cycle;</td>
</tr>
<tr>
<td>LRFD</td>
<td>Load and Resistance Factor Design for Steel Structure;</td>
</tr>
<tr>
<td>MoP</td>
<td>Measurement of Performance</td>
</tr>
<tr>
<td>NGT</td>
<td>Northern Gas Transport;</td>
</tr>
<tr>
<td>NPV</td>
<td>Nett Present Value;</td>
</tr>
<tr>
<td>NOGAT</td>
<td>Northern Offshore Gas Transport;</td>
</tr>
<tr>
<td>NOGEPa</td>
<td>Netherlands Oil and Gas Exploration and Production Association;</td>
</tr>
<tr>
<td>NORSOK</td>
<td>Norwegian Oil Industry Standardization Organization;</td>
</tr>
<tr>
<td>OLF</td>
<td>The Norwegian Oil Industry Association;</td>
</tr>
<tr>
<td>OPEX</td>
<td>Operational Expenditure;</td>
</tr>
<tr>
<td>PI</td>
<td>Performance Indicator</td>
</tr>
<tr>
<td>PSA</td>
<td>Petroleum Safety Authority (Norway);</td>
</tr>
<tr>
<td>RP</td>
<td>Recommended Practices;</td>
</tr>
<tr>
<td>SIM</td>
<td>Structural Integrity Management;</td>
</tr>
<tr>
<td>SRA</td>
<td>Structural Resistance Analyses;</td>
</tr>
<tr>
<td>SSM</td>
<td>State Supervision of Mines (the Netherlands);</td>
</tr>
<tr>
<td>SSC</td>
<td>System, Structure or Component;</td>
</tr>
<tr>
<td>VALID</td>
<td>Verified Asset Logistics Information Domain</td>
</tr>
<tr>
<td>WGT</td>
<td>Western Gas Transport.</td>
</tr>
</tbody>
</table>
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