Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

MASTER'S THESIS

Study programme/specialisation: Offshore Technology / Industrial Asset Management	Spring / ~~Autumn~~ semester, 20.17. Open/~~Confidential~~
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Title of master's thesis: Asset Management Practices in Norwegian Industrial Sectors	
Credits: 30	
Keywords: Asset Management, Asset, Holistic, Value, Whole-Life Management, ISO 55000, Oil and Gas, Land-Based Manufacturing, Land-Based Process	Number of pages: ……103…… + supplemental material/other: ……4…… Stavanger,……12/06/2017…… date/year

Asset Management Practices in Norwegian Industrial Sectors

By

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A Thesis
Presented to the Faculty of Science and Technology
University of Stavanger

In Fulfillment of the Requirements for the degree of
Master of Science
(MSc)

Faculty of Science and Technology
2017

Abstract

Several industrial sectors in Norway have been subjected to challenging industrial conditions in recent years, due to factors such as declining markets and large market fluctuations. On top of these challenging industrial conditions are also the elevated demands of modern industrial society, encompassing such factors as increasing stakeholder concerns related to environmental and social effects of industrial organizations' activities and an increasing pressure to deliver improved services and products without increasing costs or risks. A key aspect in meeting such elevated demands and challenging industrial conditions is the way in which industrial organizations manage their assets and the value they create. The discipline of asset management is interesting in this regard, as it promotes enhanced value delivery from assets, at lower risk and with improved sustainability. The principles of asset management allow industrial organizations to regularly achieve their organizational objectives and meet stakeholder expectations on a regular basis, regardless of their operating sector and organizational context. The Norwegian oil and gas (O&G) industry is an industrial sector that is known to operate with asset management principles and manage assets in a way that balances costs, risks and benefits. As the discipline of asset management partially originated from the O&G industry in the North Sea, the Norwegian O&G industry has gained solid experience within the field. However, when looking at other industrial sectors in Norway, such as land-based manufacturing and land-based process, there is still limited available information regarding the current state of their asset management practices and how their individual practices actually compare to each other.

The purpose of this thesis is to perform an analysis to compare the asset management practices found in a selection of Norwegian industrial sectors, namely O&G, land-based manufacturing and land-based process. The included analysis incorporates an industry-leading organization within each of the industrial sectors and utilizes the common asset management practices of the ISO 55000 suite, the first ISO (International Organization for Standardization) standard for asset management, as analysis criteria. Published in January 2014, the ISO 55000 suite contains a systemized framework for practicing asset management at a prominent level in any industrial sector, for any type of asset. Its elevated level of applicability allows for a reliable cross-industrial comparison of asset management practices centered around a common set of criteria. The included analysis has resulted in an uncovering of specific performance gaps and improvement areas related to the included organizations' asset management practices, which were found to encompass factors such as leadership differences, the lack of a formalized asset management approach and differences in the individual organizations' perception of value. To facilitate a solid understanding of the included analysis and the uncovered results, there have also been conducted comprehensive literature studies on asset management and the ISO 55000 suite, both of which precede the included analysis of asset management practices in this thesis.

This thesis is aimed at providing interested parties with relevant insights into the current state of asset management practices in Norwegian industrial sectors. It should also function as a highly useful knowledge base for any industrial organization that contemplates an implementation of asset management practices through the framework of the ISO 55000 suite.

Acknowledgements

The thesis you are now reading concludes my Master of Science degree in Industrial Asset Management at the University of Stavanger. The process of writing this thesis has been both challenging and an invaluable learning experience. The writing of this thesis would not have been possible without the help of several knowledgeable and resourceful people, and I would like to take this opportunity to express my sincerest gratitude for their assistance.

First, I would like to thank my academic supervisor Professor Jayantha Prasanna Liyanage. The feedback I have received from Professor Liyanage has been highly useful in setting the direction of this thesis and he has provided me with useful feedback along the way. He has also been a major contributor in preparing me for the process of writing this thesis, through his elevated level of teaching and sharing of knowledge in several of the courses I have taken during my studies at the University of Stavanger.

Next, I would like to thank Apply Sørco for providing me with an interesting and challenging topic for my master's thesis. A special, extended thank you goes to my external supervisor Jawad Raza, for helping me define the structure and direction of this thesis, and sharing his valuable time, knowledge and experience whenever I had questions or required feedback.

I would also like to thank each of the industrial organizations that took part in the analysis of asset management practices, and especially the personnel that lent me their time and knowledge. This thesis would not be made possible without your honest feedback and relevant answers.

Lastly, I want to thank my family and especially my parents, for always supporting me and being there for me.

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List of Abbreviations

ALARP – As Low As Reasonably Practicable

BIM – Building Information Modelling

BSI – British Standards Institution

CAPEX – Capital Expenditure

CBA – Cost Benefit Analysis

CMMS – Computerized Maintenance Management System

FMECA – Failure Modes, Effects and Criticality Analysis

GFMAM – Global Forum on Maintenance and Asset Management

HAZOP – Hazard and Operability

HSEQ – Health, Safety, Environment and Quality

IAM – Institute of Asset Management

IO – Integrated Operations

ISO – International Organization for Standardization

KPI – Key Performance Indicator

LCC – Life Cycle Cost

O&G – Oil and Gas

OEE – Overall Equipment Effectiveness

OPEX – Operational Expenditure

PAS – Publicly Available Specification

RBM – Risk-Based Maintenance

RCM – Reliability-Centered Maintenance

ROI – Return On Investment

SAMP – Strategic Asset Management Plan

S.M.A.R.T – Specific, Measurable, Achievable, Realistic and Timebound

SMRP – Society for Maintenance and Reliability Professionals

SWOT – Strengths, Weaknesses, Opportunities and Threats

TBL – Triple Bottom Line

Chapter 1 – Introduction

1.1 Background

Several industrial sectors in Norway have been through a period of declining markets and challenging industrial conditions in recent years, as both 2015 and 2016 were years where the overall industrial turnover in Norway was subjected to decline (Statistics Norway, 2017). On top of these challenging industrial conditions are also the elevated demands of modern industrial society. Increasing concern from stakeholders regarding the social and environmental impact of organizations' activities and increased pressure to provide improved services and products without increasing costs or risks are just some of the demands that must be dealt with by modern industrial organizations on a regular basis, regardless of their operating sector (Edwards, 2010a; Pilling, 2010; Liyanage, 2012). An important aspect in being able to operate through such challenging industrial conditions and continually meet the demanding standards of modern industrial society is the way in which industrial organizations manage and operate their assets, and the potential value they create to both themselves and their stakeholders.

Woodhouse (2010a) refers to the discipline of asset management in that regard, as a discipline that facilitates improved value delivery from an organization's assets, at lower risk and with greater sustainability. Asset management introduces organizations to a more holistic value perception, by considering all aspects of costs, risks, performance and longevity, to identify the optimized compromise between such competing factors. By applying the principles of asset management, organizations are able to shape their own success and continually meet the expectations of their stakeholders to the greatest degree possible (Woodhouse, 2010a).

The Norwegian oil and gas (O&G) industry is an example of a Norwegian industrial sector that is known to have implemented asset management principles, by managing and operating assets in a way that balances costs, risks and benefits, thus also strengthening the possibilities of both meeting stakeholder demands and enhancing the value-creating abilities of assets. Through several years of experience, the industry can show for a wide selection of practices with regards to asset management, many of which are well documented in both the NORSOK standards and in regulations issued by the Petroleum Safety Authority.

The public recognition of asset management and its potential benefits led to the publishing of the ISO 55000 suite, the first official ISO (International Organization for Standardization) standard for asset management, in January 2014. The ISO standard contains a framework for practicing asset management at a prominent level, through a systemized approach. What is even more useful is the applicability of the ISO standard, as it is made to be useful in any industrial sector, for any type of asset. The common asset management practices, as included in the ISO 55000 suite, allow for an implementation to occur in a wide range of industrial organizations, regardless of their context and operating sector (ISO 55000, 2014).

Despite the public recognition of asset management as a discipline and proven benefits of both a qualitative and quantitative type, there is still limited available information regarding the current standing of asset management practices in Norwegian industrial sectors outside the O&G industry. Consequently, there is also limited information of how the asset management practices of the Norwegian O&G industry compare to practices found in other industrial sectors. However, the systemized asset management approach of the ISO 55000 suite now facilitates such a cross-industrial comparison of asset management practices, as its common asset management practices are applicable with any operating sector and any type of asset.

1.2 Aim of Thesis

The aim of this thesis is to perform an analysis to compare the asset management practices found in a selection of Norwegian industrial sectors, namely O&G, land-based manufacturing and land-based process. The analysis includes an industry-leading organization from each of the industrial sectors and is to be based on the common asset management practices of the ISO 55000 suite. The analysis shall result in an uncovering of specific performance gaps and improvement areas related to the included organizations' asset management practices.

The content of this thesis and the included analysis should provide interested parties with relevant insights into the current state of asset management practices in Norwegian industrial sectors. It should also act as a useful knowledge base for industrial organizations that contemplate an implementation of asset management practices through the ISO 55000 suite.

1.3 Scope of Work

A comprehensive literature study on the discipline of asset management, consisting of important definitions, history and development, scope, asset management subjects and key benefits.

A detailed study of the ISO 55000 suite, consisting of a presentation of a management system for asset management, the specific requirements and clauses of the ISO standard, and benefits of both a qualitative and quantitative type, related to an implementation process.

An analysis of three industry-leading organizations' asset management practices, each representing its own respective Norwegian industrial sector, namely O&G, land-based manufacturing and land-based process. The specific analysis criteria shall be the seven requirements and 24 corresponding clauses of ISO 55001 (2014), the sub-standard of the ISO 55000 suite that specifies the implementation of an asset management system. As part of the analysis there shall also be developed quantitative indicators presented in radar charts, which shall effectively outline each organization's degree of compliance with the seven requirements and 24 clauses of ISO 55001 (2014). The radar charts shall allow for a visual comparison of the included organizations' asset management practices and form the basis for the uncovering of specific performance gaps and improvement areas related to their asset management practices.

1.4 Methodology

Chapters 2 and 3, which can be thought of as the first part of this thesis, consist of detailed and comprehensive literature studies on the discipline of asset management and the ISO 55000 suite, the first international standard for asset management. The literature studies are built around relevant academic literature, including published books, international standards, resources provided by professional bodies, and literature obtained through lectures and classes at the University of Stavanger.

Chapters 4, 5, 6 and 7, which can be thought of as the second part of this thesis, includes the analysis of asset management practices, presentation of performance gaps and improvement areas, and general discussions regarding the analysis results. The content of these chapters is based on information gathered by the author through a series of semi-structured interview sessions, conducted to identify the current state of asset management practices within the three industrial organizations that have been selected to partake in the analysis process. To obtain the required level of detail needed to properly assess each organization's asset management practices against the asset management practices outlined in the ISO 55000 suite, the author has chosen to use in-depth, semi-structured interviews that are based on a qualitative research method. Every interview session was conducted by following the same, pre-planned interview guide (Appendix A) developed by the author. The interview guide is based on the asset management practices of the ISO 55000 suite and has been established to cover each of the seven requirements and the 24 corresponding clauses of ISO 55001 (2014), the sub-standard of the ISO 55000 suite that contains specific requirements for the implementation of an asset management system. The semi-structured interview format allowed the author to ask follow-up questions and initiate a conversation regarding each question in the interview guide, which was a key factor in achieving sufficient information. Further details on the selected analysis approach, including the development of the radar charts, their quantitative indicators and the way in which the analysis results are presented, are included in section 4.1, which precedes the actual presentation of the analysis results.

The author has taken several measures to strengthen the quality of the selected methodology and the analysis results. A lot of consideration has been put into selecting interviewees that were in fact knowledgeable and competent enough to provide useful and relevant answers regarding their respective industrial organizations' asset management practices. This led to the selected interviewees all holding relevant positions as either directors, managers or other significant leader roles within their respective industrial organizations. Furthermore, every interview session was conducted in a face-to-face setting at each respective industrial organization's location and was audio recorded to allow the author to review the interviews multiple times and extract useful information in relation to each of the questions and clauses of ISO 55001 (2014). The use of recording equipment was clarified with all interviewees prior to the interview sessions, which lasted from 45 to 65 minutes. Also, every interviewee was contacted prior to the interview session and clearly presented with the purpose, objectives and context of both the interview and this thesis.

As a final remark regarding the selected methodology, it should be noted by the reader that such semi-structured interviews will inevitably be subjected to some degree of subjectivity and personal interpretations from both the interviewer and the interviewees, regardless of the efforts and measures being taken. Still, it is the author's opinion that he has succeeded in his efforts of remaining objective during both the interview sessions and the analysis process, thus securing valid and reliable analysis results.

1.5 Delimitations

The analysis of asset management practices in this thesis is limited to the asset management practices of three industry-leading organizations from the O&G industry, the land-based manufacturing industry and the land-based process industry, respectively. The reasoning behind this approach is the comprehensiveness of undertaking an analysis process against the asset management practices of the ISO 55000 suite. A wider analysis approach consisting of a larger number of industrial sectors or several organizations from each industrial sector would not be feasible within the given timeframe of this thesis. It was therefore determined by the author that the best possible approach would be to seek out industry-leading actors within the selected industrial sectors, to form a picture that is as representative for each industrial sector as possible.

Furthermore, it is essential that the reader notes that neither the interview guide (Appendix A), the presentation of the seven requirements and 24 corresponding clauses of ISO 55001 (2014) in section 3.2.1-3.2.7, or the analysis of asset management practices included in Chapter 4 cover the content of the ISO 55000 suite in its entirety. Originally, the 24 clauses of ISO 55001 (2014) contain a comprehensive set of 72 "shall do" activities that must be met to be certified against the ISO standard. To facilitate a simplified presentation of the ISO 55000 suite and a feasible analysis of asset management practices, the author has put a considerable amount of effort into extracting the essence and main components of each clause and incorporating them into this thesis. Consequently, whenever the author refers to the degree of compliance with any of the seven requirements and 24 corresponding clauses of ISO 55001 (2014) in this thesis, it is towards the clauses as they are presented in section 3.2.1-3.2.7. In other words, an indication of what could be regarded as full compliance with a given clause of ISO 55001 (2014) in the analysis of asset management practices refers to the clause at the level of detail in which it is presented in this thesis, and not against the complete clause as it is originally presented in the ISO 55000 suite. This approach has been taken, first and foremost, to facilitate an analysis of asset management practices that would be feasible to complete within the given timeframe and workload of this thesis. However, it is also based on the fact that it is not in the scope of this thesis to perform a full certification process against the ISO 55000 suite, neither is the author in any way authorized to do so. The usefulness of the ISO 55000 suite with regards to this thesis is simply related to the ISO standard's common asset management practices and elevated level of applicability, which facilitates a reliable cross-industrial comparison of asset management practices centered around a common set of criteria. The analysis of asset management practices contained within this thesis should therefore not be viewed or used as a means for certification against the ISO 55000 suite, neither is it intended to act as one.

1.6 Thesis Structure

The structure of this thesis is as follows:

Chapter 2 contains a comprehensive literature study on the discipline of asset management, including important definitions, history and development, scope, asset management subjects and key benefits.

Chapter 3 contains a detailed study of the ISO 55000 suite, including its scope, requirements and clauses, and a selection of qualitative and quantitative benefits related to an implementation of the ISO standard.

Chapter 4 contains the analysis of asset management practices. The analysis encompasses the asset management practices found within each of the three industrial organizations included in this thesis, measuring their degree of compliance with the seven requirements and 24 corresponding clauses of ISO 55001 (2014) and then outlining them in further detail.

Chapter 5 builds further on the analysis results that were uncovered in Chapter 4, as it outlines specific performance gaps and improvement areas with regards to the asset management practices of the three industrial organizations that are included in this thesis.

Chapter 6 contains discussions related to such topics as whether the scope of work included in this thesis was met, interesting observations and findings that were uncovered in the analysis of asset management practices, suggestions for future studies, and challenges that were encountered during the work with this thesis.

Chapter 7 consists of a short conclusion, including some final remarks regarding the content of this thesis.

Chapter 2 – Asset Management

2.1 Introduction

Before proceeding to a detailed introduction to asset management, some aspects of the discipline must first be understood. While the term 'asset management' traditionally was used in relation to the discipline of financial asset management, which aim is simply to undertake activities to increase returns in a financial context, this is not the case of this thesis (Lloyd, 2010a; Liyanage, 2012). Neither is it a thesis that is purely concerned with the maintenance and reliability of equipment, which is a common misconception regarding asset management (Woodhouse, 2010a). This thesis embraces asset management as a holistic, integrative discipline that allows for optimized balancing of costs, risks and benefits of assets, throughout the entirety of the assets' life cycles. The discipline of asset management is recognized for its ability to promote integration of activities across an organization, and provide it with tools that facilitate risk-based, information-driven decision-making that increases organizational performance and promotes regular achievement of organizational objectives (Lloyd, 2010a; ISO 55000, 2014). An illustration of some of the key attributes of asset management is shown in Figure 1.

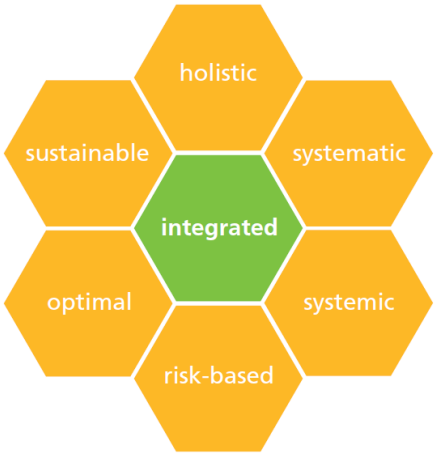

Figure 1 – Key attributes of asset management (BSI PAS 55-1, 2008)

To provide an initial understanding of asset management, some basic definitions will first be presented. The term 'asset management' is defined as the *"coordinated activity of an organization to realize value from assets"* (ISO 55000, 2014, p.14). The selection of activities included in the term 'coordinated activity' will be further elaborated throughout section 2.4, which introduces the reader to the specific subjects of asset management. The term 'asset' is defined as *"an item, thing or entity that has potential or actual value to an organization"* (ISO 55000, 2014, p.13). Assets can be both physical (equipment, machinery and properties) and non-physical (brands, reputation and licenses). What constitutes as potential or actual value to an organization may vary, depending on factors such as the organization itself, its environment and its stakeholders. The potential or actual value in question may be both financial and non-financial, as well as tangible and intangible (ISO 55000, 2014).

2.2 History and Development

The discipline of asset management has evolved over an extended period of time. There is consensus among knowledgeable personnel that the discipline primarily emerged from two sources, the O&G industry in the North Sea and the public services sector in Australia and New Zealand, both during the 1980s (Edwards, 2010b; Woodhouse, 2010a). The common ground of both sources is that the discipline emerged as a result of incidents significantly affecting industry performance.

The O&G industry in the North Sea was already struggling with low oil prices and weak market conditions when it was hit hard by the occurrence of the Piper Alpha oil platform disaster in 1988. Still regarded as one of the worst offshore disasters of all time, the Piper Alpha oil platform disaster led to 167 people losing their lives (Woodhouse, 2010b). The aftermath of the Piper Alpha oil platform disaster revealed the need for radical changes in safety routines and operational procedures. Some of the changes that were implemented included the creation of dynamic, multidisciplinary teams used to manage the oil platforms and an increased focus on life cycle management, both of which led to enhancements in performance, safety and productivity of the industry (Woodhouse, 2010b).

The incidents in the public service sectors in Australia and New Zealand were primarily driven by poor planning and high cost levels, which eventually created the need for change. A series of activities were initiated to improve strategic planning and prioritization in the sectors, with an increased focus on assets and their life cycles. The changes that were implemented in the public services sectors in Australia and New Zealand led to the adoption of the term ‘asset management’ in the first ‘Total Asset Management Manual’ for public sectors, which was published in 1993 (Woodhouse, 2010a; 2014).

Pilling (2010) supplements with an evolutionary view on the development of asset management, arguing that the discipline has primarily emerged as a result of changing industrial conditions and changing requirements of management techniques, leading to a gradual incorporation of several practices and disciplines. The practices and disciplines presented by Pilling (2010) range from the early developments of project management in the 1970s, to the introduction of the ‘Balanced Scorecard’ by Kaplan and Norton in the 1990s (Kaplan and Norton, 1996). The view of Pilling (2010) is partially supported by Ratnayake (2010), which argues that asset management has grown from being a “necessary evil” during the early 1970s, when people were mostly concerned with short-term thinking and corrective actions, to a modern discipline that embraces a long-term, life cycle-oriented, holistic way of managing assets. A model that shows the evolution of asset management and corporate thinking on the matter is shown in Figure 2.

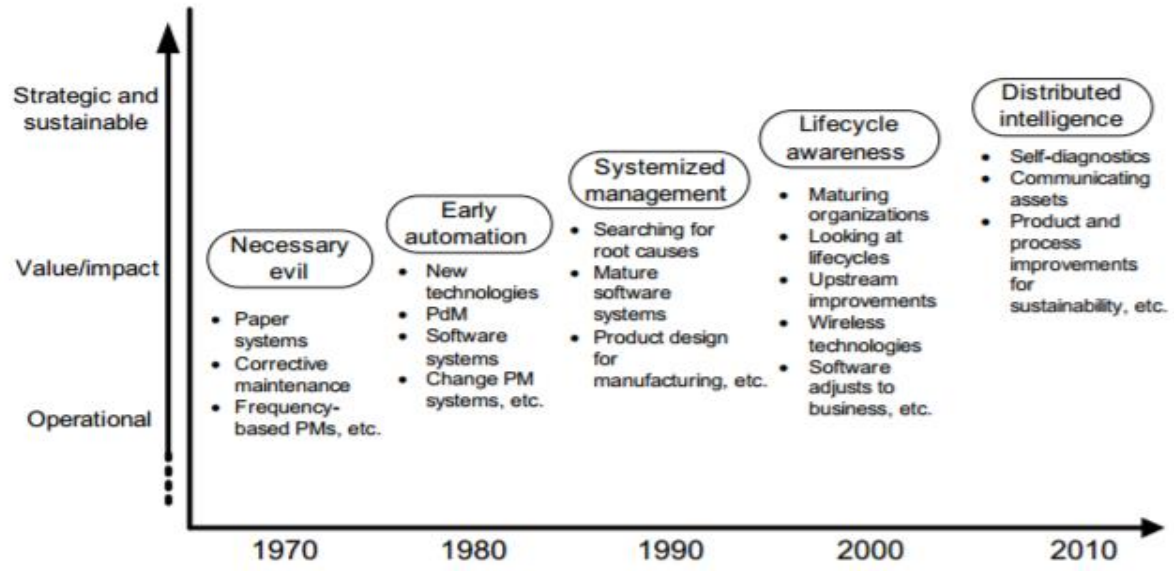

Figure 2 – The development of asset management and corporate thinking (Ratnayake, 2010)

The development of asset management reached an important milestone in 2004, when the BSI PAS 55 standard was published for the first time. Published by the British Standards Institution (BSI) and co-developed by the Institute of Asset Management (IAM), the BSI PAS 55 standard was the first Publicly Available Specification (PAS) standard for the management of physical assets. The standard was published due to an increasing industry demand towards a standardization of terms and procedures regarding asset management (BSI PAS 55-1, 2008). The BSI PAS 55 standard contains definitions on key elements of asset management and a total of 28 requirements that specifies the establishment and implementation process of an optimized, whole-life management system for the management of physical assets (BSI PAS 55-1, 2008).

The usefulness and applicability of the BSI PAS 55 standard was of a great magnitude, providing interested parties and organizations with a common framework and terminology for asset management. The standard was exceptionally well received by several industries, with organizations from a number of countries having chosen to adopt the practices outlined in the standard (IAM, 2015). The popularity of the BSI PAS 55 standard led to it being republished and updated in 2008, with new and improved definitions and procedures (BSI PAS 55-1, 2008). An example of a Norwegian organization that has undergone an implementation of the BSI PAS 55 standard is Statnett, which through a series of certification audits in 2012, received its certification in 2013 (Statnett, 2013).

The public recognition of the BSI PAS 55 standard initiated the process of turning the standard into an official ISO standard. The development of what would later be known as the ISO 55000 suite was approved in 2010, with participants from a number of countries attending a series of development meetings, before the standard was finally published in January 2014 (Hodkiewicz, 2015). The publishing of the ISO 55000 suite, as the first official ISO standard concerned with asset management, marked another milestone in the recognition of the discipline and was an important step towards a common, widespread understanding of asset management.

2.3 The Scope of Asset Management

The Global Forum on Maintenance and Asset Management (GFMAM) is a forum consisting of leading expert organizations within the field of asset management. Members include respected organizations from all over the world, including the IAM, the Asset Management Council and the Society for Maintenance and Reliability Professionals (SMRP). The forum has been established to collectively share advancements, knowledge and standards within the field of asset management. Several of its members were important contributors to the development of both the BSI PAS 55 standard and the ISO 55000 suite (GFMAM, 2014).

To clarify the understanding of asset management, the GFMAM has established a framework defining the scope and boundaries of asset management. The framework has been established to *"enable asset management knowledge and practices to be compared, contrasted and aligned around a common understanding of the discipline of asset management"* (GFMAM, 2014, p.6). The framework established by the GFMAM defines the scope or "core" of asset management as a combination of the asset management subjects and asset management fundamentals.

Asset Management Subjects
The asset management subjects are a group of 39 subjects that have been established by the GFMAM. The 39 asset management subjects have been derived from an international review of an extensive list of asset management models and assessment methodologies. Based on the international review, it has been reached a global consensus that the 39 asset management subjects together embrace the complete, integrated discipline that is asset management (GFMAM, 2014). The asset management subjects will be presented in further detail throughout section 2.4.

Asset Management Fundamentals
The asset management fundamentals are a set of four fundamentals established as a part of the ISO 55000 suite (ISO 55000, 2014). Together, the asset management fundamentals present the very fundamentals on which asset management is based, as they effectively act as underlying principles behind all asset management activities. The reader should note that the asset management fundamentals and asset management subjects have been developed to be compliant with each other, thus ensuring a complete alignment between the content of the ISO 55000 suite and the 39 asset management subjects. The four asset management fundamentals consist of value, alignment, leadership and assurance. A fuller and more detailed presentation of the four asset management fundamentals is included on the next page (page 10), which ends section 2.3.

The asset management fundamentals are (ISO 55000, 2014):

Value:
The primary reason for the existence of assets is to provide value to an organization and its stakeholders. Asset management is not focused on the asset itself, it is focused on the potential value the asset may create to the organization. This value may be financial or non-financial, tangible or intangible, all depending on the context of the organization and its stakeholders. Realization of potential value is achieved through use of efficient life cycle management and decision-making processes that are compliant with the needs of both the organization and its stakeholders.

Alignment:
Asset management translates the organizational objectives of an organization into technical and financial decisions, plans and activities. Doing so ensures an alignment, or "line of sight" between the asset management activities of the organization and its organizational objectives. This alignment is effectively what assures that decisions related to asset management collectively contribute to the achievement of organizational objectives. An important factor in achieving such an alignment is to be able to integrate asset management activities and processes into several parts of an organization, such as finance, engineering, human resources and information systems.

Leadership:
Realization of value is determined by leadership and workplace culture. This requires leadership and complete engagement from all managerial levels of the organization. The leaders of the organization are responsible for defining clear roles of their employees, delegation of responsibilities and ensuring that employees are aware and competent within the field of asset management.

Assurance:
Asset management provides the necessary assurance that assets will contribute to value creation and fulfill their required purpose. This assurance is an important part of letting all relevant stakeholders, both internal and external, know that the activities of the organization is aligned with its organizational goals and objectives. Some of the activities that will ensure assurance within an organization include implementing processes for measuring continual improvement, personnel competence, resource management and performance of individual assets.

2.4 Asset Management Subjects

To present the 39 asset management subjects, the author has chosen to use the conceptual model for asset management, established by the IAM. The IAM's conceptual model for asset management is fully approved and endorsed by the GFMAM (GFMAM, 2014). It presents the 39 asset management subjects by dividing them into six separate subject groups. The conceptual model and the included subject groups has been established to illustrate *"the breadth of activities within the scope of asset management, the interrelationships between activities and the need to integrate them, and the critical role for asset management to align with and deliver the goals of an organization's strategic plan"* (IAM, 2015, p.17). The IAM's conceptual model for asset management is shown in Figure 3, illustrating several of the interdependencies that exist between the six subject groups. Furthermore, the placement of each of the 39 asset management subjects within the conceptual model is illustrated in Figure 4.

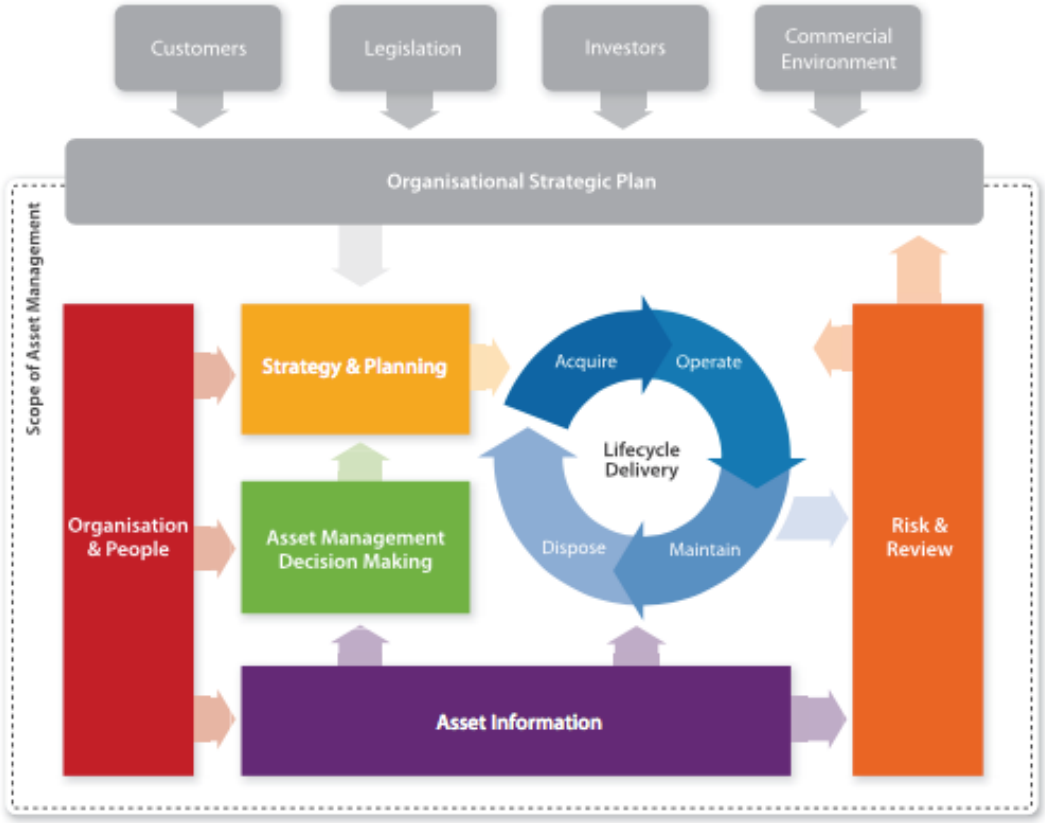

Figure 3 – The IAM conceptual model for asset management (IAM, 2015)

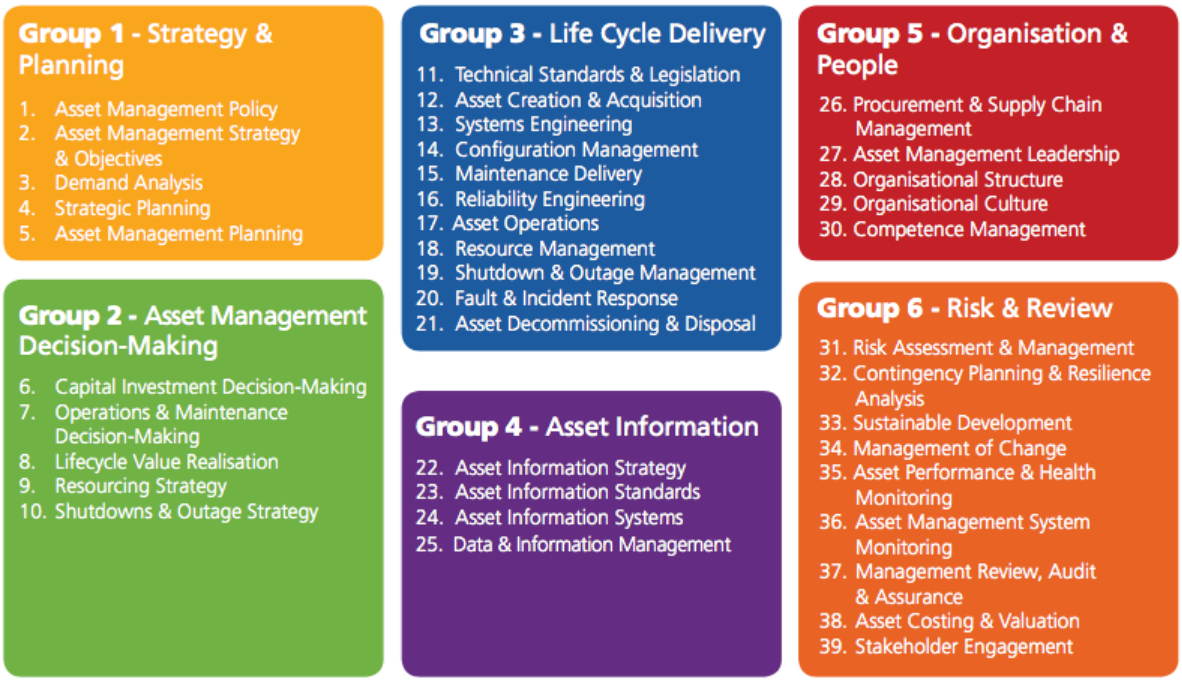

Figure 4 – The placement of the asset management subjects in the IAM conceptual model for asset management (IAM, 2015)

Before proceeding to the presentation of the asset management subjects, the reader should note that it is essential to understand that none of the 39 asset management subjects or the six subject groups should be treated independently or self-standing. This is underlined by Edwards (2010b, p.3), who states that *"many aspects of asset management are not new; it is the integration of the activities within these six areas that asset management is seeking to achieve"*. Asset management is a holistic discipline and cannot be properly understood unless its subjects and subject groups are addressed as a holistic body of knowledge (GFMAM, 2014). The division of asset management into individual subjects and subject groups is simply a measure that is taken to increase clarification of individual components, and to underline the width of activities that are included in the discipline. This is elaborated further by the IAM (2015, p.24), which states: *"The IAM strongly encourages individuals to develop an appreciation of ALL the asset management subjects. This is essential to understand how best to obtain maximum value from applying asset management"*.

Based on these statements, the author has chosen to include an introduction to all the 39 asset management subjects defined by the GFMAM. However, the relative length and level of detail within each asset management subject will vary, as the author has chosen to elaborate on subjects that are best suited to draw the bigger lines of asset management. This is most visible in the information-intensive subject groups 'Life Cycle Delivery' (section 2.4.3) and 'Risk and Review' (section 2.4.6), where some asset management subjects are described using simpler definitions and explanations, rather than specific examples and tools. For a fuller and more complete introduction to all the 39 subjects of asset management, interested parties are encouraged to study the publications 'Asset Management – an Anatomy (Version 3)', published by the IAM (2015) and 'The Asset Management Landscape (Second Edition)', published by the GFMAM (2014).

2.4.1 Strategy and Planning

'Strategy and Planning' embraces the strategic side of asset management. The included subjects represent essential links between an organization's asset management activities and its organizational strategic plan and organizational objectives. Such an alignment has already been elaborated as one of the fundamentals of asset management in section 2.3, and is what ensures that all asset management activities undertaken by an organization collectively contribute towards the achievement of its organizational objectives and long-term strategic goals. Figure 5 illustrates how the included subjects contribute to such an alignment, by showing their placement in an asset management system (the scope of the asset management system is marked by the grey area). The asset management system shown in Figure 5 will be described in further detail in Chapter 3, as it is only included for illustrative purposes in this chapter.

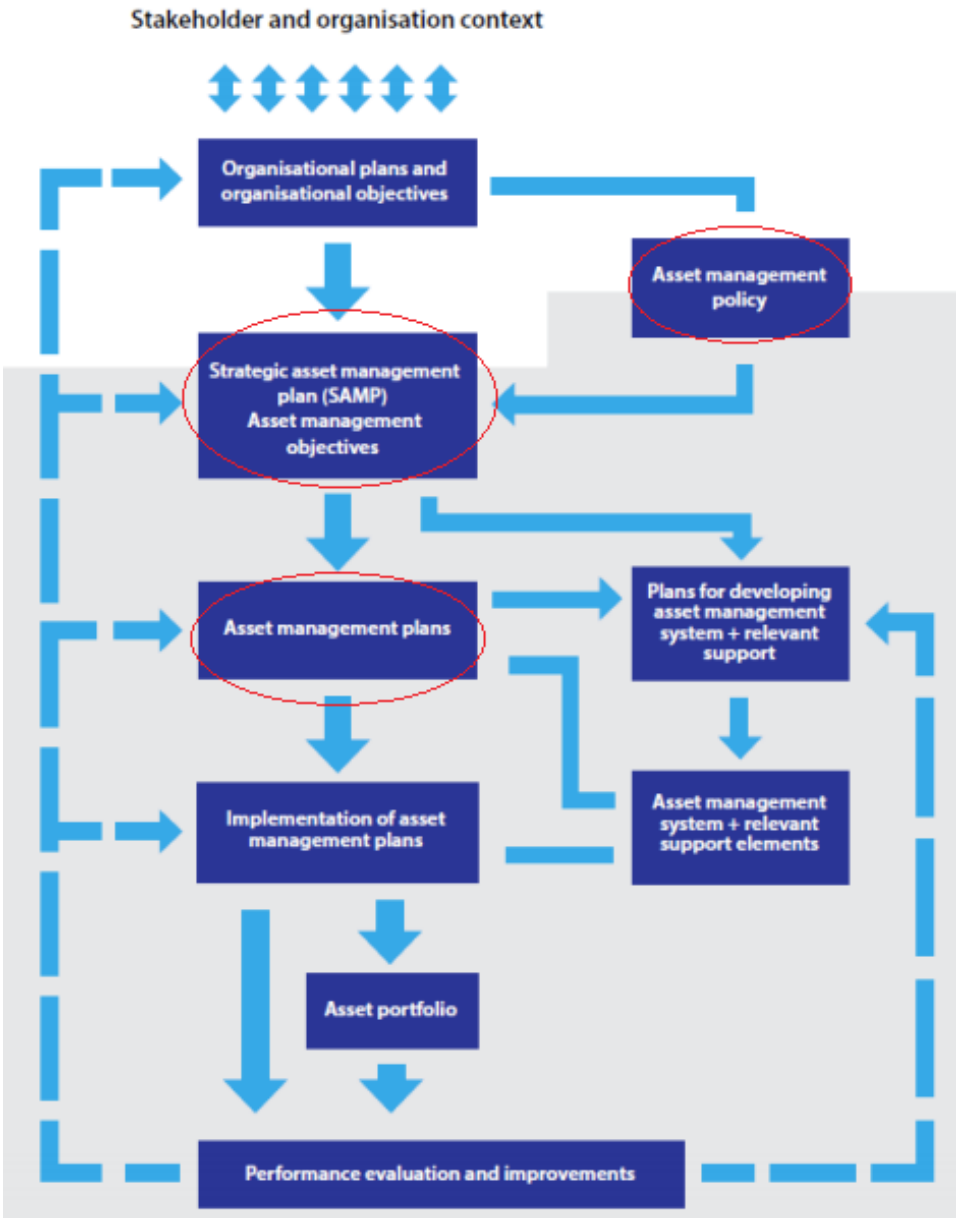

Figure 5 – Key elements of an asset management system (ISO 55000, 2014)

Asset Management Policy

An asset management policy can, as illustrated in Figure 5, be viewed as the first component that is linking an organization's asset management activities to its organizational objectives. The policy is a short, high-level statement, which states the principles by which an organization intends to use asset management to achieve its organizational objectives (ISO 55000, 2014; Hastings, 2010). The policy is to be established in alignment with other existing organizational policies and be used as a framework or guidance tool for the development of a Strategic Asset Management Plan (SAMP). Furthermore, it should also be properly documented, either as an included part of a SAMP or in a separate, designated document. The asset management policy of an organization should always be made easily available to relevant personnel for necessary updates or reviews (ISO 55002, 2014).

Strategic Asset Management Plan and Asset Management Objectives

(Note: Figure 4 presents a Strategic Asset Management Plan (SAMP) as an asset management strategy. However, in the ISO 55000 suite, the term 'Asset Management Strategy' is replaced with the term 'SAMP'. To ensure an alignment of terms, the author has chosen to use the term 'SAMP' exclusively throughout the remainder of this thesis.

A SAMP can, as illustrated in Figure 5, be regarded as the second component that is linking an organization's asset management activities to its organizational objectives. A SAMP is a strategic document that is containing specific information of how an organization intends to translate its organizational objectives into specific asset management objectives and how asset management plans should be developed in alignment with organizational objectives (ISO 55000, 2014). The importance of a SAMP is highlighted by Burns (2010) as an essential component in the strategic aspect of asset management, especially with regards to strategic decision-making. Contained within the SAMP should be specific asset management objectives, which are objectives that are specific to an organization's assets and its asset management activities. Asset management objectives should be established so they reflect the desired results of an organization's asset management activities, while remaining in complete alignment with its existing organizational objectives (GFMAM. 2014). Asset management objectives may be developed as both quantitative (mean time between failures) and qualitative (customer satisfaction, brand reputation, etc.) objectives. They are largely context-dependent, and may embrace a wide range of aspects, such as asset performance, financial factors, environmental impact, reliability and availability (ISO 55002, 2014). Just like regular organizational objectives should asset management objectives be established as S.M.A.R.T objectives, where applicable. The S.M.A.R.T acronym is a well-established criteria guide in setting goals and objectives, and refers to the objectives being Specific, Measurable, Achievable, Realistic and Timebound (ISO 55002, 2014). A generic example of an asset management objective could for example be to achieve a minimum of 93% availability (the ratio of delivered to expected service (Birolini, 2014)) of an asset throughout its effective life cycle. The actual development process of both a SAMP and asset management objectives will be further covered in the asset management subjects 'Demand Analysis' and 'Strategic Planning'.

Demand Analysis

It is essential that the development process of a SAMP and asset management objectives is customized to fit an organization's context and activities, to obtain the required level of alignment between its organizational objectives and its asset management activities. It should therefore always be conducted a demand analysis, prior to the development process of a SAMP and asset management objectives (GFMAM, 2014). Such a demand analysis should include a mapping of the current and forecasted future demand of an organization's products or services, and how these demands may affect the required performance of the organization's assets (IAM, 2015). The specific characteristics of such a demand analysis suggest that a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) could be a useful approach in that regard (Business Dictionary, n.d.). The relevance and general applicability of undertaking a SWOT analysis prior to the development process of a SAMP and asset management objectives is supported by Woodhouse (2010b), who is highlighting it as a valuable tool in that regard.

Strategic Planning

Once a demand analysis has been performed and the necessary results have been uncovered, the next step in the process is to actually develop and establish the SAMP and asset management objectives. Such a development process is the main objective within the asset management subject 'Strategic Planning' (GFMAM, 2014). According to the IAM (2015), is the first step of such a development process to translate existing organizational objectives into specific asset management objectives. The translation of existing organizational objectives into specific asset management objectives should consider all relevant factors that may affect an organization's asset management activities, including the results uncovered in the demand analysis and the content of the organization's asset management policy. Following the translation process of organizational objectives into specific asset management objectives, the SAMP itself may be developed. The development process of a SAMP should consider numerous factors connected to the characteristics of an organization, including the following (IAM, 2015):

- Its existing organizational objectives and organizational strategic plan.
- Current asset condition and performance, as well as potential future changes.
- The needs and expectations of stakeholders.
- Potential constraints of organizational resources, including financial resources, human capital, knowledge, competence and equipment.
- Organizational attitude towards risk and how risk management is utilized in the organization.
- Organizational capability of managing change.

Asset Management Planning

The final piece of the strategic asset management puzzle is to develop specific asset management plans. Asset management plans are action plans that define how assets should be managed during their entire life cycles, to meet the previously defined asset management objectives (ISO 55002, 2014). The development process of asset management plans should be a direct result of the content defined in the SAMP and asset management objectives, thus ensuring a complete alignment of goals and objectives, all the way from the organizational objectives down to specific day-to-day operations contained in the asset management plans (as illustrated in Figure 5). Looking back at the generic example of an asset management objective that was presented in the asset management subject 'Strategic Asset Management Plan and Asset Management Objectives' (section 2.4.1), a corresponding asset management plan would consist of *how* to achieve a minimum of 93% availability of the given asset throughout its effective life cycle.

There is no set formula for what should be included in an asset management plan, as the content and level of detail will depend on factors like the size of an organization, the type of asset and the organization's general commitment to asset management (ISO 55002, 2014). However, it is recommended that asset management plans should at least consider the following (GFMAM, 2014; IAM, 2015):

- The specific activities that an organization will undergo to achieve its asset management objectives.
- The resources required to deliver the activities, including financial resources, human resources, required competence and required equipment.
- Specified operational and maintenance plans.
- The expected outcome(s) of the asset management plans.
- Defined timescales to complete the activities.
- The roles and responsibilities contained in each asset management activity.
- Threats and risks related to the delivery of the asset management activities.

2.4.2 Asset Management Decision-Making

Decision-making is an essential part of asset management. For an organization to maximize the value created by its assets and continually meet the expectations of its stakeholders, it must be able to make decisions that are supportive towards the same, specific objectives. Woodhouse (2010a) characterizes an optimized asset management decision-making process as a process where an organization is able to continually assess all the aspects of costs, risks, performance and longevity, to identify the optimal compromise between the competing factors. Doing so requires an organization to apply a more holistic view on both value creation and the effective life cycle of its assets, to avoid the pitfalls of short-term thinking (Woodhouse, 2010a). Making decisions that continually promote a whole-life approach to assets is the recurring theme of the asset management subjects included in the subject group 'Asset Management Decision-Making'.

Capital Investment Decision-Making

Capital investment decision-making refers to the processes undertaken by an organization that contribute to an evaluation of decisions related to capital investments (GFMAM, 2014). When undergoing a process related to a capital investment, for example an investment in a new asset or the replacement of an existing asset, it is considered good asset management practice to conduct a thorough evaluation related to the investment decision, to ensure that the optimal alternative is selected. As it may be tempting to just go for the alternative with the lowest capital expenditure (CAPEX), this might not always be the ideal solution with regards to long-term value creation. By applying the whole-life approach of asset management to capital investment decisions, an organization can see beyond the CAPEX and effectively determine which alternative or investment decision is the preferable solution in the long run.

A useful tool that is commonly used in capital investment decision-making processes is a Cost Benefit Analysis (CBA). A CBA can be regarded as an engineering and economical optimization tool that is used to identify the alternative that generates the optimal combination of revenue and costs throughout its effective life cycle, when deciding between several alternatives (Markeset and Kumar, 2000). A CBA effectively evaluates different asset designs or configurations using discounted cashflows, which allows for a good overview of the total life cycle costs of the investment alternatives. Common economic decision criteria used in CBA analyses include net present value and internal rate of return. Due to the degree of uncertainty of future predictions, CBA analyses should always be accompanied with a basic risk assessment or a risk analysis, to fully support the argumentation and conclusion of the analysis (Markeset and Kumar, 2000; 2003).

Operations and Maintenance Decision-Making

Much like capital investment decision-making, is also operations and maintenance decision-making an important contributor towards the value-creating abilities of an organization's assets. Decision-making related to operations and maintenance should always be conducted in a manner that continually facilitates regular achievement of asset management objectives (GFMAM, 2014). An important contributor towards enhanced operations and maintenance decision-making is the establishment of an efficient maintenance strategy (IAM, 2015). The action of establishing a maintenance strategy allows an organization to plan maintenance and operational interventions to occur at preferable points in time, throughout the entire life cycle of the assets that are included within the scope of the strategy. Doing so ensures optimized asset performance and asset availability, as well as an optimized balance between the associated levels of costs and risks.

There are several useful techniques that can be used to establish an efficient maintenance strategy, which supports optimized operations and maintenance decision-making. Edwards (2010b) points specifically towards Reliability-Centered Maintenance (RCM) and Risk-Based Maintenance (RBM) as reliable techniques that would be highly useful in that regard. The development of a maintenance strategy to support operations and maintenance decision-making is a measure that has well-documented benefits. Studies performed on the field of RBM have revealed that by adopting a risk-based, strategic approach, selected organizations have been able to achieve a 20-30% reduction in operational expenditures (OPEX), without experiencing an increase in risk (Edwards, 2010b).

Life Cycle Value Realization

Life cycle value realization embrace the decision-making and corresponding activities performed by an organization to balance costs and benefits of different renewal, maintenance, overhaul and disposal interventions of an asset. Or in other words, throughout all phases of an asset's life cycle (GFMAM, 2014). The configuration of an asset's life cycle may vary quite a bit, depending on the asset type. This is effectively illustrated in Figure 6, which outlines some possible variations of assets' life cycle configurations.

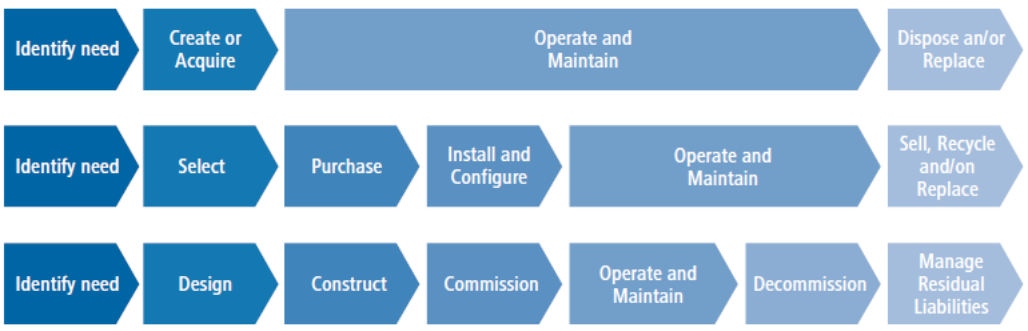

Figure 6 – Different life cycle configurations of assets (IAM, 2015)

The realization of optimal value throughout an asset's life cycle requires thorough consideration of the interactions between different activities undertaken during the separate life cycle phases. As previously stated in section 2.1, what constitutes as value to an organization depends on the preferences of the organization itself and its stakeholders. A common method that is regularly used to validate the process of life cycle value realization from a financial point of view, is to apply a Life Cycle Cost (LCC) analysis (Markeset and Kumar, 2000). An LCC analysis is a tool that is used to uncover the complete costs of an asset during its entire life cycle, or during an organization's period of responsibility for said asset. By applying a combination of capital investment decision-making processes and operations and maintenance decision-making processes, an organization can achieve the optimal balance between costs, risks and performance. Just like a CBA analysis should the LCC analysis always be accompanied by a corresponding risk assessment or risk analysis process to deal with the uncertainties of future events (Markeset and Kumar, 2000; 2003). Correct application of an LCC analysis has the possibility of leading to increased financial and economic benefits, improved decision-making effectiveness and improved communication with stakeholders (Markeset and Kumar, 2000; IAM, 2015).

A common mistake that prevent organizations from achieving optimized life cycle value realization is a lack of forward thinking. A lack of forward thinking, or "short-termism", is an attribute that is not well suited for organizations that wish to succeed with their asset management efforts. Woodhouse (2010b) excellently illustrates how a lack of forward thinking may have large economic implications, by referring to the purchase process of a Boeing 747 jet. The jet itself has a purchase price of $100 million, but this amount only accounts for about 5% of the total life cycle costs of the jet. Life cycle costs related to activities such as maintenance, overhaul and renewal account for the remaining 95% of the costs. The life cycle costs of the jet will remain "hidden" unless one applies the appropriate processes for revealing them, which is exactly what an LCC analysis facilitates.

Resourcing Strategy

A resourcing strategy refers to an organization's strategic approach to internal and external resource distribution. Resources in this context can mean human capital, competence, materials, equipment and financial resources (ISO 55000, 2014). The measure of defining a specific resourcing strategy is an important contributor in asset management decision-making. Optimized decision-making related to resource distribution may potentially act as a driver towards enhanced value creation and achievement of asset management objectives (GFMAM, 2014).

Shutdowns and Outage Strategy

Several tasks related to operations and maintenance of assets require them to be shut down or put out of activity. Doing so can easily act as a driver towards periods of unnecessary downtime, which may lead to increased risks and loss of revenue. By defining a specific shutdown and outage strategy, an organization can use decision-making criteria to plan such shutdowns and outages to occur at preferable intervals, and thus mitigate or remove the negative effects of shutdowns and outages, which in turn can lead to enhanced value creation (IAM, 2015).

2.4.3 Life Cycle Delivery

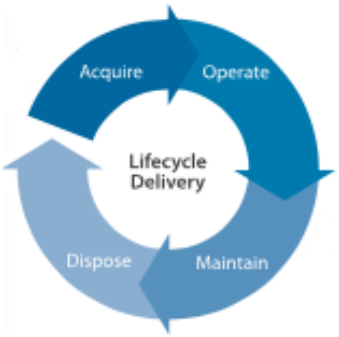

Figure 7 – A generic asset life cycle (Extracted from the IAM conceptual model for asset management) (IAM, 2015)

The asset management subjects that are contained within the subject group 'Life Cycle Delivery' embrace all relevant activities undertaken by an organization on its assets, during their effective life cycle (IAM, 2015). Figure 7 is extracted from the IAM's conceptual model for asset management and illustrates a generic life cycle configuration of an asset, which is divided into four phases: Acquisition, operation, maintenance and disposal. The main target of any organization that wishes to succeed in its asset management efforts is to achieve an integration of all activities being performed during each of these life cycle phases, as oppose to treating each activity or phase in isolation. An integration of life cycle activities is a key component in the whole-life approach required to achieve good asset management practices and optimize the value created by assets. The IAM (2015) exemplifies the benefits of such an integration by pointing out that good asset design, a well-planned acquisition phase and good operative practices facilitate a reduction of the required level of corrective maintenance later in an asset's life cycle, thus increasing both availability and reliability at lower costs.

Technical Standards and Legislation

To succeed with its asset management efforts, an organization must first ensure that it has undertaken the necessary processes to ensure that its asset management activities are compliant with the technical standards and legislation that are relevant for its respective industrial operating sector. Doing so include considering all relevant standards and legislation when developing relevant strategic asset management documents, such as the asset management policy, the SAMP, asset management objectives and asset management plans (GFMAM, 2014).

Asset Creation and Acquisition

Asset creation and acquisition embrace the creation, installation and commissioning phase of an asset (GFMAM, 2014). Looking back at Figures 6 and 7, it becomes clear that an optimal asset creation and acquisition phase is difficult to define, due to the differences in separate assets' life cycle configurations. Its importance, however, cannot be understated. The way in which an asset is created or acquired is an aspect that may have major implications towards the asset's value creating abilities and the incurred level of costs throughout its life cycle. Figure 8 illustrates its importance by showing how the opportunity to influence life cycle costs is concentrated at the planning and acquisition phases of an asset's life, while the cumulative cost incurred rises steadily throughout the rest of the asset's life cycle (Hastings, 2010).

Changing an asset once it has been put into operation is no desirable solution. An organization operating with asset management principles and a whole-life approach to its assets would recognize this fact, and ensure that the asset was being created and acquired in a manner that is compliant with its existing asset management objectives and organizational objectives as early in the asset's life cycle as possible.

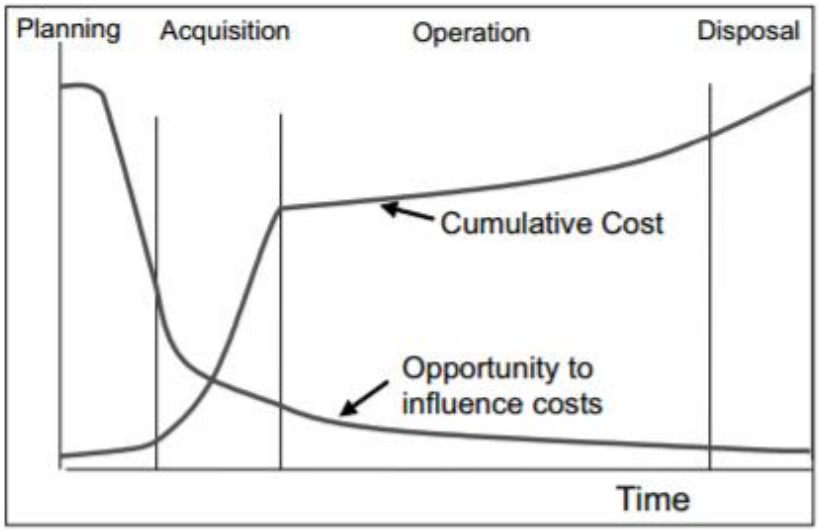

Figure 8 – The ratio between cumulative costs and the opportunity to influence them (Hastings, 2010)

Systems Engineering

The engineering discipline of systems engineering is especially beneficial and applicable for organizations that operate with complex asset systems or asset groups. It is a discipline that focuses on management of the complete life cycle of technical systems, starting from the very beginning of the design phase to the decommissioning phase (Biahmou, 2015). Parnell and Driscoll (2011, p.12) defines the systems engineering thought process as *"a holistic, logically structured sequence of cognitive activities that support systems design, systems analysis and systems decision-making to maximize the value delivered by a system to its stakeholders for the resources"*. The definition of Parnell and Driscoll (2011) clarifies the importance of system engineering in asset management, as its holistic approach and idea of value creation both align very well with the principles of asset management. Application of the principles of systems engineering as a life cycle activity will contribute to secure high-quality designs of assets or asset systems, thus potentially reducing cumulative life cycle costs and associated risk levels. Another important aspect of systems engineering is that it focuses on utilization of multidisciplinary teams, which is another key aspect of asset management (Parnell and Driscoll, 2011). The use of multidisciplinary teams and its implications towards good asset management will be elaborated further in section 2.4.5.

Configuration Management

Configuration management refers to the management process of determining and maintaining consistency of an asset's physical and functional attributes throughout its life cycle (GFMAM, 2014). This particular asset management subject will not be covered in any more detail at an individual level in this thesis.

Maintenance Delivery

A common misconception regarding asset management is that it is just another word for maintenance. This misconception is well and truly debunked by Woodhouse (2010a), who points to the fact that maintenance is just one single aspect of the wider, holistic and integrative discipline that is asset management. The importance of maintenance as a life cycle activity, however, cannot be understated. Maintenance is a necessity in sustaining the desired performance level of physical assets throughout their life cycles, thus achieving both optimized value creation and regular achievement of asset management objectives. Maintenance delivery is directly linked to the asset management subject of 'Operations and Maintenance Decision-Making', and can essentially be viewed as the activity of realizing a pre-defined maintenance strategy. Maintenance can broadly be divided into three separate categories or methodologies (Mobley, 1990; IAM, 2015):

Inspection, testing and monitoring: Activities related to condition monitoring of an asset's integrity and health, to determine the need for maintenance. Usual techniques include visual inspections, vibration analysis and lubricant analysis (Moubray, 1997).

Preventive maintenance: Planned activities performed on an asset to lessen the likelihood of it failing or deteriorating. Preventive maintenance can be risk-based, condition-based and time-based.

Corrective maintenance: Activities performed on an asset that has already failed or experienced a nonconformity, to restore the asset's health and performance level.

Reliability Engineering

Reliability engineering is the discipline of systematically applying engineering principles throughout the complete life cycle of an asset to ensure its continual reliability (IAM, 2015). The term 'reliability' can in this context be defined as *"a characteristic of the item, expressed by the probability that it will perform its required function under given conditions for a stated time interval"* (Birolini, 2014, p.2). In other words, the probability that an asset can deliver the expected performance during its effective life cycle. The goal of reliability engineering is to reduce downtime, costs and risks, by identifying potential asset failure in its initial stages, thus allowing for timely implementation of mitigating measures. Timely implementation of mitigating measures will in turn ensure steady performance levels throughout the life cycle of an asset and increase the probability of achieving both asset management objectives and organizational objectives. A common reliability engineering tool used to identify potential failures is the application of a Failure Modes, Effects and Criticality Analysis (FMECA) (Birolini, 2014). Application of an FMECA allows for a systematic analysis of the components in a system and identification of significant failure modes, their causes, and effects on the system's performance. The importance and validity of FMECA is underlined by Aven (2015), who suggests that it is a requirement in several enterprises today that an FMECA is included in the design process of a product or an asset, and that the analysis results are included in the product, system or asset documentation.

Asset Operations

Asset operations refers to the processes undertaken by an organization to ensure that its assets are operated in a manner that enhances the probability of it achieving its organizational objectives. The subject is concerned with how an organization provides instructions and guidance to its operators and personnel, as well as training procedures. Asset operations is a wide subject, as its relative content are highly dependent on an organization's context, operating sector and the type of asset in question. The common ground, however, is that operators must operate assets within the appropriate operational parameters, asset design and selected maintenance methodology (GFMAM, 2014).

Resource Management

Resource management is the discipline of implementing a resourcing strategy, as previously presented in section 2.4.2. Controlled and sustainable resource management is an important principle in the efficient delivery of asset management activities. Resource planning and resource management can be supported by utilizing tools and techniques derived from project management, such as Work Breakdown Structures and Organizational Breakdown Structures (Gardiner, 2005; IAM, 2015).

Shutdown and Outage Management

Much like the connection between resourcing strategy and resource management, is shutdown and outage management the process of implementing a shutdown and outage strategy, as previously presented in section 2.4.2. Shutdown and outage management includes all processes used to identify, plan, implement, and control the work performed in the event of a shutdown or outage of an asset, or several assets (GFMAM, 2014).

Fault and Incident Response

Fault and incident response includes the processes undertaken by an organization as a response to a sudden fault or incident related to its assets (GFMAM, 2014). The scope and general comprehensiveness of such processes will naturally depend on the severity and size of the fault or incident that has occurred. An organization's response to an asset-related fault or incident should ideally be concentrated on revealing the root cause of the fault of incident, mitigating it and initiate a proper documentation of the process, to facilitate a process of learning and improvement (ISO 55002, 2014).

Asset Decommissioning and Disposal

The need for decommissioning and disposal of an asset, or assets, may arise due to several reasons. An asset may have reached the natural end of its life cycle, new technology may have rendered it obsolete, or it may not be able to provide the required performance levels anymore (IAM, 2015). Depending on an organization's operating sector, the cost of decommissioning and disposal may prove to be quite significant, as well as having implications towards both environmental and social factors. An organization that operates with asset management principles will most likely be well-prepared for a decommissioning and disposal process, due to its decision-making processes (LCC analysis) and whole-life approach to assets, thus avoiding hidden financial costs or issues related to social or environmental factors (IAM, 2015).

2.4.4 Asset Information

Asset management is reliant on good and reliable asset information. Reliable and useful asset information is ultimately what lays the foundation for asset management decision-making and strategic planning processes that facilitate regular achievement of both asset management objectives and organizational objectives. For an organization to be able to succeed in achieving its asset management objectives and achieve optimized value creation from its assets, it is required to have clearly defined routines of how asset information is specified, collected, utilized and stored (Edwards, 2010b). How to best create and implement such routines is the main theme and objective of the asset management subjects included in 'Asset Information'.

Asset Information Strategy
The process of achieving good routines of handling asset information starts with the establishment of an asset information strategy. An asset information strategy is used to outline an organization's approach to asset information and how it is managed. The strategy should contain specific guidelines of how an organization indents to apply asset information to maximize the potential of achieving its asset management objectives (Edwards, 2010b). The asset information strategy of an organization should be established in complete alignment with existing strategic documents that are concerned with asset management, such as the SAMP and its associated set of asset management objectives (IAM, 2015). Doing so ensures the required alignment of tasks and practices, which is one of the asset management fundamentals as presented in section 2.3. According to the GFMAM (2014), an asset information strategy should include the following:

- A defined policy on asset information.
- A clear identification of relevant asset information needs to support asset management decision-making.
- Defined roles and responsibilities for the management of asset information.
- A CBA of the defined asset information needs, to ensure that the benefits of the collected information outweighs the costs of collecting it.
- Processes for continual improvement of the organization's asset information procedures.

Asset Information Standards
The procedures of collecting and storing asset information should follow a standardized, consistent structure. This includes defining how asset information is structured, as well as the required completeness and accuracy of the collected asset information (Edwards, 2010b). Active utilization of asset information standards ensures that all relevant personnel of an organization is aware of *which* asset information should be collected, *how* the asset information should be collected, and *what* to do with the collected asset information. An important benefit of asset information standards is their potential of reducing the probability of poor decision-making caused by misunderstandings related to asset data or asset information, such as faults caused by use of incorrect information metrics or measuring incorrect information. Consequently, asset information standards can be regarded as an essential assurance towards

an organization's ability of continually making well-judged, information-driven decisions that are aligned towards its SAMP, which facilitates regular achievement of asset management objectives. The importance of asset information standards is further elaborated in ISO 55001 (2014), which suggests that all organizations would benefit from implementing an aligned information terminology across all its departments and activities. An aligned information terminology ensures the required line of sight, from the top level of the organization, down to operators working on ground level. It may also act as an enabler towards improved process integration across organizational departments, as it contributes towards a common language within an organization (ISO 55000, 2014).

Asset Information Systems

Most modern industrial organizations have complex and large information structures related to their assets. Large and complex information structures combined with detailed asset information requirements lead to situations where significant amounts of data and information are to be collected, stored and analyzed. A common tool used to deal with this issue is to use software-based IT systems that collect, analyze and store relevant asset information on a continual basis (Hastings, 2010). Correct use of such systems is an excellent measure towards being able to successfully manage assets throughout their life cycles. Sometimes referred to as Computerized Maintenance Management Systems (CMMS), as many of the systems had their origin in maintenance-related operations, the systems offer solutions that allow for reliable asset information management, which in turn supports reliable management of assets throughout their life cycles (Hastings, 2010). A known, widespread actor within the field of asset information systems is SAP, which offers Enterprise Asset Management solutions to support excellent whole-life management of assets, through continual monitoring of asset performance and other types of asset information (SAP, 2017).

Data and Information Management

Data and information management is concerned with how data and information that has been collected by an organization is managed (GFMAM, 2014). Edwards (2010b) and the IAM (2015) also promote the area of asset knowledge within this subject, suggesting that asset knowledge is sometimes underrated in decision-making processes and information management processes. Having good knowledge and experience with assets may in some cases be just as important as having a wide database of historical asset data and information. It is therefore suggested that managing asset knowledge is an equally important part of an organization's data and information management activities. Both the IAM (2015) and the Institution of Civil Engineers (2015) point towards the use of Building Information Modelling (BIM) as an increasing trend within the fields of asset management and knowledge management, which is used to conserve asset knowledge and prevent the loss of it. In short, BIM is described as the management of information through the complete life cycle of a built asset, which delivers value through shared models and corresponding intelligent structured data (Institution of Civil Engineers, 2015).

2.4.5 Organization and People

The implementation of an asset management approach is an action that requires a lot of an organization and its personnel. It requires relevant personnel to have a complete understanding of the benefits that asset management brings to the organization, how everyone's role and tasks collectively contribute towards the achievement of asset management objectives, and how asset management objectives are linked towards the overarching organizational objectives of the organization (Edwards, 2010b). The focus of the asset management subjects included in 'Organization and People' is on the actual capability of an organization and its personnel to effectively implement all aspects of asset management.

Procurement and Supply Chain Management
An organization that outsources one or more of its asset management activities is required to ensure that tasks being performed by the external personnel remain applicable and aligned with its existing asset management objectives. It is important that the organization understands how the performance of external personnel affects the value-creating abilities of its assets, and that it continually assess and manage the associated risks of outsourcing asset management activities (ISO 55000, 2014). It is considered good asset management practice to perform regular performance assessments regarding the contribution of outsourced tasks or functions towards the achievement of asset management objectives and their alignment towards the SAMP (ISO 55000, 2014).

Asset Management Leadership
The significance of leadership in asset management is effectively underlined by its inclusion as one of the four fundamentals of asset management, as defined in section 2.3. The responsibility of effective implementation, operation and improvement of an organization's asset management activities should always remain with top management and relevant leader roles. Implementation of asset management refers to the strategic aspects of the discipline, such as the establishment of an asset management policy, a SAMP, asset management objectives and asset management plans. These should all be established by an organization's top management (ISO 55000, 2014). Furthermore, it is also the responsibility of top management and relevant leader roles to both operate and improve an organization's asset management efforts. Doing so involves continual promotion of asset management and its benefits across the organization, thus making sure that all relevant personnel are aware of the benefits of asset management, that they are competent in their work tasks, and that relevant roles, responsibilities and authorities concerned with asset management have been clearly defined and documented (ISO 55002, 2014). Asset management can, in this specific context, be viewed as a discipline that requires a top-down approach. This is underlined by Lloyd (2010a), who suggests that good asset management is characterized by a clear alignment from top management in the boards rooms to the personnel responsible for performing daily, individual work tasks, such as operators and technicians. On a more general level, however, the top-down approach of top management must also interact with a bottom-up approach, to ensure continual improvement of asset management plans and asset management activities performed on operator level (Lloyd, 2010b).

Organizational Structure

Organizational structure refers to how people are grouped and organized within an organization (IAM, 2015). The structure of an organization may have large implications towards the effectiveness of its asset management efforts. An ideal organizational structure, from an asset management perspective, is one that promotes a whole-life approach to assets by allowing for information-driven decision-making and regular integration of organizational processes. The importance of alignment and open information flows in asset management suggests that an ideal organizational structure is one of an open and integrative nature. Lloyd (2010b) highlights the forming multidisciplinary teams to solve multidisciplinary problems as an essential component in unifying asset management efforts across an organization. He further suggests that forming multidisciplinary asset management teams is an effective way of promoting a holistic approach to decision-making and asset management activities, while at the same time overcoming more traditional approaches that promote closed, departmental thinking.

The process of overcoming traditional approaches that promote closed, departmental thinking is a challenge that must be faced by any organization that wishes to fully succeed with its asset management efforts. Closed, departmental thinking is commonly referred to as functional silos, or "functional silo syndrome" (Ensor, 1988). Functional silos represent a good illustration of an organization that lacks a holistic mindset and fails to promote process integration. An organization that struggles with functional silos have its activities and departments strictly divided by specific functions or tasks (Liyanage, 2012). This will make it difficult to succeed with asset management, as it easily leads to closed information loops and increased internal competition for resources, rather than actively seeking process integration and regular achievement of a set of common objectives (Johnson, 2010; Liyanage, 2012). The struggles caused by functional silos are illustrated in Figure 9.

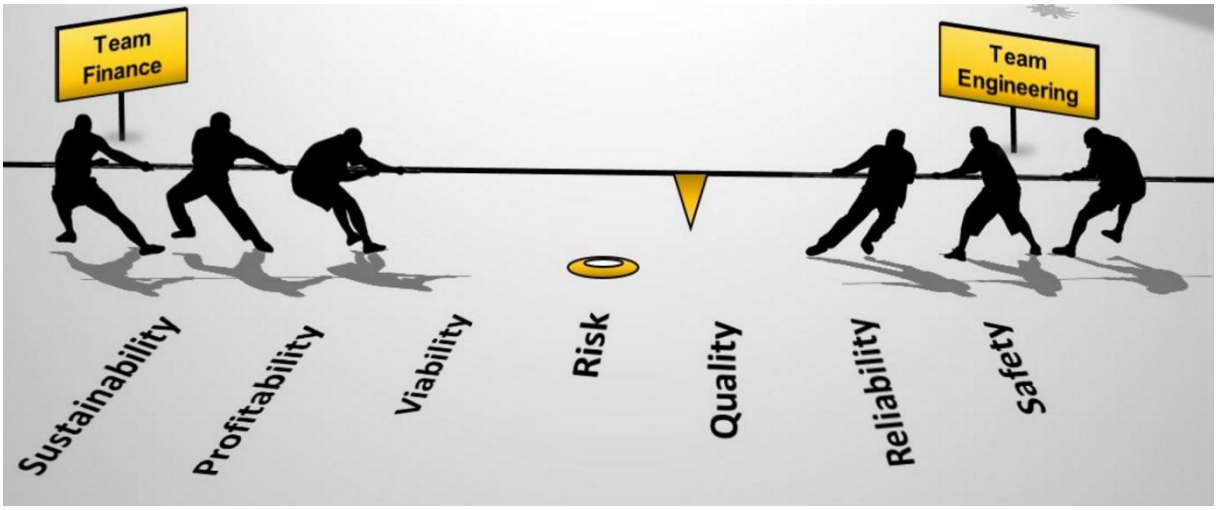

Figure 9 – The struggles of functional silos (Assetinsights, n.d.)

Organizational Culture

Organizational culture is a complex, but important contributor to organizational performance, including asset management (GFMAM, 2014). It is complex in the sense that culture is something that is usually built over time, and cultural change is not something that can be forced or altered by a "quick fix". Organizational culture can easily be overlooked when measuring the performance and capability of an organization, as it is challenging to measure, quantify and change. Building an organizational culture that supports and recognizes the importance of asset management is not easy, but its importance cannot be understated. Johnson (2010) suggests that creating a culture for asset management within an organization is an integral component needed to achieve the necessary levels of process integration to promote good asset management. There is no blueprint or single, correct solution towards the creation of an organizational culture that supports asset management. In an effort to clarify the role of organizational culture towards asset management, the IAM (2015) has established a set of guiding principles that, if focused on over time, will be likely to strengthen an organization's efforts of creating an organizational culture that supports asset management. These principles include:

- Top management and relevant leader roles in the organization must be clear about its context and purpose.
- Top management and relevant leader roles should ensure that their support and engagement to asset management is visible to all parts of the organization.
- All personnel should be aware of how asset management supports the achievement of organizational objectives.
- Cross-functional problem-solving and integration of processes should be promoted across the organization to ensure that all organizational departments (financial, human resources, engineering, operations, etc.) are aware of how they best can contribute to asset management activities and the achievement of asset management objectives.

Competence Management

Competence management encompasses the processes undertaken by an organization to develop and maintain the competence found amongst its personnel to be able to continually fulfill its asset management objectives (GFMAM, 2014). The responsibility of competence management lies with top management and relevant leader roles of the organization (ISO 55000, 2014). The process of competence management, from an asset management perspective, include ensuring that jobs and tasks that are of relevance towards the performance of assets and achievement of asset management objectives, are continually being performed by personnel with sufficient levels of competence. This includes formal tasks being performed in board rooms, as well as practical tasks performed by operators (GFMAM, 2014). A common tool used to manage asset management competence is to use job descriptions, which contain detailed competence requirements and standardized work procedures. This ensures that all tasks are being performed by competent personnel, in a manner promotes asset performance and regular achievement of asset management objectives. It is also considered good practice to conduct regular reviews of such job descriptions and continually update them to incorporate any possible changes (ISO 55002, 2014).

2.4.6 Risk and Review

Asset management requires continual review of the processes and activities undertaken by an organization to achieve its asset management objectives (IAM, 2015). Such a continual review process is not limited to a traditional picture of risk and financial costs, but also include other factors that may have implications towards the achievement of the aforementioned objectives. Factors such as stakeholder engagement, sustainability concerns, and contingency planning are all included during the length of the subject group 'Risk and Review'. The growing importance of sustainability and stakeholder engagement in review processes is underlined by Edwards (2010a), who points towards a growing stakeholder concern regarding organizations' social and environmental impact. To fully support the whole-life approach of asset management, such factors must also be incorporated into an organization's review processes.

Risk Assessment and Management

Assessment and management of risk are both key components required to achieve good asset management practices. The importance of risk management within the discipline of asset management is outlined by the IAM (2015, p.67), which states that *"effective risk management is an essential part of the successful delivery of all life cycle activities"*. Risk management is also a necessity with regards to asset management decision-making, made evident by the required inclusion of a risk assessment or risk analysis in both CBA and LCC analyses, as well as risk being a key aspect in both RCM and RBM approaches. Obtaining a good understanding of risk also has major implications towards the strategic aspects of asset management, as both the SAMP and asset management objectives of an organization will depend on its risk approach and risk tolerability limits.

Risk assessment and risk management are not covered in detail in the ISO 55000 suite, the first ISO standard for asset management. The ISO standard includes some basic advice and simple guidelines, but for a more comprehensive approach to risk assessment and risk management, the ISO 55000 suite refers directly to the risk management practices that are outlined in ISO 31000, the ISO standard for risk management (Hodkiewicz, 2015). Based on this, the author has chosen to include a presentation of the risk management process that is outlined in ISO 31000, in relation to this specific asset management subject. The presentation of the ISO 31000 risk management process will be supported by relevant and corresponding tools and methods presented by Aven (2015) and Edwards (2010b). The process for risk management that is included in ISO 31000 is outlined in Figure 10.

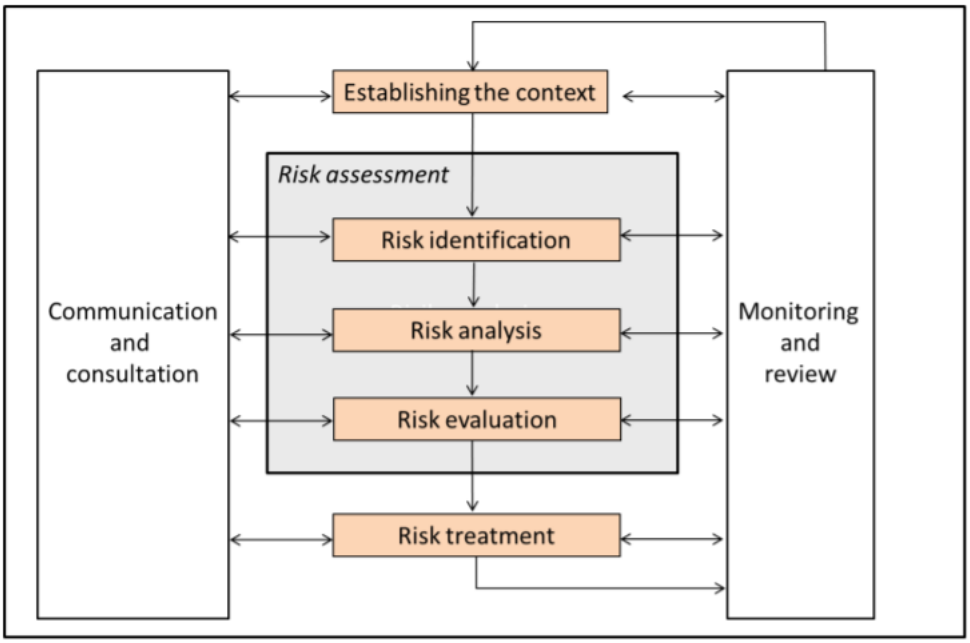

Figure 10 – Process for risk management included in ISO 31000 (Petroleum Safety Authority Norway, 2013)

Establishing the context: The first step is to identify the assets or asset groups that will be part of the risk assessment. Asset groups may be analyzed as a unit or separately, depending on the type of assets and the organization's approach to risk.

Risk identification: The second step is to conduct a thorough identification of possible initiating events, to identify the risk. Useful tools in such an identification process include FMECA (as previously described in section 2.4.3) and Hazard and Operability studies (HAZOP). Both tools will provide an organization with a structured and clear approach for determining possible initiating events.

Risk analysis: The third step is to conduct a risk analysis. This is done by undergoing cause- and consequence analyses, as well as quantifying the risk. The cause analysis should provide an answer to the question "What is needed for the initiating events to occur?". It may be supported by a fault tree analysis, which builds further on the information covered by the FMECA in the risk identification process. Next, a consequence analysis should help uncover the possible effects and consequences of each initiating event that were covered in the cause analysis. When conducting a consequence analysis, it is important to consider the specific attributes of each asset or asset group, and the existing degree of interdependency. A useful tool in the consequence analysis process is an event tree analysis. The final part of the risk analysis is to quantify the risk. Quantification of risk into numbered probabilities and uncertainties is an activity that should be treated with care. On one side, assigning probabilities and numbers to risk is an effective way of expressing it. It also makes it easier for an organization to apply certain limits and levels of tolerability. The drawback is that not all aspects of risk is quantifiable and visible through numbers. Thus, an organization is required to undertake a careful, balanced approach when quantifying risk related to its activities.

Risk evaluation: The fourth step is to draw a risk picture and evaluate the risk. A widespread approach is to do this by drawing a risk matrix. A risk matrix is an understandable and relatable way of presenting risk. Risk matrices can be presented in different configurations, but are typically established as color-coded, 5x5 matrices consisting of three categories, based on the ratio between likelihood and severity of an event. How the risk is categorized will largely depend on an organization's risk tolerability limits. An example of a risk matrix is shown in Figure 11.

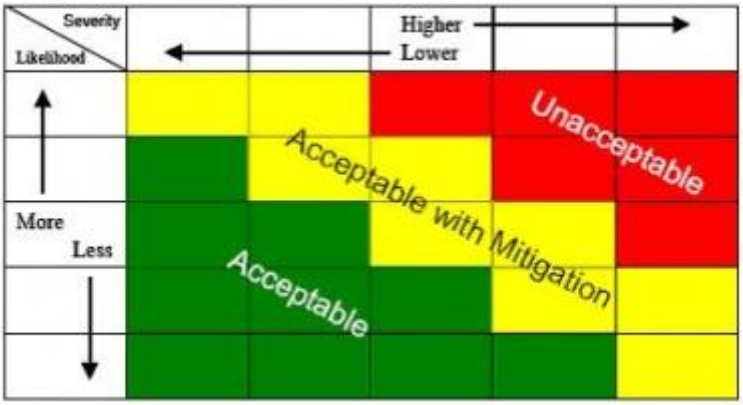

Figure 11 – Example of a risk matrix (Skybrary, 2016)

Risk treatment: The fifth and final step is to determine the treatment of the identified risk. Once again, how an organization chooses to treat risk is largely dependent on is attitude and tolerability limits. A general approach would be to not act on the risk found in the "Acceptable" region of the matrix and to act, regardless of the cost levels, towards risk found in the "Unacceptable" region of the matrix. The region that is marked "Acceptable with Mitigation" can be managed using the ALARP principle. The ALARP principle states that risk should be reduced to a level that is As Low As Reasonably Practicable (Aven, 2015). What this means is that an organization should always implement mitigating measures, unless there is proven to be a gross disproportion between the benefits if implementing the measures and the related cost levels.

Contingency Planning and Resilience Analysis

Contingency planning and resilience analysis embraces the processes initiated by an organization to ensure continual performance of its assets, despite serious incidents or disasters (IAM, 2015). Contingency planning and resilience analysis is separated from the asset management subject of 'Fault and Incident Response' presented in section 2.4.3, due to the differences in severity of incidents and disasters. Good asset management practices would imply that an organization has established its own designated contingency plans and are conducting regular review analyses that determine the resilience of its assets and associated operations (GFMAM, 2014). The scope of contingency planning and resilience analysis is of a wide nature and largely depends on an organization's context, its operating sector and operating location. Serious incidents that may be covered in an organization's contingency plans include major natural disasters such as storms and floods, and other serious incidents such as terrorist attacks or major breaches to its cyber security systems.

Sustainable Development

The importance of sustainable development has already been discussed briefly in the intro of this section (2.4.6), as Edwards (2010a) suggests that the focus of customers and stakeholders is not only on economic factors, but to a growing degree also concerned with an organization's sustainable and environmental impact. Asset management plays an important part in this regard, as both physical assets and asset management activities may have impacts that are of a social, financial and environmental nature. This fact clearly underlines the importance of reviewing the sustainability of an organization's actions and decision-making processes. A common way of referring to sustainable development is by using Elkington's (1997) concept of the Triple Bottom Line (TBL), illustrated in Figure 12. The concept of the TBL suggests that an organization and its activities can be regarded as sustainable if it can document a positive Return On Investment (ROI) on all three bottom lines, that is economic, environmental and social (Savitz and Weber, 2006). The IAM (2015, p.68) underlines the importance of conducting sustainable development reviews by stating that *"A sustainable development review supports the development of a long-term, holistic approach for an organization's asset management"*. It is also added that a sustainable development review forms an essential input in both strategic planning processes and asset management decision-making.

Figure 12 – The triple bottom line (Powerhouse Growers, 2013)

Management of Change

Change is a factor that is inevitable towards an organization's activities, strategic documents, and assets. It is bound to affect any organization in any industrial sector. It is therefore a necessity to include change and change management into review processes on a regular basis. The importance of change management is underlined by Frankel (2008), who suggests that good management of change is the principal objective for successful management in the modern age. Based on Frankel (2008), it becomes evident that it is necessary to incorporate change management into review processes that are concerned with asset management. It is essential to understand how change may potentially affect an organization's asset management objectives and organizational objectives, and to deal with it in an appropriate way. This might imply to apply mitigating measures, or just document and monitor the effects of the change (ISO 55002, 2014). What is important, however, is that change is acknowledged and properly dealt with, to ensure continual achievement of objectives and goals.

Asset Performance and Health Monitoring

The performance and health of assets should be subjected to continual or regular monitoring and review throughout their effective life cycles (GFMAM, 2014). The term ‘asset health’ can in this context be linked to the reliability of an asset, as described in section 2.4.3. To verify both the performance and health of assets, there should be established clear measurement indicators, or key performance indicators (KPIs), that are directly linked to both asset management objectives and the SAMP. The link between KPIs, asset management objectives and the SAMP is essential in terms of obtaining the alignment that is described in the asset management fundamentals in section 2.3. It is this specific alignment that must be in place for an organization to facilitate detailed monitoring of the performance of its assets against the associated set of asset management objectives. The importance of having a clear link between KPIs, objectives and strategy is described by both Campi (1993) and Hawkins (2014), as it is effectively what ensures that asset management can contribute to regular value creation and achievement of organizational objectives.

Asset Management System Monitoring

In addition to measuring and reviewing the performance and health of its assets, an organization should also measure and review the performance of its asset management system, if one has been implemented (GFMAM, 2014). The reader will be introduced to an asset management system in Chapter 3, as a part of the ISO 55000 suite, so the subject it will not be elaborated any further in this chapter.

Management Review, Audit and Assurance

Looking back at section 2.4.5 and the asset management subject of ‘Asset Management Leadership’, it became clear that the responsibility for asset management within an organization ultimately lays with its top management. It is therefore necessary that top management conducts regular audits and reviews to obtain assurance of the continual efficiency of its organization’s asset management activities, to ensure that asset management objectives and organizational objectives are being achieved on a continual basis (GFMAM, 2014). Management reviews and internal audits will be covered further in Chapter 3, as a specific part of the requirements found in the ISO 55000 suite. It will therefore not be covered in any more detail in this chapter.

Asset Costing and Valuation

Asset costing is concerned with the accumulation of all costs of an asset throughout its life cycle, while asset valuation is concerned with an estimation of the accumulated economic value it may create throughout its life cycle (GFMAM, 2014). The usefulness of asset costing and asset valuation as a review process can be seen in relation to asset management decision-making, where both capital expenditure decisions and decisions related to operations and maintenance will benefit from accurate financial information of an organization’s assets.

Stakeholder Engagement

The final subject of the subject group 'Risk and Review' and the IAM's conceptual model for asset management is stakeholder engagement. A stakeholder can be defined as *"a person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity"* (ISO 55000, 2014, p.12). The importance of stakeholder engagement in asset management is highlighted by Hastings (2010), as an integral part of asset management planning and decision-making. Identifying and meeting the needs and requirements of stakeholders is also described by Liyanage (2012), as an operational principle that is important and central in asset management terms. Looking back at the asset management subjects that are included in the subject group 'Strategy and Planning', in section 2.4.1, it becomes apparent that the creation of a SAMP and setting of asset management objectives should always be made with stakeholder needs and requirements in mind, as a whole-life approach to assets is dependent on stakeholder support. The needs and requirements of stakeholders are also important aspects that should be considered in asset management decision-making processes, further underlining the importance of conducting regular reviews of stakeholder needs and expectations. Stakeholders come in several shapes and sizes, largely depending on the characteristics of an organization. Some examples include the employees of an organization, shareholders, customers, owners, local communities and government agencies (ISO 55002, 2014).

2.5 Key Benefits of Asset Management

The width of the activities and elements that are included in the 39 asset management subjects, as defined by the GFMAM (2014), leads the discipline of asset management to bring a wide range of potential benefits. To clarify, and perhaps even simplify, a selection of key benefits of asset management has been included in the ISO 55000 suite. These benefits can include, but are not limited to the following (ISO 55000, 2014):

- Improved financial performance, through an enhanced ROI and cost control.
- Informed asset investment decisions, allowing for an optimal balance between costs, risks and benefits.
- Managed risk related to financial losses, health and safety and the environment.
- Improved services and outputs, allowing for regular conformity towards stakeholders.
- Demonstrated social responsibility.
- Demonstrated compliance towards legal and regulatory requirements.
- Enhanced organizational reputation.
- Improved organizational sustainability.
- Improved efficiency and effectiveness of organizational processes and asset performance.

Chapter 3 – ISO 55000: The ISO Standard for Asset Management

3.1 Introduction

When reviewing Chapter 2 of this thesis, it quickly becomes apparent that asset management is a wide discipline, consisting of a wide range of subjects. It is a discipline that affects several parts of an organization and a substantial number of its processes. Consequently, it may prove to be a challenging task for an organization to have sufficient control over its asset management activities, which is a necessity required to obtain regular achievement of organizational objectives through the value created by its assets. It is therefore suggested that most organizations would benefit from a framework or an overarching management system to support both the implementation and operation of their asset management activities (ISO 55000, 2014).

The ISO 55000 suite represents the first ISO standard for asset management. Published for the first time in January 2014, it provides organizations with the necessary framework and overarching management system to effectively control their asset management activities. The ISO 55000 suite represents a structured approach of performing asset management, by utilizing a management system for the management of assets. Such a management system is simply referred to as an 'asset management system' (ISO 55000, 2014). A graphical overview of some of the key elements of the asset management system presented in the ISO 55000 suite has already been outlined in Figure 5.

Correct implementation of the asset management practices described in the ISO 55000 suite may potentially have major implications towards an organization's asset management capabilities, as well as the outcome of its asset management activities. It is suggested that adoption of the principles described in the ISO 55000 suite enables an organization to achieve its organizational objectives through the effective and efficient management of its assets, while at the same time ensuring that the objectives are achieved in a consistent and sustainable manner over time (ISO 55000, 2014). This is further supported by both the IAM (2015) and Hawkins (2014), which suggest that implementing the practices found in the ISO 55000 suite will help organizations to deliver both the performance and assurance needed to achieve good asset management practices. A more comprehensive overview of potential and actual benefits of both a qualitative and quantitative type related to the implementation of an asset management system is further outlined in section 3.3.

The implementation of an asset management system, as described in the ISO 55000 suite, is applicable with any relevant industrial sector and any type of organization. The elevated level of applicability is underlined by the following statement:

"International cooperation in the preparation of these standards has identified common practices that can be applied to the broadest range of assets, in the broadest range of organizations, across the broadest range of cultures" (ISO 55000, 2014, p.v).

Despite the elevated level of applicability, there are still some details of the ISO standard that should be noted before proceeding. Although the ISO 55000 suite specifies that it may be used to manage both physical and non-physical assets, it is also noted in the standard that it is *intended* to be used for managing physical assets in particular (ISO 55000, 2014). Another important detail is that certain aspects of asset management will not be covered entirely by an implementation of the practices outlined in the ISO 55000 suite. Certain aspects of a more abstract nature, such as organizational culture (as presented in section 2.4.5), may have significant implications towards an organization's asset management activities and its ability to regularly achieve organizational objectives. However, such aspects cannot be established or improved purely by the implementation of an asset management system, as they have deeper roots in an organization. Consequently, such aspects may have to be partially managed by activities that, according to the ISO 55000 suite, are located outside the range of the asset management system (ISO 55000, 2014). This is illustrated in Figure 13, which shows the relationship between asset management as a discipline, and the boundaries of the asset management system described in the ISO 55000 suite.

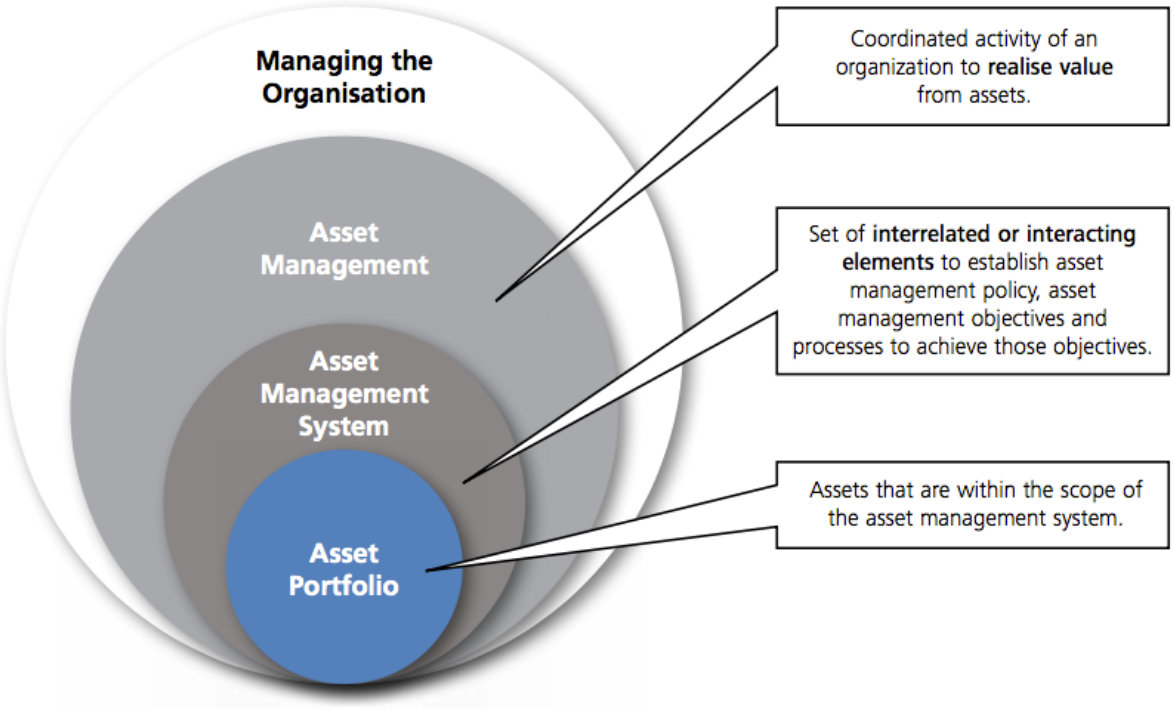

Figure 13 – The relationship between asset management and an asset management system (ISO 55000, 2014)

The ISO 55000 suite consists of a set of three sub-standards, ISO 55000, ISO 55001 and ISO 55002. Each of the sub-standards contains valuable information on asset management and asset management practices. However, to gain the full benefits of the standards and be able to implement a functioning asset management system, they should really be thought of as an entity. The individual content of each standard is as follows:

ISO 55000 – Overview, Principles and Terminology:
ISO 55000 contains a general overview of the subject of asset management. It also includes a general overview of the elements of an asset management system, as well as an introduction to the fundamentals of asset management, as included in section 2.3.

ISO 55001 – Management Systems – Requirements:
ISO 55001 contains a detailed introduction to the elements of an asset management system. A set of specific requirements and accompanying clauses that must be met to successfully implement an asset management system are presented in detail. The requirements and clauses included in ISO 55001 will be presented in detail throughout section 3.2.

ISO 55002 – Management Systems – Guidelines for the Application of ISO 55001:
ISO 55002 acts as a direct extension of ISO 55001, as it contains specific guidelines and further elaborates on the requirements and clauses of ISO 55001. ISO 55002 is also actively used throughout section 3.2, to underline and elaborate on the included requirements and clauses.

3.2 Elements of an Asset Management System

The ISO 55000 suite is compliant with the Annex SL format, a standardized high-level structure used in ISO standards for management systems. The Annex SL structure provides management system standards published by ISO with an identical structure, as well as a common terminology (Reece, 2015). The standardized high-level structure ensures consistency between different ISO standards for management systems, it contributes to increased understanding amongst organizations that choose to adopt ISO standards, and perhaps most importantly, it enhances the possibilities of an integrated approach to multiple management systems.

Adoption of an integrated management systems approach is highlighted in section 2.6 in ISO 55000 (2014). It is suggested that adoption of an integrated management systems approach will allow for an organization's asset management system to be partially built on elements and foundations of other management systems, such as quality (ISO 9001) and environment (ISO 14001). Adopting an integrated management systems approach may potentially reduce the effort and costs of undergoing an implementation of the ISO 55000 suite, while at the same time increase cross-functional integration of processes within the organization, which is a key concept of asset management (ISO 55000, 2014).

As per the Annex SL format, ISO 55001 (2014) presents a total of seven asset management system requirements. The requirements are:

- Context of the Organization
- Leadership
- Planning
- Support
- Operation
- Performance Evaluation
- Improvement

As previously outlined, each of the seven requirements of ISO 55001 (2014) contains a set of corresponding clauses, which must be met to successfully implement an asset management system. There is a total of 24 clauses within the seven requirements, all of which will be presented throughout section 3.2.1-3.2.7. Before proceeding, the reader should note that the order in which the requirements and clauses are presented in this thesis do not reflect their relative importance towards the achievement of good asset management practices, nor does it imply the order in which the requirements are to be implemented (ISO 55001, 2014). Implementation of the requirements and clauses of ISO 55001 (2014) is not to be regarded as a one-time process, but rather a continual, iterative process. The iterative nature of the implementation process is illustrated in Figure 14, which presents the seven requirements and 24 corresponding clauses in a modified Plan-Do-Check-Act cycle. (The numeration in Figure 14 is based on the numeration in ISO 55001 (2014) and is not relevant for this thesis.)

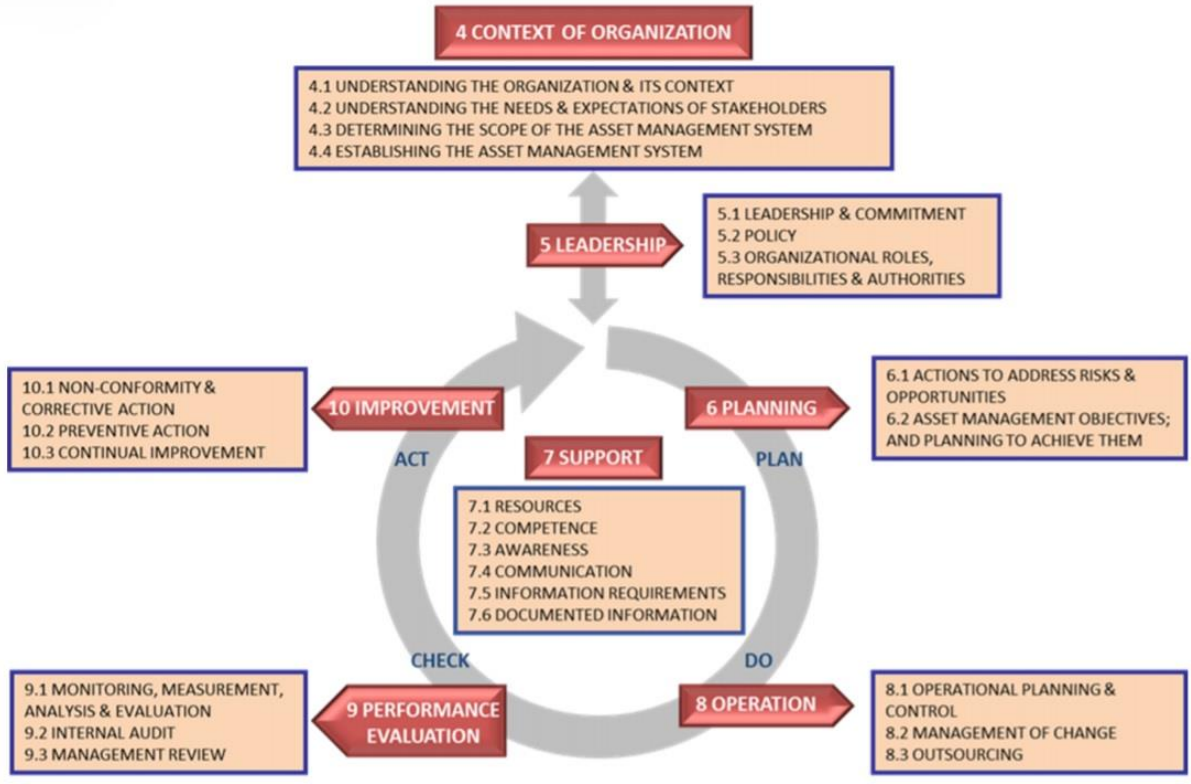

Figure 14 – The requirements and clauses of ISO 55001 (2014) in a Plan-Do-Check-Act cycle (Woodhouse, 2014)

3.2.1 Context of the Organization

The information presented throughout section 3.2.1 - 3.2.7 is drawn from ISO 55001 (2014), unless otherwise referenced. The reader should also note that these sections contain previously visited terms such as 'SAMP', 'asset management policy', 'asset management objectives' and 'asset management plans', all of which have been presented in section 2.4.1, as part of the asset management subject group 'Strategy and Planning'.

Understanding the Organization and its Context

When establishing an asset management system, it is vital that the organization has sufficient knowledge of its existing organizational objectives. The asset management objectives that are to be established as part of the SAMP and the asset management system shall be consistent with, and aligned to the existing organizational objectives of the organization. The organization should also be aware of both internal and external factors that may be relevant to its purpose and ability to achieve its desired asset management objectives, as well as the desired outcomes of the asset management system. Some selected examples of external factors include the social, cultural, economic and physical environments of the organization, while some examples of internal factors include the organizational culture, its values and its vision (ISO 55000, 2014).

Understanding the Needs and Expectations of Stakeholders

The needs and expectations of both internal and external stakeholders may have significant impact on the organization's asset management activities and its asset management system. As one of the objectives of asset management is to regularly meet the needs and expectations of stakeholders, the organization should be active in its approach of identifying stakeholders' needs and expectations, and regularly incorporate them into decision-making processes and strategic planning processes. Some selected examples of stakeholders that may affect an organization's asset management system and asset management activities include employees of the organization, government agencies, shareholders, owners, local communities and customers (ISO 55002, 2014).

Determining the Scope of the Asset Management System

When creating the asset management system, the organization should set the boundaries and determine its applicability, to clearly define and determine its scope. The scope of the asset management system is required to be aligned with the organization's SAMP, as well as its asset management policy. Setting the boundaries and applicability of the asset management system also involves determining which assets will be part of the asset portfolio covered by the asset management system. Failing to clearly define and document the scope of the asset management system will easily lead to unnecessary usage of organizational resources. The scope of the asset management system should be subjected to periodic reviews, to reveal and incorporate any possible changes (ISO 55002, 2014).

Asset Management System

The organization shall establish, implement, maintain and continually improve an asset management system to control its asset management activities. It should do so by developing, implementing and maintaining a SAMP, which documents how organizational objectives should be translated into asset management objectives, how asset management plans shall be developed and how the asset management system shall assist the organization in achieving its asset management objectives (ISO 55002, 2014). For a more detailed description of a SAMP and its included content, the reader is encouraged to return to section 2.4.1.

3.2.2 Leadership

Leadership and Commitment

Top management and leaders have several responsibilities regarding the organization's asset management system. Top management is responsible for the development and planning of the organization's asset management policy, the SAMP and the asset management objectives. In addition to this, it is also the responsibility of both top management and leaders to show strong leadership and commitment towards asset management. This can be achieved by regularly communicating the importance of effective asset management, by promoting cross-functional cooperation within the organization, and by working towards an organizational state where the SAMP, asset management objectives and asset management plans remain in alignment with organizational objectives on a continual basis (ISO 55000, 2014). The responsibility of top management with regards to leadership and commitment is further underlined in ISO 50002 (2014), where it is suggested that the accountability and ownership of asset management should always remain at top management level of the organization. Leadership is also included as one of the four fundamentals for asset management, as presented in section 2.3.

Policy

Top management of the organization is responsible for developing an asset management policy, which is a policy that outlines how the organization intends to use asset management to achieve its organizational objectives. Top management is also responsible for regularly updating the policy whenever it is required, to make sure that it remains relevant to the organization's context, purpose and objectives on a continual basis. For a more detailed description of an asset management policy and its included content, the reader is encouraged to return to section 2.4.1.

Organizational Roles, Responsibilities and Authorities

The roles, responsibilities and authorities of all personnel that is conducting work within the boundaries of the asset management system should be clearly defined. This process is the responsibility of top management and relevant leader roles. The process includes defining both internal and outsourced roles and responsibilities (ISO 55002, 2014). The process of defining organizational roles, responsibilities and authorities involves an analysis of the competence, experience and training of organizational personnel. It should be clearly defined and

documented which roles are responsible for which activities. Tools that are helpful in this regard includes job descriptions and organizational charts (ISO 55002, 2014).

3.2.3 Planning

Actions to Address Risks and Opportunities for the Asset Management System
Risks and opportunities related to the asset management system and its desired outcomes must be actively managed by the organization. In doing so, the organization should determine the necessary actions for addressing risks and opportunities related to the establishment, operation and maintenance of the asset management system, as well as its assets (ISO 55002, 2014). The risk management approach related to the asset management system should, where applicable, be aligned with the overall risk management approach of the organization. Such an alignment promotes organizational consistency and increases the possibility of achieving an integration of risk management processes across the organization (ISO 55002, 2014). The organization's risk management approach should be properly documented, to provide useful data for future reference and be used as a measure for continual improvement. The ISO 55000 suite does not describe a risk management approach in detail, as the standard applies the risk management principles of ISO 31000, the ISO standard for risk management. A risk management approach that is applicable with the content of ISO 31000 is presented in section 2.4.6.

Asset Management Objectives and Planning to Achieve Them
The organization shall define and establish specific asset management objectives that are compliant with the organization's interests and stakeholder requirements. The defined asset management objectives shall remain in clear alignment with the organization's asset management policy and be derived as a result of having developed a SAMP. To meet and fulfill the defined asset management objectives, the organization shall also establish specific asset management plans, outlining just how the asset management objectives shall be met. Asset management plans shall consider all relevant requirements of the organization, both internal and external. For a more detailed description of asset management objectives and asset management plans, the reader is encouraged to return to section 2.4.1.

3.2.4 Support

Resources
Resources required for the establishment, maintenance, operation and continual improvement of the asset management system shall be determined and provided by the organization. Doing so involves establishing procedures for determining the resources needed to conduct the activities contained in the organization's asset management plans, thus being able to meet the defined asset management objectives. An efficient procedure of resource allocation should include an analysis process where available resources are mapped against available resources, to reveal possible resource gaps. The results of such a gap analysis may then be used a tool for determining future resourcing options and to optimize resource prioritization within the organization, to further optimize the potential benefits of the asset management system and the organization's assets (ISO 55002, 2014).

Competence
The organization shall determine the required competence of personnel performing tasks that affect either the performance of its assets, asset management or the asset management system. Doing so includes making sure that its personnel has received the necessary training and education, or that they have the required experience to perform tasks in a way that continually supports high performance of assets, asset management and the asset management system. Competence and knowledge of asset management should be found and addressed at all levels of the organization, to ensure alignment between roles, organizational levels and departments (ISO 55002, 2014). A helpful tool with regards to competence management is to utilize a documentation system or a database that retains appropriate documented information as evidence of competence, such as received training, competence and courses of all personnel. Such a documentation system ensures that the organization can consistently determine the competence of personnel that is performing tasks that affect its assets, asset management or the asset management system. The documentation system can also be utilized to shape training programs or educational resources used to further improve asset management competence (ISO 55002, 2014).

Awareness
All personnel that is working within the organization should have the appropriate knowledge and awareness regarding the organization's asset management system and asset management activities (ISO 55002, 2014). Awareness could be raised by making sure that everyone is aware of factors such as the organization's asset management policy, how everyone's personal contributions are affecting the effectiveness and performance of the organization's assets, the benefits of improved asset performance, and how well the organization is performing in meeting its objectives. There are several practical ways to gain such awareness, including regular consultations with personnel regarding asset management, inclusion of asset management in newsletters or periodic briefings from top management (ISO 55002, 2014).

Communication

The organization shall determine efficient procedures related to both internal and external communications relevant to its assets, asset management activities and the asset management system. This includes determining what to communicate, the frequency of the communications and who are the relevant recipients of the communicated information. It is further suggested in ISO 55002 (2014) that most organizations would benefit from developing designated communication plans, which could include such topics as the potential benefits asset management brings to the organization, improvement schedules and other information that is of relevance to both internal and external stakeholders.

Information Requirements

The organization is responsible for determining its information requirements to support its assets, the asset management system and the achievement of organizational objectives. This involves determining the attributes of the required information, the required quality of the information and the process of obtaining, maintaining and evaluating collected information. It is suggested in ISO 55002 (2014) that it is beneficial to implement a systematic approach for identifying, collecting, reviewing and saving relevant information that is of importance towards the performance level of the organization's assets and its asset management system. A selection of areas that should be of interest when considering information requirements include information related to strategy and planning, performance indicators (KPIs), asset properties, technical information, maintenance management, risk management and performance management (ISO 55002, 2014).

Documented Information

The organization shall determine the documented information needed to ensure effectiveness of its assets, asset management and the asset management system (ISO 55002, 2014). Documented information can refer to information regarding the asset management system itself, as well as individual assets or asset groups. This clause can be viewed as an extension of the clause 'Information Requirements', as it describes how the gathered information should be documented and treated after it has been obtained. Documented information should be regularly subjected to controls, to ensure its continual effectiveness. It should also be updated at regular intervals and be made easily available to relevant personnel.

3.2.5 Operation

Operational Planning and Control

The organization shall establish operational planning and control processes to support an efficient delivery of the activities that are included in its asset management plans. When conducting activities that are part of the pre-defined asset management plans, it is important that the activities are subjected to sufficient levels of support and control, to ensure that the outcome of the asset management plans will be as expected. This includes ensuring that the implementation of the asset management plans is conducted by competent personnel, that sufficient resources have been allocated to the activity, and that roles and responsibilities are clearly defined. It should also include proper documentation of the implementation process of asset management plans, to allow for a documented verification of the expected results. A useful measure in this regard is the use of work orders (ISO 55002, 2014).

Management of Change

The organization should be aware of any risks associated with planned or unplanned change that can have an impact on its ability of achieving its asset management objectives. If it is revealed that a planned change may potentially affect the organization's ability to achieve its asset management objectives, the change should be subjected to a thorough risk assessment before an implementation of the change is considered. The organization should have procedures for taking mitigating measures, if that is found necessary. Examples of planned changes that may affect an organization's ability to achieve its asset management objectives include changes to organizational roles, organizational processes, resource demands and implementation of new technological solutions (ISO 55002, 2014).

Outsourcing

Any outsourced tasks, activities or services that may influence the organization's ability to achieve its asset management objectives should be subjected to regular reviews. The organization should consider implementation of controlling measures to ensure that such tasks, activities or services are being performed in a manner that supports the achievement of asset management objectives. External personnel should be introduced to the procedures and standards of the organization, to ensure that they are aware of the organization's context and its performance expectations. It is also specified in ISO 55002 (2014) that the organization should consider the ownership and protection of intellectual property, information and corporate knowledge when outsourcing asset management activities.

3.2.6 Performance Evaluation

Monitoring, Measurement, Analysis and Evaluation

To ensure that the organization is on track towards regular achievement of its asset management objectives, it should develop and maintain processes for monitoring and evaluating the performance of its assets and asset management activities, as well as the effectiveness of its asset management system. In doing so, the organization should determine what is to be measured, the methods for doing so, when the measuring should take place, and how the measured data should be processed, evaluated and stored. A set of specific performance indicators, or KPIs, should be developed and utilized in this regard. The KPIs may be both quantitative and qualitative (ISO 55002, 2014). What is important is that the KPIs are developed as a direct result of the asset management objectives, to ensure a reliable and useful performance measurement process.

Internal Audit

To ensure the effectiveness of the asset management system, asset management activities and assets, the organization should conduct internal audits at planned intervals. The audits should be used as a tool to reveal whether the asset management system performs according to the requirements set by the organization, and if the asset management system is implemented and maintained in an effective way. Internal audits should also consider the quality of asset management activities and the performance levels of the organization's assets (ISO 55002, 2014). The organization is responsible for selecting appropriate audit criteria, audit scope and audit personnel with sufficient competence, as well as reporting audit results to relevant management of the organization and ensure proper documentation of audit results for future reference.

Management Review

Top management of the organization is responsible for reviewing the performance of the organization's assets, asset management activities and the asset management system at planned intervals, to ensure that their performance and effectiveness are continually meeting both the initial requirements and associated objectives (ISO 55002, 2014). Management reviews are expected to include status updates from previous management reviews, details of any organizational changes that may affect the performance of assets, risk management updates and a review of results obtained in previously conducted internal audits. The results of management reviews should be thoroughly documented, to ensure documentation that can be used for future management reviews and as a tool for continual improvement.

3.2.7 Improvement

Nonconformity and Corrective Action

The organization should, in the case of a nonconformity or incident in its assets or asset management system, deal with this nonconformity or incident as applicable. This involves acting to control and correct the nonconformity or incident, mitigate its potential consequences, or deal with the consequences in an applicable way. A preferable approach to dealing with a nonconformity or incident in assets is to actively seek the root cause of the incident or nonconformity, and eliminate the cause of failure (ISO 55002, 2014). Once a mitigating or corrective action has been taken, it should be followed by a thorough review of the effectiveness of the action, as well as proper documentation of the action and its effects. In the aftermath of an incident or nonconformity related directly to the asset management system, the organization should consider making changes to the configuration of the asset management system, if there are evidence suggesting that the same incident or nonconformity may occur again (ISO 55002, 2014).

Preventive Action

The organization should be proactive in its efforts of identifying potential degradation of asset performance, by implementing processes to proactively identify potential failures in asset performance in their preliminary stages and evaluate the need for preventive actions. Identification of potential asset failure or performance degradation in preliminary stages involves the implementation of both preventive and predictive actions, actively seeking root causes and applying a proactive methodology to do so (ISO 55002, 2014) Once a potential failure has been identified, the organization should apply the principles of the clause 'Nonconformity and Corrective Action'. Identification of potential failures and application of preventive actions should be an ongoing, iterative process across the entire organization (ISO 55002, 2014).

Continual Improvement

Opportunities for improvement should be identified, assessed and implemented across the organization on a continual basis, with regards to its assets, asset management and the asset management system. The process of continual improvement should be an iterative process, with a final aim of achieving organizational objectives (ISO 55002, 2014). Selected sources that may provide data to promote continual improvement include studies of incidents involving nonconformities, implemented preventive actions, performance trends, internal and external audits and management reviews. The organization should also look outwards in their search for continual improvement, for example by studying competitors, investing in research and development, attending seminars and conferences, and actively participate in professional bodies, networks and industry clusters (ISO 55002, 2014).

3.3 Key Benefits of an Asset Management System

The act of meeting the requirements and clauses that are presented throughout section 3.2.1-3.2.7, and thereby implementing an asset management system to systematically govern and control asset management activities, is likely to be a highly beneficial measure for most organizations. To elaborate on the matter, ISO 55000 (2014) has defined a set of four specific areas that highlight some potential qualitative benefits of undergoing an implementation process. These potential qualitative benefits include:

The creation and implementation of an asset management system is beneficial in itself:
The benefits of implementing an asset management system may present themselves prior to the completion of the implementation phase. The process of implementing an asset management system requires organizations to look inwards, at their own processes, values and ideas. Doing so can bring new perspectives on existing organizational processes, improve the organizations' value creation from their assets, and improve decision-making processes.

Improved cross-functional integration and new insights is beneficial to top management:
An asset management system creates an increased understanding of how assets and their performance affect an organization's ability to achieve its organizational objectives. It provides benefits related to communication, functional integration and information transfer, which should be recognized and promoted by top management. The holistic and sustainable approach to decision-making supported by an asset management system is of great importance to the strategic planning processes undertaken by top management.

Financial functions and decision-making will benefit from improved data and enhanced inter-organizational communication:
An asset management system creates a good framework for balancing the achievement of short-term financial gain with long-term achievement of organizational objectives and goals, due an increased focus on open information transfer and information quality. It also enables integration of operational and financial risks in decision-making processes related to assets, allowing for an optimized balancing of costs, risks and benefits.

A wide range of areas within the organization will benefit from the implementation of an asset management system:
The integrative and cross-functional nature of an asset management system allows for a wide range of areas and departments of an organization to benefit from its implementation. Integration of previously isolated asset information through the asset management system can act as a driver towards improved organizational decision-making and break down functional silos within the organization. An asset management system can also contribute to increased awareness amongst the individuals of the organization. Personnel will be more aware of how their contributions are creating value, and how they affect both asset performance and the achievement of organizational objectives. Gaining such awareness can act as a motivating factor and raise the profile of asset management within the organization.

As further verification of the potential qualitative benefits of undergoing an implementation process of an asset management system, as described by ISO 55000 (2014), both Woodhouse (2014) and Jay and Hamer (2015) present some quantitative results that should raise further awareness and motivation regarding the ISO 55000 suite's significant implications towards organizational success and value creation. Woodhouse (2014) points towards the company Scottish Power, which through the application of asset management system principles has obtained the following quantitative results:

- 10% reduction in CAPEX.
- 20 % reduction in operations and maintenance costs (OPEX).
- 22% increase in overall plant availability.
- 25% reduction in forced outages.

Jay and Hamer (2015) present some noticeable results obtained by the company Sodexo, a global, world-leading company within quality-of-life services. Since 2011, Sodexo has been working with a standardized asset management model in all their businesses. The model was initially based on the requirements of BSI PAS 55, before it was adjusted to fit the requirements and clauses of ISO 55001 (2014) once the ISO 55000 suite was published in 2014. As of 2015, Sodexo can present the following overall achievements obtained by the utilization of an asset management system:

- An average of 7-8% improved control of day-to-day activities and business efficiencies.
- 40% reduction of risk-related costs.
- 100% compliance in regulatory activities.
- 20% reduction of failure rates.

Chapter 4 – Analysis of Asset Management Practices

4.1 Introduction to the Selected Analysis Approach

This chapter presents the results of the analysis of asset management practices found within the three industry-leading organizations that have been included in this thesis. Each presentation is preceded by an introduction of the respective organization, as well as an introduction to the selected interviewees. Due to a matter of company and personal confidentiality will this thesis not directly name or refer to any individuals, names or companies. The introduction of each organization will remain restricted to its operating sector and organizational context, while the interviewees will be introduced by their working titles. The order in which the analysis results are presented goes O&G industry (section 4.2), land-based manufacturing industry (section 4.3) and land-based process industry (section 4.4).

The presentation of the analysis results is done in two parts, through a section of written text and a corresponding radar chart. The radar chart is presented first, as it effectively outlines the respective organization's degree of compliance with the seven requirements of ISO 55001 (2014). The indicators contained within the radar chart are derived from a more comprehensive scorecard that is developed to indicate the respective organization's degree of compliance with all the 24 clauses of ISO 55001 (2014). The scorecard of each respective organization is enclosed together with its corresponding radar chart in the presentation of the analysis results. The specific indicator scale used to develop the scorecard indicators is adapted from the IAM's Asset Management Maturity Scale, using slightly different criteria and numeration (IAM, 2016). The indicator scale is based on a 1-4 scoring system with the following criteria:

4 - The organization presents asset management practices that can be regarded as compliant with the respective clause of ISO 55001 (2014).

3 - The organization presents good asset management practices, however there are minor elements missing to be regarded as compliant with the respective clause of ISO 55001 (2014).

2 - The organization presents weak asset management practices, presenting severe or several shortcomings compared to the respective clause of ISO 55001 (2014).

1 - The organization presents asset management practices that are of zero compliance with the respective clause of ISO 55001 (2014).

As the scorecard outlines the respective organization's degree of compliance with the 24 clauses of ISO 55001 (2014), it also effectively outlines its degree of compliance with the seven corresponding requirements, through the average score of their included clauses. The average requirement scores are further rounded to comply with the initial 1-4 scale and then plotted into the corresponding radar chart.

The rounding of the average requirement scores is based on the following intervals, where X represents the average score of a given requirement prior to rounding:

($X = 4$ gives a rounded score of 4)
($3 \leq X < 4$ gives a rounded score of 3)
($2 \leq X < 3$ gives a rounded score of 2)
($1 \leq X < 2$ gives a rounded score of 1)

Next, succeeding the radar chart is the aforementioned section of written text. Here, the respective organization's asset management practices within each of the 24 clauses of ISO 55001 (2014) are presented in further detail, providing deeper insights into the content of its corresponding radar chart and scorecard. The section of written text is directly derived from the answers provided by the interviewees during the interview session and includes a fuller introduction to the respective organization's asset management practices, containing detailed insights into specific tools, methods and practices. The layout and order in which the specific clauses are presented in the section of written text follows the same order as the clauses are presented in section 3.2.1-3.2.7, with the seven requirements of ISO 55001 (2014) as headlines.

The reasoning behind the selected analysis approach can be found in ISO 55002 (2014, p.5), which states that *"an initial review of the organization's current processes against the requirements of ISO 55001 will determine the areas that need to be developed to support the functioning of a compliant asset management system"*. In other words, an initial review of the organizations' current processes against the requirements and clauses of ISO 55001 (2014) forms an excellent basis for uncovering each organization's asset management practices based on a common set of criteria. The analysis results presented throughout Chapter 4 are what is forming the basis for the comparison of performance gaps and improvement areas presented in Chapter 5.

Before proceeding to the analysis results, the reader should note some final details. First, some of the clauses of ISO 55001 (2014) have been merged in the written text section of the analysis, as both the clauses and the corresponding set of answers provided by the organizations are highly interdependent. The clauses in question are 'Determining the Scope of the Asset Management System' and 'Asset Management System', as well as 'Information Requirements' and 'Documented Information'. This has only been done in the written text section of the analysis for simplicity reasons. Next, the labelling of the 24 clauses of ISO 55001 (2014) in each organization's scorecard is based on the order in which they are presented throughout section 3.2.1-3.2.7. For example, 'Clause 1' of 'Leadership' is 'Leadership and Commitment', 'Clause 1' of 'Support' is 'Resources', 'Clause 2' of 'Operation' is 'Management of Change' and so forth. This labelling approach had to be taken as the substantial number of clauses and their comprehensive terms did not facilitate an inclusion of their full terms within the scorecards. Finally, the reader is once again reminded of the statements made in 'Delimitations' in section 1.5, as the degree of compliance measured in the analysis of asset management practices is towards the 24 clauses of ISO 55001 (2014) as they are presented in this thesis. For further details on the matter, the reader is advised to return to section 1.5.

4.2 O&G Industry

Overview of the Selected Organization

The organization representing the O&G industry is an industry-leading actor within the industrial sector. Involved in activities ranging from exploration to development and production of petroleum resources, it represents one of the major players on the Norwegian Continental Shelf. The organization is currently operating several fields on the Norwegian Continental Shelf, which leads it to have a significant asset portfolio, consisting of several facilities and substantial amounts of equipment and machinery.

Interviewee

The results presented throughout section 4.2. are based on the responses of the Operations Engineering Manager within the selected organization, provided during the semi-structured interview session.

4.2.1 Overview of Asset Management Practices

Figure 15 – Asset management practices of the O&G organization

	Context of the Organization	Leadership	Planning	Support	Operation	Performance Evaluation	Improvement
Clause 1	4	4	4	4	4	4	4
Clause 2	4	4	4	4	4	4	4
Clause 3	4	4		4	4	4	4
Clause 4	4			4			
Clause 5				4			
Clause 6				4			
Avg. Score	4	4	4	4	4	4	4
Rounded Score	**4**	**4**	**4**	**4**	**4**	**4**	**4**

Table 1 – Scorecard of the O&G organization

4.2.2 Context of the Organization

Understanding the Organization and its Context
The Operations Engineering Manager was able to provide good insights into the organization's existing organizational objectives, which are gathered in an organizational strategic plan. The plan is reviewed and updated at regular intervals, and it is also regularly communicated out to the personnel of the organization to provide everyone with a clear picture of the organization's context. The existing practices and knowledge regarding the existing organizational objectives forms a solid foundation for the development of asset management objectives.

Understanding the Needs and Expectations of Stakeholders
The organization shows extensive understanding and awareness regarding the needs and expectations of stakeholders, and these are incorporated into both decision-making processes and strategic planning processes. The Operations Engineering Manager listed good measures of incorporating both internal and external stakeholders into decision-making processes and strategic planning processes, ranging from long-term perspectives (5 years and more), to short-term perspectives (yearly basis, quarterly basis and day-to-day operations). Stakeholders that were mentioned during the interview include own employees, government agencies, shareholders and owners. The needs and expectations of these stakeholders are documented and made easily available to relevant personnel. Stakeholders' needs and expectations are actively being studied whenever top management sets new organizational objectives or alter existing ones, proving that the organization is aware of both external and internal factors that may affect the achievement of its organizational objectives.

Asset Management System and Determining the Scope of the Asset Management System
Asset management is a well-known term in this organization, as it is a discipline that is utilized broadly. Despite this, there is no existing familiarity with the ISO 55000 suite. Consequently, the organization has not been certified against the standard. However, there has still been developed an overarching management system to control and govern the organization's asset management activities. The management system is based on the organization's own extensive experience with asset management. As a result of having implemented an overarching management system to control its asset management activities, the organization has also established a SAMP, which translates its organizational objectives into specific asset management objectives, just like the practices outlined in the ISO 55000 suite. Top management have clear goals and ideas of what they want the organization to achieve from its asset management activities and this is clearly reflected in the SAMP. As part of the SAMP, the organization has also established and documented the boundaries of its asset management activities. Relevant personnel are aware of what is included in the scope of the organization's asset management activities and which assets are included in the asset portfolio covered by the asset management system. This is both documented and communicated internally at regular intervals.

4.2.3 Leadership

Leadership and Commitment

In addition to having established a SAMP and an overarching management system to govern the organization's asset management activities, top management also supports asset management through continual promotion of cross-functional collaboration and by continually communicating the importance of having a whole-life approach to the management of assets. Cross-functional collaboration, through active use of multidisciplinary teams and open, cross-departmental communication and information transfer, is an area where significant resources are being placed. Use of multidisciplinary teams is viewed as a measure that allows for increased synergy within the organization, including asset management activities connected to both maintenance and operational tasks. Communication of the importance of having a whole-life approach to the management of assets is achieved through regular communication of the organization's asset management policy, its SAMP and the corresponding asset management objectives. The general level of top-down communication in the organization is very good. It is ensured through an alignment of goals and objectives across the entire organization. The goals and objectives set by top management are being reflected downwards in the organization, through middle-managers and down to operator level. A lot of time and resources are being spent on how plans and objectives are best communicated, as this is viewed as a continual improvement process. A specific example of a top-down communication channel is the organization's comprehensive intranet web page, where there are published regular blog posts written by members of top management. The posts are concerned with communication of plans, objectives and goals. Measures have also been taken to ensure that personnel onshore and offshore receive the exact same messages, to ensure an alignment of goals and objectives regardless of people's locations.

Policy

Top management of the organization has established a discrete asset management policy. The policy reads *"We want to be an asset-centric organization"*. The main message contained in this policy is that both the organization and its success criteria shall be built around its assets, by continually managing them in a manner that creates value to both the organization itself and its stakeholders.

Organizational Roles, Responsibilities and Authorities

Roles, responsibilities and authorities are defined and documented in an excellent manner. There is extensive use of job descriptions for positions at both onshore and offshore locations, where responsibilities and competence requirements are clearly presented. The importance of job descriptions is especially significant for personnel that are stationed offshore, made evident by the fact that such job descriptions are more detailed. To match the more detailed job descriptions that are being utilized for offshore positions, the organization also operates with a designated competence documentation system of offshore workers, where all personnel's competence, training and courses are documented.

4.2.4 Planning

Actions to Address Risks and Opportunities for the Asset Management System

The organization has established its own company-specific risk management approach, in the form of a framework that is aligned across all the organization's activities, including asset management and in relation to its assets. The framework includes clear guidelines of how a risk is defined and how risk should be dealt with. Risk is defined through the use of several relevant tools, including risk matrices. Risk with low criticality and probability is handled on operator level, through predefined procedures. As the criticality and probability of risks increases, the risk management process is moved upwards in the organization, reaching management levels and a designated risk management team. The risk management team performs extensive HAZOP studies at regular time intervals, and FMECA is regularly being utilized in situations involving maintenance operations. Through extensive use of risk assessments and risk management activities, the organization has built up a significant database of historical data, which is being used to plan preventive maintenance activities to occur at optimal intervals on known faults or weaknesses. Another key factor in the risk management procedures of the organization is that it makes a conscious choice of selecting the same suppliers and sub-suppliers over and over, which provide good knowledge and experience related to its own equipment and its failure modes. Additionally, there is also wide utilization of safe job analyses, as a risk mitigating tool in asset management activities.

Asset Management Objectives and Planning to Achieve Them

As part of the SAMP, the organization has defined several specific asset management objectives. There have been defined objectives related to output level, availability, reliability, health and safety, financial factors, environmental impact and maintenance (the ratio between corrective and preventive maintenance). The all-important alignment between the asset management objectives and organizational objectives is well solidified through the organization's SAMP and asset management policy, providing it with a firm alignment of goals and objectives. To achieve the asset management objectives, the organization has also defined corresponding asset management plans. The asset management plans have been developed as a direct response to the asset management objectives and include an integrated set of activities and information, including life cycle plans, maintenance strategies, modification strategies, risk management procedures and resource requirements.

4.2.5 Support

Resources
There are good existing routines of undergoing mapping processes of available resources against required resources before undertaking activities to the organization's assets. Resource mapping is done on many levels of the organization and in different settings. It is considered an especially important action in the processes of both creating and executing asset management plans. The organization's asset management plans contain detailed resource requirements, especially for financial and human resources. A mapping of required resources up against available resources is therefore viewed as a necessity in establishing functional and efficient asset management plans.

Competence
Personnel that are performing tasks that may affect the performance of the organization's assets, thus also affect the performance of its asset management system, are subjected to rigid competence requirements. This is especially true for personnel that are working at the organization's offshore locations. Operators and technicians have their own competence profiles, containing received training, courses and other relevant competence details. The competence profiles are documented and updated continually, as part of a competence documentation system. There is also extensive use of task descriptions, both onshore and offshore. Active use of task descriptions ensure that tasks are only performed by personnel with the required level of competence, thus supporting optimized performance of the organization's assets.

Awareness
Raising awareness regarding asset management and how each individual employee contributes to both enhanced asset performance and regular achievement of organizational objectives is an area that is gaining significant priority in the organization. There have been established good routines of communicating the asset management policy, the SAMP and the asset management objectives internally in the organization at regular intervals. At a more individual level, there are being held regular appraisal interviews, where personnel receive an individual development plan that is directly linked to the overall objectives of the organization, as well as its asset management objectives. The individual development plans are a direct result of goals and objectives set by top management being aligned downwards in the organization, through middle managers and down to operator level. The Operations Engineering Manager used the phrase *"…ensuring that everyone pulls in the same direction"* during the interview process, to describe the purpose of the development plans. The statement is very much in the spirit of the ISO 55000 suite.

Communication

Procedures related to both internal and external communications that are relevant to the organization's assets are clearly defined. The procedures are differing, depending on the content being communicated and the recipients. However, there have been defined clear routines on what to communicate, when to communicate it, to whom the communication is relevant, and the frequency of the communications. The Operations Engineering Manager also highlighted the use of a common terminology and common communication methods, which is important contributors towards reliable communication processes and breakdown of functional silos.

Information Requirements and Documented Information

The organization has defined specific information requirements related to its assets and their performance at a prominent level. Information requirements have been defined in relation to all the asset management objectives set by the organization, which includes asset performance, health and safety, environmental impact, financial information and maintenance information. The information is obtained and maintained by standardized procedures. There have also been defined procedures for how information shall be documented and updated. Collected asset information is documented and used for continual improvement on a regular basis. A specific example includes the collection and documentation of maintenance information, which is done using a CMMS. The CMMS stores relevant maintenance information and historical data, which are further used in continual improvement processes.

4.2.6 Operation

Operational Planning and Control

There have been implemented several supporting measures for both the implementation of activities contained in the organization's asset management plans and other activities performed on the organization's assets. The organization operates with a wide set of achievement criteria related to plans and activities being implemented. The outcome of plans or activities is continually being measured up against the predetermined achievement criteria, to ensure that the desired result has been achieved. If there is a gap between the intended results and the achieved result, this is logged and investigated. Relevant tools such as work orders are also being used extensively. Work orders must be signed and checked before an activity can be considered finalized.

Management of Change

Changes that may affect the organization's assets, thus also its ability to achieve asset management objectives, are countered through a company-specific management of change procedure. The procedure is developed by the organization itself and acts as a designated framework that dictates how the organization should act to deal with both planned and unplanned change. The management of change procedure covers a wide variety of changes, including organizational changes (changes involving personnel and their competence), strategic changes (changes to the organizational objectives, the SAMP, the asset management policy or asset management plans) and technological changes (changes related directly to assets and their performance). The management of change procedure includes a thorough risk assessment and risk management process, which must be completed before a change is implemented or dealt with otherwise.

Outsourcing

Outsourced activities are common for this organization. To have outsourced tasks continuously contributing towards optimized asset performance and regular achievement of organizational objectives is therefore an area that is highly prioritized. According to the Operations Engineering Manager is the final goal of the organization to achieve a "one team" approach in outsourced activities. A "one team" approach is a term used to describe an organizational state where all personnel, both internal and external, pulls in the same direction and towards the same objectives. The organization does not have a competence documentation system based on external personnel as it does with internal personnel. The competence of external personnel is ensured through a designated supply chain organization, which handles all external contacts and personnel. The supply chain organization operates with the same rigid competence requirements and certification requirements as the organization does with its internal personnel. This measure ensures that the performance of the external personnel meets the requirements of the organization and effectively contributes towards the achievement of its objectives.

4.2.7 Performance Evaluation

Monitoring, Measurement, Analysis and Evaluation

The organization has implemented good procedures for measuring the performance of its assets, as well as the performance of its asset management system. Measurement of asset performance is done continually, through a set of KPIs that has been developed as a direct result of the organization's asset management objectives. The KPIs are being measured on a continual basis and measured up against the pre-defined asset management objectives. The link between measured asset performance and the achievement of organizational objectives is once again solidified through the link between measured asset performance and asset management objectives. The asset management objectives are further linked to the organizational objectives, through the SAMP. The existing level of alignment ensures that measurements of asset performance and day-to-day activities act as direct indicators of how the organization is performing against its organizational objectives.

Internal Audit

Internal audits are considered common practice in the organization. There have been established designated audit teams that deal with audits of a larger scale. The main focus of such internal audits is mostly on barrier management and risk, but they also incorporate asset management activities and asset performance at regular intervals, with an enhanced focus on maintenance activities. Internal audits are also being done at smaller scales in the organization, where engineers and engineering teams perform audits on their own activities and the assets in which they work on. Every audit that is being performed in the organization, whether it is of a larger or smaller scale, is documented and made available for future reference, for example to be used in gap analyses and processes for continual improvement.

Management Review

Management reviews are, just like internal audits, considered common practice within the organization and they are being performed at regular intervals. Management reviews cover a wide area of practices, including the performance of the organization's assets and processes related to strategic planning. The Operations Engineering Manager gave an example of a recent management review, which led to top management wanting a higher output level of certain assets. As a result of this management review are both the corresponding asset management objectives and asset management plans facing certain alterations in near future, to incorporate the changes suggested by top management.

4.2.8 Improvement

Nonconformity and Corrective Plan
The organization has established designated procedures and tools to deal with nonconformities and incidents related to its assets. The procedures and tools vary, based on the type and severity of the nonconformity or incident in question. Root cause analyses are commonly used to get to the root cause of a nonconformity or incident, to completely mitigate the fault. There is generally a good culture of getting to the root of problems in the organization and eliminate factors that may harm or alter the achievement of its objectives. Root cause analyses are done by multidisciplinary expert teams that deal exclusively with quality management. It is also considered common practice to involve equipment suppliers in root cause analyses, to facilitate a learning process for both the organization itself and the supplier. All processes that are concerned with the identification and mitigation of nonconformities and incidents are subjected to a process of documentation.

Preventive Action
The organization's approach to identifying potential failures or performance degradation of assets must be classified as highly proactive. Vulnerability analyses are being performed at regular intervals, through a framework that has been established by the organization itself, built on its extensive experience and knowledge of the field. There has also been formed a multidisciplinary expert team that deals exclusively with vulnerabilities and asset degradation, to enable optimal asset performance at all times. The 10 most significant vulnerabilities in the organization's asset portfolio are provided extra focus and resources, being dealt with on top management level. Vulnerabilities are not limited to technical faults, but can also include organizational or strategic factors that may affect asset performance. The top 10 list of vulnerabilities is continually assessed and updated to include any possible changes.

Continual Improvement
The organization's focus on continual improvement is quite significant, both with regards to its assets and the achievement of organizational objectives. From an asset management perspective, there has been formed a multidisciplinary team that deals exclusively with continual improvement and performance enhancements. The team works with processes that embrace both technical aspects, organizational aspects and strategic aspects. The team's work is based on a designated set of KPIs that are purely concerned with continual improvement. A recent initiative that has been implemented in the organization is a stronger focus on LEAN and its associated methodologies for continual improvement, which is highlighted by Woodhouse (2010b) as a related excellent asset management practice. Large portions of the organization's staff, mainly management and leaders so far, have gone through courses and training in recent times, to learn to embrace the continual improvement thought process of LEAN. This initiative is expected to include a wider portion of the organization's personnel in near future.

4.3 Land-Based Manufacturing Industry

Overview of the Selected Organization

The organization representing the land-based manufacturing industry is an industry-leading actor within the manufacturing of agricultural machinery and equipment. The industry-leading position has been obtained by the organization's ability to remain futures-oriented, by continually developing new and innovative products. The organization is operating a large-scale manufacturing facility, consisting of a significant amount of machinery and production equipment, which leads to it having a wide asset portfolio.

Interviewee

The results presented throughout section 4.3 are based on the responses of the Technical Director within the selected organization, provided during the semi-structured interview session.

4.3.1 Overview of Asset Management Practices

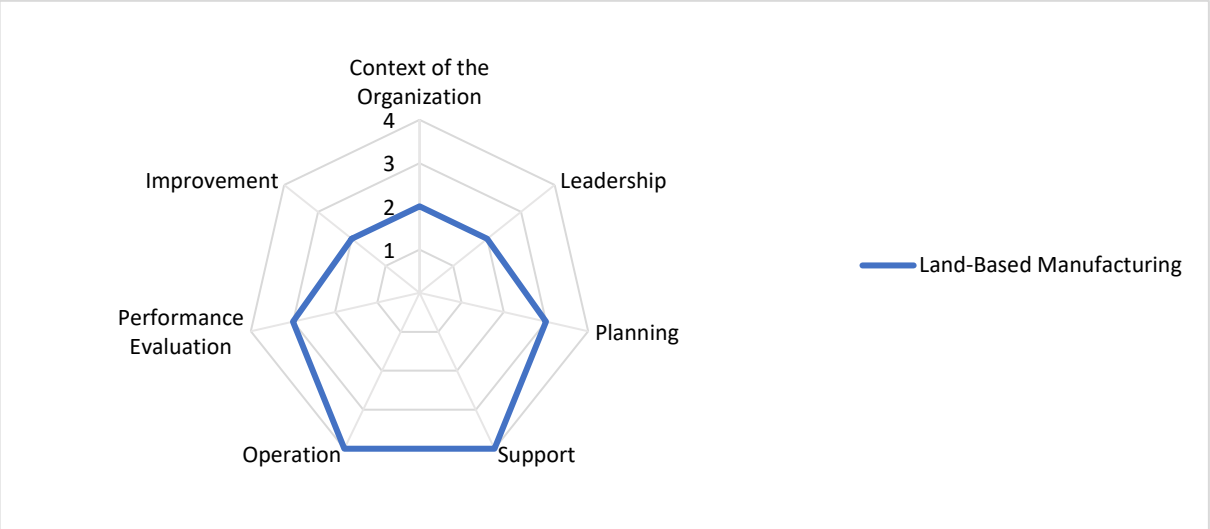

Figure 16 – Asset management practices of the land-based manufacturing organization

	Context of the Organization	Leadership	Planning	Support	Operation	Performance Evaluation	Improvement
Clause 1	4	2	4	4	4	3	2
Clause 2	4	1	3	4	4	4	2
Clause 3	2	4		4	4	4	4
Clause 4	1			4			
Clause 5				4			
Clause 6				4			
Avg. Score	2.75	2.33	3.5	4	4	3.67	2.67
Rounded Score	**2**	**2**	**3**	**4**	**4**	**3**	**2**

Table 2 – Scorecard of the land-based manufacturing organization

4.3.2 Context of the Organization

Understanding the Organization and its Context
The Technical Director was able to provide good insights into the organization's main objectives, which are gathered in an organizational strategic plan. The plan is reviewed and updated at regular intervals or as the organization sees fit, with the last review having occurred as recently as last year. The organizational plan is regularly communicated to the personnel of the organization, providing easy access to the organization's objectives and its context. The organization's existing knowledge and procedures related to its organizational objectives form a solid foundation for the setting of asset management objectives.

Understanding the Needs and Expectations of Stakeholders
The needs and expectations of both internal and external stakeholders are well-incorporated into decision-making processes and strategic planning processes. The Technical Director presented measures for including the needs and expectations of internal personnel, shareholders, owners, regulatory authorities and customers. Specific examples include union representatives that represent internal personnel in all important decision-making processes and strategic planning processes that affect them directly, as well as regular customer feedback through field days, product presentations and testing. Feedback received through all stakeholders, as well as their needs and expectations, are documented and used in both the setting of new organizational objectives and alteration of existing ones.

Asset Management System and Determining the Scope of the Asset Management System
A small grouping within the technical engineering department, including the Technical Director, are familiar with the discipline of asset management and aware of the ISO 55000 suite. However, there has not been undergone an implementation process of the ISO 55000 suite in the organization and the specific term 'asset management' is not being utilized on a widespread scale within the organization's strategic planning processes. Consequently, there has not been developed an overarching management system to control the organization's asset management activities. Neither has there been developed a SAMP, which translates organizational objectives into specific asset management objectives. The Technical Director pointed out that the organization is in fact certified against the ISO 9001 standard, which provides guidelines towards the implementation of a quality management system. The existing ISO 9001 certification would facilitate a simplified implementation process of the asset management practices outlined in the ISO 55000 suite, by adopting an integrated management systems approach as described in section 3.2. Still, there have not been taken any efforts of doing this as of today.

4.3.3 Leadership

Leadership and Commitment

Top management and leaders within the organization actively promote the use of cross-functional collaboration, mainly through the use of multidisciplinary teams. A practical example that was outlined during the interview session was the forming of a multidisciplinary team consisting of members of production, operations and development, to ensure that the manufacturing process of a product is aligned all the way from the early design phase through to the production phase. Furthermore, the Technical Director admitted that the organization has some challenges when it comes to top management and leaders promoting a whole-life approach to the management of the organization's assets. There seems to be large degrees of short-termism when it comes to asset operations, as corrective maintenance is quite widespread within the organization. Asset management activities related to both preventive operations and maintenance are regularly being subjected to resource cuts, as the priority of top management remains on short-term financial performance, rather than applying a whole-life perspective to the value created by the organization's assets. There is also an existing culture of "fixing" the same fault or incident multiple times, instead of top management providing the attention required to completely mitigate the fault and gain extended future value. From an asset management perspective, this is no preferable solution. It is also the responsibility of top management to develop a SAMP, which has not been done. The overall quality of top-down communication from top management and leaders, however, is established on a prominent level. Extensive use of bulletin boards and e-mail correspondence across the organization ensure daily communications and a close relation to top management. Leader forums are being arranged at monthly intervals, where team leaders meet up with top management and discuss relevant topics, including organizational objectives and asset performance. The content of such leader forums is consequently being passed on to all personnel of the organization.

Policy

There has not been established an asset management policy in the organization. This can be viewed as a direct result of the organization's lack of an overarching management system to control its asset management activities, as well as not having implemented the asset management practices of the ISO 55000 suite.

Organizational Roles, Responsibilities and Authorities

Organizational roles, responsibilities and authorities have been clearly defined within the organization. Job descriptions are in regular use, where responsibilities and competence requirements is presented in detail. There has also been established competence profiles for all personnel, where each individual's competence, courses and training is included. The competence profiles also include the responsibilities and authorities included in each organizational role. Leader roles are subjected to further control, through the use of authentication matrices, which are concerned with responsibilities and authorities in high-level tasks involving the organization's assets.

4.3.4 Planning

Actions to Address Risks and Opportunities for the Asset Management System
The organization has established a company-specific risk management approach, in the form of a framework that is aligned across the organization and all its activities. The framework includes standardized procedures of how a risk is defined and how the risk should be dealt with. The framework is a three-level framework, where the lower level tasks are performed by operators. Operators can make basic risk assessments and implement mitigating measures. Risks of a more severe nature are required to be taken up a level. This is done by an operator documenting the risk and leaving it to his or her respective team leader, who solves the situation as they see fit. Risks of critical severity is moved up another level in the organization, to top management. Critical risk situations will normally involve third party specialists being called in by top management. Such a procedure is likely to involve a complete risk management procedure, involving relevant high-level risk management tools. All three steps of the risk management framework involve thorough documentation of the procedures.

Asset Management Objectives and Planning to Achieve Them
Asset management objectives have to some extent been established, as the organization has established several objectives that are concerned with both the performance of its assets and associated activities. However, these objectives are not derived as part of a SAMP or linked to an asset management policy, which weakens the alignment between the organization's asset management activities and its organizational objectives. Still, there have been established a variety of relevant objectives that are concerned with factors such as output level, availability, reliability and maintenance activities. There has also been established objectives related to measurements of OEE (Overall Equipment Effectiveness), which is a measurement of the percentage of productive manufacturing time. To achieve the asset management objectives, the organization have defined corresponding action plans. The action plans are documented as part of a wider success plan and is concerned with factors such as risk management, maintenance strategies and resource allocation.

4.3.5 Support

Resources
Mapping of available resources against required resources is a common activity in the organization and it is normally being performed in relation to both the establishment of asset management objectives and when performing activities included in the corresponding actions plans. The organization has created a designated resource management tool that is commonly used to ensure optimal resource allocation and awareness regarding the ratio between required resources and available resources before an asset-related activity is initiated.

Competence
The organization operates with clearly defined competence requirements across all its activities. The human resources department has put a lot of work into documenting the competence of all personnel in a competence documentation system. The competence documentation system includes abilities, training, competence and courses. This has resulted in a wide competence database that is actively in use, especially when activities are to be performed on critical assets. The competence profiles included in the competence documentation system are subjected to regular updates, to include possible changes to employee profiles or general competence requirements. To further ensure the competence of personnel performing activities that may affect asset performance, such activities are always accompanied with detailed task descriptions and associated competence requirements.

Awareness
Awareness regarding each employee's personal contributions towards asset performance and organizational objectives is raised through numerous measures within the organization. An example is the extensive use of whiteboards in all departments, where each employee is regularly being presented with personal key figures related to the previously discussed asset management objectives and a thorough walkthrough of how the organization is currently performing against its organizational objectives. These whiteboard sessions are covered during meetings performed at regular time intervals. There are also regular communications related to organizational objectives, which is mainly being done through a document named 'Success 2017'. The document is actively being used as a tool for awareness creation and top management has made it a priority to make regular references to the document and its included objectives in internal communication processes.

Communication

Procedures of both internal and external communications related to the organization's assets and their performance is at a functional level. The intervals in which the organization communicates information to external stakeholders, such as shareholders, are clearly defined. As are the procedures of internal communications. There is generally a good understanding of what is being communicated, who are the relevant recipients and how the content of the communications should be used to optimize both asset performance and the achievement of organizational objectives.

Information Requirements and Documented Information

There has been defined a good set of specific information requirements related to the organization's assets and their performance. The information requirements are established as a direct result of the organization's asset management objectives. The objectives effectively dictate which information are of relevance to the organization. Information is gathered and documented using standardized procedures. These procedures involve the utilization of an ANDON system, which is a LEAN-based monitoring system that monitors the manufacturing process. The system both tracks and documents asset performance at a continual basis, measuring the actual performance up against the corresponding asset management objectives that has been established. The ANDON system is further linked up to SAP, where all information is documented and stored. The documented information is frequently used in improvement processes and as a tool in strategic planning processes.

4.3.6 Operation

Operational Planning and Control
Implementation of planned activities to assets is supported by several useful tools and functions. The aforementioned competence requirements and resource management tool, combined with clear allocation of roles and responsibilities ensure reliable implementation processes of planned activities. There is also extensive use of work orders that must be signed prior to completion of an activity. Once an asset-related activity has been performed, the organization measures the actual result derived by the activity up against the desired or planned result, to gain an overview of the quality of the implementation process.

Management of Change
The organization shows good awareness regarding the potential effects that change may pose to their assets and their performance. There have been taken several measures, as part of a management of change procedure, to make sure that change is countered in a manner that is compliant with both asset performance and achievement of organizational objectives. As an example, are changes that may affect organizational roles countered through specialized cooperation with staffing agencies, to prevent loss of competence and knowledge. Another example that was brought up during the interview session is change related to the introduction of new technological solutions. The organization is proactive in its approach to new technology and solutions, and features regularly at industry forums and research hubs to keep up with the latest technology, thus being quite aware of how implementation of new technological solutions might alter the performance of their assets and other organizational processes.

Outsourcing
Outsourcing of tasks and functions is common in this organization. To ensure that outsourced tasks keep contributing to the organization's objectives and satisfactory asset performance, several measures have been taken. All external personnel must comply to the organization's safety procedures. To ensure that this is done are the organization's safety procedures regularly being communicated to the external workforce in the form of documentation that must be read and signed before it is returned. Work orders are also in use for external personnel and must be signed before an activity is considered done. In addition to work orders, external personnel are also required to sign extensive service reports. The extensiveness of these measures clearly illustrates how the organization is aware of the potential effects an external workforce may have on its own objectives and the performance of its assets.

4.3.7 Performance Evaluation

Monitoring, Measurement, Analysis and Evaluation

The organization has implemented good practices for measuring asset performance. Asset performance is measured and monitored on a continual basis, by the previously discussed ANDON system. The system is measuring a set of pre-defined KPIs that are derived from asset management objectives concerned with asset performance, such as output level, availability and reliability. The system is directly linked to SAP, which facilitates a reliable gathering and analysis process of the measured data. The link between measured asset performance and organizational objectives is defined through the aforementioned asset management objectives. However, as previously discussed in the section 'Planning' (section 4.3.4), the asset management objectives of the organization have not been established as part of a SAMP. The lack of a SAMP to further strengthen the link between measured asset performance and organizational objectives must be considered a weakness compared to the practices outlined in the ISO 55000 suite.

Internal Audit

As a result of having been certified against the ISO 9001 standard, it is considered common practice to conduct internal audits in the organization. There has been formed a designated control team that does regular quality checks of processes and procedures within the organization's boundaries. As a result of these audits, the organization regularly checks the performance of their assets, the quality of asset management activities and how well the organization is performing against its organizational objectives and main goals.

Management Review

Management reviews are also considered common practice in the organization, as a result of the certification against ISO 9001. Previous external audits of the organization's ISO 9001 practices revealed that management reviews were a point of weakness, not being performed as well as they should have been. The organization has therefore taken measures to improve the quality of management reviews in recent years, making it a specific focus area. Today, top management performs comprehensive reviews of organizational processes at regular intervals, including the quality of asset management activities and the performance of assets. The occurrence of management reviews is determined by an annual cycle. There are also being held regular meetings between top management and the control team performing the internal audits, to create increased synergy in the organization's review processes.

4.3.8 Improvement

Nonconformity and Corrective Plan

Dealing with nonconformities and incidents is an area where there is significant improvement potential for the organization. This was clearly underlined by the Technical Director during the interview session. There has been implemented a nonconformity system that alerts operators of nonconformities, which is a good measure, but the way these are being mitigated is not ideal. There are certain tendencies of fixing the same faults multiple times, by performing the same, simple corrective maintenance operations, instead of seeking the root cause. The Technical Director used the term "first aid" maintenance, which is a fitting term. The organization is aware of the improvement potential in its procedures of handling nonconformities and incidents, as there is an increasing focus on improving the organization's routines on conducting root cause analyses, instead of undertaking reactive actions, time and time again. However, it is a slow process and there is a major improvement potential in that regard.

Preventive Action

The organization's approach to identifying potential failures or degradation of asset performance is also an area where there is significant improvement potential. Looking back at its routines of dealing with nonconformities and incidents, it becomes apparent that there is some work to be done before its approach of identifying potential failures or asset degradation can be classified as proactive, at least from the author's perspective. There is limited use of condition monitoring equipment, except for basic visual inspections. Preventive maintenance is being utilized in some situations, but corrective, reactive maintenance is still the dominating maintenance approach. There is a slightly different approach being taken on critical assets, as these are handed some extra attention and are subjected to a different maintenance regime. The organization has defined lists containing the top 10 and top 40 most critical assets, where especially the top 10 list is subjected to a more proactive approach, in the form of increased preventive maintenance and inspections.

Continual Improvement

Continual improvement is an area that is gaining significant attention within the organization. It is regularly attending forums and research hubs, which must be viewed as an effort to promote and achieve continual improvement of both organizational processes and asset management activities. The organization has also undertaken LEAN manufacturing principles and ran a total of 200 employees through courses which shall help create a mindset and culture for continual improvement of organizational processes. This measure may also have major implications towards its asset management activities, as LEAN is highlighted by Woodhouse (2010b) as a related excellent asset management practice. Looking back at the answers provided by the Technical Director to each of the requirements and clauses, it also becomes evident that he is highly aware of the areas where the organization is not currently performing as well as it should, which indicates a strong awareness regarding improvement areas. Areas such as root cause analyses and preventive actions were highlighted as weak areas, but it was also pointed out that the organization are aware of them and intend to improve. This is perhaps the strongest indicator of the organization's will to seek continual improvement.

4.4 Land-Based Process Industry

Overview of the Selected Organization

The organization representing the land-based process industry is an industry-leading actor within the process of refining and producing nickel and other metals. Its highly-advanced process technology has made the organization's plant one of the most effective and technologically advanced refineries not only in Norway, but the world. The plant contains a significant amount of production and processing equipment, leading the organization to operate with a wide portfolio of assets.

Interviewees

The results presented throughout section 4.4 are based on the responses of the HSEQ Manager (Health, Safety, Environment and Quality), the Director of Operational Excellence and the Preventive Maintenance Group Leader within the selected organization, provided during the semi-structured interview session. The reader should note that the interview was done in one session, despite it being conducted with more than one interviewee.

4.4.1 Overview of Asset Management Practices

Figure 17 – Asset management practices of the land-based process organization

	Context of the Organization	Leadership	Planning	Support	Operation	Performance Evaluation	Improvement
Clause 1	4	4	4	4	4	4	4
Clause 2	4	4	4	2	4	4	4
Clause 3	4	4		4	4	4	4
Clause 4	4			4			
Clause 5				4			
Clause 6				4			
Avg. Score	4	4	4	3.67	4	4	4
Rounded Score	**4**	**4**	**4**	**3**	**4**	**4**	**4**

Table 3 – Scorecard of the land-based process organization

4.4.2 Context of the Organization

Understanding the Organization and its Context
The interview group presented good insights into the organization's strategic plan, where the organizational objectives are clearly documented. The organizational plan is regularly used in communication processes and made easily available to relevant personnel. The plan is reviewed and altered at regular intervals or whenever it is required. The content and detail of the plan illustrates a strong awareness of both internal and external factors that may affect the achievement of organizational objectives, as well as the organization's context. The current familiarity with organizational objectives forms a solid foundation for developing asset management objectives.

Understanding the Needs and Expectations of Stakeholders
The awareness regarding stakeholders' needs and expectations are at a prominent level. The organization operates with a document containing every stakeholder that is of relevance to the organization, as well as their expectations and requirements. Each stakeholder or stakeholder group is assigned criticalities, clearly elaborating just why and how each stakeholder is important to the organization and its processes. The stakeholder document is actively in use, whenever important strategic planning processes or decision-making processes are initiated. Some of the stakeholders that are included in the document include the organization's own employees, owners, shareholders, the local environment and relevant government agencies.

Asset Management System and Determining the Scope of the Asset Management System
Nobody in the interview group were familiar with the ISO 55000 suite from before, neither has the organization been certified against the standard. Despite this, is the discipline of asset management being utilized on a widespread scale. The organization used to work with a company-specific methodology called 'asset entitlement' in that regard, which has since been developed into a designated business system. Through the self-developed business system there has in fact been implemented an overarching management system to control the organization's asset management activities. The self-developed business system is built on the foundations of the management system introduced by ISO 9001, with specific asset management tasks and responsibilities having been defined and integrated into existing functions, just as previously described in the presentation of an integrated management systems approach in section 3.2. As a part of the self-developed business system, there has also been established and documented a SAMP, which translates organizational objectives into specific asset management objectives, just like the practices outlined in the ISO 55000 suite. Top management shows high awareness of what they want to achieve from the organization's assets and how the value they create are directly related to the achievement of organizational objectives. As a part of the SAMP, the scope of the organization's asset management activities has been clearly defined and documented. It has also been documented which assets are included in the asset portfolio covered by the organization's self-developed business system.

4.4.3 Leadership

Leadership and Commitment

The interview group was adamant that their organization would not have achieved the success it has, or have the market position it currently does, without the extensive use of cross-functional collaboration. Both multidisciplinary teams and open communication across organizational departments are viewed as key components in the organization's success and are therefore measures that are being actively promoted by top management. The use of multidisciplinary teams was especially highlighted during the interview, as a measure that is considered an optimal solution whenever asset management activities are either planned or performed. A specific example that was mentioned, which includes use of multidisciplinary teams is the process of conducting root cause analyses. Having a whole-life approach to the management of the organization's assets is also a priority of top management, as there is large support towards utilization of life cycle activities. The value perception of top management seems to be of the holistic nature that is required to implement and succeed with asset management. The organization's SAMP, asset management policy and asset management objectives are featuring regularly in communications from top management. Such top-down communications are an area that highly prioritized, with several measures having been taken to ensure their quality. There is a prominent focus on face-to-face meetings, with leaders and middle-managers transferring information from top management to operators and technicians.

Policy

Top management has chosen to establish an overarching one-page organizational policy embracing several subjects and areas. This measure has been taken to avoid the potential confusion of having a variety of differentiating policies for separate subjects and areas, and because it makes it easier to communicate the policy to both internal and external stakeholders. The overarching one-page organizational policy outlines how the organization shall act to remain profitable and sustainable within "People, Planet and Profit", which is another term for Elkington's TBL (as presented in section 2.4.6). Included in the policy is also how the organization shall manage their assets to obtain as much value from them as possible, while balancing both costs, risks and benefits. ISO 55002 (2014) specifies that it is not a necessity to have a discrete asset management policy, it can also be contained in other high-level policies or documents, as it currently is in this specific organization.

Organizational Roles, Responsibilities and Authorities

Roles, responsibilities and authorities within the organization are clearly communicated and documented. There have been established good routines when it comes to the use of job descriptions, where details of roles, responsibilities authorities and required competence are outlined. There have also been clearly defined which members of top management are responsible for the setting of both asset management objectives and organizational objectives, as well as updating existing strategic planning documents.

4.4.4 Planning

Actions to Address Risks and Opportunities for the Asset Management System

The organization's risk management approach is determined by a concern-specific risk management system. The concern-specific risk management system is built on the foundations of ISO 31000, the ISO standard for risk management. The organization has therefore not been certified against ISO 31000, but all of its risk management procedures and activities are still effectively guided and regulated by the practices outlined in ISO 31000. The risk management approach outlined in the concern-specific risk management system is utilized across all the organization's activities, also with regards to the organization's assets and asset management activities. As previously mentioned in both section 2.4.6 and section 3.2.3, the ISO 55000 suite does not have its own detailed guidelines on risk management, but refers to ISO 31000 as a guiding document for risk management. Consequently, the risk management practices of the organization must be viewed as highly compliant with the demands of the ISO 55000 suite.

Asset Management Objectives and Planning to Achieve Them

Asset management objectives have been established and documented as part of the organization's SAMP. There has been put considerable time and resources into creating asset management objectives that are directly aligned to organizational objectives of the organization, as well as being compliant to stakeholder requirements. Specific asset management objectives that were mentioned embraced availability, reliability, output level, OEE, financial factors, risk management and maintenance management. To achieve the pre-defined asset management objectives, corresponding asset management plans have also been defined. The asset management plans of the organization are defined as a result of close cooperation between top management and middle-managers that represent their own respective departments, with the personnel of each department being responsible for the execution of the asset management plans. The content and detail of asset management plans vary, depending on the criticality and type of asset. However, a general approach to an asset management plan in the organization would consist of an integrated set of activities and information, including maintenance strategies, life cycle activities, risk management procedures and basic resource requirements.

4.4.5 Support

Resources
There have been established good routines for undergoing mapping processes concerned with available resources against required resources before undertaking activities in the organization, including activities that are part of the organization's asset management plans. There have been established procedures for mapping required competence, financial resources, human resources and equipment before activities are undertaken. During asset management activities of a larger scale it is considered common practice to hold extensive meetings where the scope and objectives of the activity is elaborated, to ensure that all parties involved are familiarized with the procedures, resources and quality demands related to the activity.

Competence
The competence of personnel within the organization is ensured through extensive use of task descriptions. Task descriptions is mandatory practice in every task or activity that has the potential of altering the performance of the organization's assets or the achievement of the organization's objectives. Despite the good practice of utilizing task descriptions on a widespread scale, there are also improvements to be made in this area. The organization is currently operating without a competence documentation system that includes documentation of the competence, training and courses of its personnel. This weakness is known to the organization and it is currently being conducted a significant mapping process of the competence and knowledge of the organization's personnel to facilitate an implementation of such a competence documentation system. The implementation of the competence documentation system is expected to take some time, so for now it must be considered a minor weakness towards the practices of the ISO 55000 suite.

Awareness
Awareness regarding personal contributions towards asset performance and the achievement of organizational objectives is actively being raised through several measures and procedures. First and foremost, it is raised through the organization's self-developed business system. The essence of the business system, which outlines the SAMP, asset management objectives and organizational objectives is gathered in a promotional document, which is printed and made easily available to the personnel of the organization. The asset management policy, which is included as a part of the overarching organizational policy, is also actively being used in communication processes. The general focus on communicating the organization's core values must be considered as quite significant. Other, more practical measures include the arrangement of regular meetings concerned with safety and efficiency, where both organizational objectives, asset management objectives and asset performance are regular topics. Such meetings are being held every morning. A more extensive meeting is held once a week, where objectives are being outlined and discussed on a more detailed level.

Communication

Procedures that are concerned with both internal and external communications relevant for assets and their performance are clearly defined. The procedures are differing, depending on the content being communicated and the recipients. However, there have been defined good routines on what to communicate, when to communicate it, to whom the communication is relevant, and the frequency of the communications. Internal communications concerning assets and asset management are generally being performed using SAP, where everything is documented and communicated to the right recipients. External communications are being done on a more aggregated level. An example is communication to the organization's owners, which are being done on a weekly basis.

Information Requirements and Documented Information

Information requirements related to the organization's assets have been established at a satisfactory level. There have been defined information requirements related to all the pre-defined asset management objectives, such as asset performance (output level, reliability and availability), as well as financial information and maintenance information. The methods of obtaining, maintaining and documenting information have also been established. Information is collected and documented using SAP, where all information is updated continually and actively being utilized in continual improvement processes.

4.4.6 Operation

Operational Planning and Control

The organization has implemented good measures for supporting the implementation of planned activities to their assets, to ensure that the results of the activities occurs as planned. These measures include active utilization of comprehensive activity-related check lists, as well as detailed work orders. There is significant focus on activities being performed up to the ambitious standards set by top management. There are also being conducted regular revisions of activities to ensure that they are being performed as well as they should. This also includes asset management activities.

Management of Change

The organization has implemented its own management of change procedure. The procedure is initiated whenever a change, planned or unplanned, that may affect the organization and its processes occurs. The procedure is the same, regardless of the type of change or placement within the organization. Thus, the procedure also includes the organization's assets, as well as the self-developed business system controlling its asset management activities, the SAMP and its corresponding asset management objectives. The procedure involves forming of multidisciplinary investigation teams that shall determine and document which possible effects a change might bring to the organization and its processes. The procedure involves detailed risk assessments and systematic check lists that investigate a wide range of possible effects that may have been initiated as a result of the change.

Outsourcing

The organization has a policy of insourcing as much work as possible, including asset management activities. This is a conscious choice, as the organization prefers to control its own processes as much as possible and build a strong, internal core competence. Because of this, there are few tasks that are being outsourced. The external personnel that perform the few tasks that are being outsourced are subjected to several security measures, to ensure that tasks are being performed in a way that supports continual achievement of the organization's objectives and stable performance levels. Regular safety days are being arranged, where external personnel are introduced to important routines and procedures that should be followed. These safety days also include a thorough presentation of the organization's expectations when it comes to its assets, sustainable performance and organizational objectives. The external personnel are introduced to the organization's business system and receives a clear presentation of the organization's core values and goals.

4.4.7 Performance Evaluation

Monitoring, Measurement, Analysis and Evaluation

The performance of the organization's assets is being monitored and measured on a continual basis. The monitoring and measurement of performance is directly related to a comprehensive set of KPIs that are established as a result of the pre-defined asset management objectives. Measurements and monitoring is done using SAP, where performance data is documented. Another software solution that is utilized is ABB 800xa, which also contributes to monitoring, storing and documentation of performance trends. This allows the organization to go through performance trends that have been collected during an extended period of time, which facilitates a thorough analysis process of the measured performance data. The link between measured asset performance and organizational objectives is clearly established through an alignment of asset management objectives and organizational objectives through the forming of the organization's SAMP.

Internal Audit

Internal audits are considered common practice in the organization. The internal audits were originally implemented as a requirement found in the ISO 9001 standard, but the scope of the audits has since been expanded upon to involve all the processes included in the self-developed business system of the organization. This has led to an extensive audit program, where both asset performance and asset management is well-incorporated. The internal audits cover a wide variety of areas, including defined objectives, strategic plans and organizational processes. An example that relates to asset management include audits of maintenance strategies and programs, which occurs on a semi-annual basis.

Management Review

The management reviews follow the same structure as the internal audits that are described above, making both asset management and asset performance parts of management reviews. A typical management review process would consist of management going through annual reports of maintenance and operations information, asset performance against asset management objectives (including availability, reliability and output level), high-level strategic plans and financial information related to the organization's assets.

4.4.8 Improvement

Nonconformity and Corrective Plan

Nonconformities and incidents in the organization's assets are given significant attention and there are provided a lot of resources towards resolving issues related to both. There has been formed a designated group that works exclusively with preventive maintenance. The group's focus is especially directed towards contributing in root cause analyses and creating a systematic approach for doing these, as well as working towards a general reduction of the amount of corrective maintenance that occurs within the organization. All the processes conducted by the preventive maintenance group are thoroughly documented. Another measure that has been taken to deal with nonconformities and incidents is the implementation of an online nonconformity registration system, as part of the organization's intranet web page. The system is open for all employees and allows for a detailed registration of an incident, a nonconformity or a fault that might lead to a larger problem sometime in the future. The introduction of this system has led to a major improvement in the detection of nonconformities and incidents, regularly preventing them from developing to larger and more serious faults.

Preventive Action

The organization's approach to identifying potential failures or asset degradation must be classified as highly proactive. There is extensive use of condition monitoring techniques, especially on critical equipment, where vibration analysis is widespread. There has also been established a good mixture of condition-based maintenance activities and calendar-based maintenance activities, all of which are planned by the preventive maintenance group. A final measure that has been taken as a proactive approach is the forming of multidisciplinary teams that are concerned purely with asset performance, such as a critical process team that works continually towards improved process flow and process efficiency.

Continual Improvement

Continual improvement is listed as a key success factor in the organization's strategic plan and it is also included as a part of the overarching one-page organizational policy. There is a widespread focus on continual improvement, both with regards to assets and their performance, as well as other organizational processes that contribute towards the achievement of organizational objectives. Much like the online nonconformity system, has there also been developed a registration system for logging improvements within the organization. There are monthly awards given to personnel that contributes towards the improvements that are of the largest importance to the organization and its success, with regards to factors such as increased asset performance, increased financial performance or increased safety, to name a few. The organization is also very proactive in its learning approach and are regularly attending forums and hubs. Lastly, the organization's efforts within LEAN manufacturing and methodology is also widely regarded as excellent.

Chapter 5 – Performance Gaps and Improvement Areas

5.1 Overview

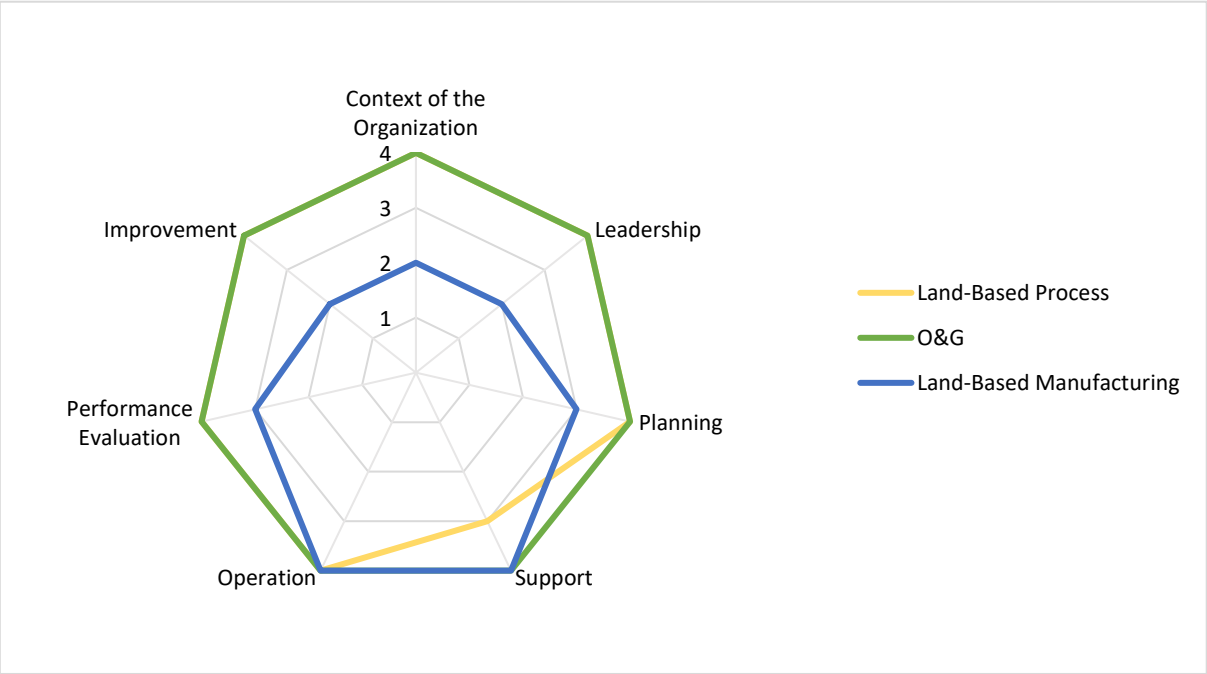

Figure 18 – Comparison of the industrial organizations' asset management practices

Note: For the remainder of the thesis, the individual industrial organizations will simply go by 'the O&G organization', 'the land-based manufacturing organization' and 'the land-based process organization' whenever specifically referred to in text. This approach has been taken due to confidentiality reasons, as previously outlined in section 4.1.

Figure 18 gathers the radar charts containing the asset management practices of the three industrial organizations included in the analysis in Chapter 4, namely Figure 15, Figure 16 and Figure 17. By studying Figure 18, it quickly becomes evident that there exist several performance gaps in the asset management practices of the individual industrial organizations. It is especially evident that there exist clear performance gaps in the asset management practices of the land-based manufacturing organization when compared to the asset management practices of both the O&G organization and the land-based process organization. The reader should note that the similar performance level in the asset management practices of the land-based process organization and the O&G organization causes the yellow line that represents the asset management practices of the land-based process organization to remain hidden in large parts of Figure 18. In total, there are existing performance gaps within every requirement of ISO 55001 (2014) but 'Operation', where all three industrial organizations presented asset management practices that could be regarded as being compliant with the included clauses. All the existing performance gaps that are illustrated in Figure 18 and their specific causes will be outlined in further detail in section 5.2, by going through them requirement for requirement.

5.2 Performance Gaps

Context of the Organization

The existing performance gap within the requirement 'Context of the Organization' is effectively caused by the land-based manufacturing organization's lack of a SAMP and an overarching management system to control its asset management activities. It is noted in ISO 55001 (2014) that it is the responsibility of an organization's top management to establish, or delegate the task of establishing a SAMP and an overarching management system to control its asset management activities. Both the O&G organization and the land-based process organization have established a SAMP and both are operating according to an overarching management system to control their asset management activities. The importance of a SAMP has already been clearly elaborated in section 2.4.1, while the benefits of establishing an overarching management system to control an organization's asset management activities are noted in both section 3.1 and in further detail in section 3.3. The land-based manufacturing organization's lack of both are the sole reason behind the performance gap within the requirement 'Context of the Organization'.

Leadership

The existing performance gap within the requirement 'Leadership' is essentially caused by two main factors in the asset management practices of the land-based manufacturing organization, or rather the lack of the two factors. The factors in question are the lack of an asset management policy and the organization's top management's failure to promote and communicate the importance of having a whole-life approach to the management of the organization's assets. Whereas the top management of both the O&G organization and the land-based process organization have defined specific asset management policies to control their organizations' asset management activities and are actively promoting and communicating the importance of having a whole-life approach to the management of their organizations' assets, this is severely lacking within the land-based manufacturing organization. The Technical Director of the land-based manufacturing organization openly admitted that the general attitude of the organization's top management towards promoting a whole-life approach to the management of the organization's assets and communicating such an approach downwards in the organization is not at the level it should be. There are clear indications of short-termism in the way that the land-based manufacturing organization's top management interpret the value created by the organization's assets, as their main focus remains on short-term financial gain. There seems to be a lack of holistic thinking with regards to value creation, which is clearly affecting the organization's asset management practices. Also, as previously mentioned, there has not been developed an asset management policy within the land-based manufacturing organization, which according to ISO 55001 (2014), is the responsibility of its top management. The fact that there has not been developed an asset management policy in the land-based manufacturing organization is directly affecting its top management's ability to promote asset management, as an asset management policy is a useful tool in communication processes. Both the O&G organization and the land-based process organization are actively utilizing their asset management policies in communication processes.

Planning

The existing performance gap within the requirement 'Planning' is more of a deviation when compared to the existing gaps within 'Context of the Organization and 'Leadership'. All the industrial organizations perform very well within this requirement, presenting good risk management procedures and having established both asset management objectives and asset management plans, which are what the included clauses of 'Planning' encompass. However, the land-based manufacturing organization's lack of a SAMP causes a performance gap towards the asset management practices of the O&G organization and the land-based process organization. Whereas the O&G organization and the land-based process organization achieve a better alignment from day-to-day activities contained within their asset management plans to their organizational objectives, the land-based manufacturing organization lacks the SAMP in their alignment chain. This is illustrated in Figure 5 and also by the asset management fundamental of alignment, as included in section 2.3.

Support

The existing performance gap within the 'Support' requirement is interesting, as it is the only requirement where the land-based manufacturing organization performs better than either of the other two industrial organizations. As seen in Figure 18, the land-based process organization performs weaker than both the O&G organization and the land-based manufacturing organization within this specific requirement. The performance gap is caused by the lack of a functioning competence documentation system or competence database within the land-based process organization. Whereas both the O&G organization and the land-based manufacturing organization have established specific competence documentation systems that allow them to determine and document competence of personnel that performs tasks that may alter the performance of their assets or the achievement of asset management objectives, this is not yet in place at the land-based process organization. The importance of competence management in relation to asset management is made very clear by the inclusion of competence management as a designated asset management subject, as included in section 2.4.5. As a final remark, it should be noted that the lack of a competence documentation system has in fact been acknowledged by the land-based process organization and there have been established plans to implement a solution in the future. This is further outlined in the specific analysis of the land-based process organization's asset management practices in section 4.4.5.

Performance Evaluation

The reason for the existing performance gap within the requirement 'Performance Evaluation' is highly interdependent with the reason for the existing performance gap within the requirement 'Planning'. As evident in Figure 18, the land-based manufacturing organization is lagging slightly behind the asset management practices of both the O&G organization and the land-based process organization within this requirement. The performance gap is once again caused by the land-based manufacturing organization's lack of a SAMP. When measuring the performance of assets up against a set of asset management objectives, they should be formed as part of the SAMP to ensure the aforementioned level of alignment between performance measurement and organizational objectives. This is in place at both the O&G organization and the land-based process organization, but not at the land-based manufacturing organization.

Improvement

Lastly, the existing performance gap within the requirement 'Improvement' can be attributed to the short-termism of the land-based manufacturing organization's top management. Whereas both the O&G organization and the land-based process organization are highly proactive in their search for root causes and are being preventive in the process of dealing with nonconformities and incidents in their assets, this is not the case for the land-based manufacturing organization. As pointed out by its Technical Director, there is a widespread acceptance within the organization of fixing the same fault or nonconformity multiple times in succession. The widespread acceptance of performing "first aid" maintenance within the land-based manufacturing organization is most likely caused by a force of habit, which is an evil cycle with regards to asset management practices. Its sub-optimal practices of dealing with nonconformities and incidents, and the lack of preventive actions to restore or withhold the performance of its assets are essentially what causes the performance gap within this requirement.

5.3 Improvement Areas

The author's original intentions were to present the improvement areas of the three industrial organizations individually. However, due to the similar performance level in the asset management practices of the O&G organization and the land-based process organization (as evident in Figure 18), they will be presented together. The author has chosen to disregard the minor performance deviation in the two organizations' asset management practices, caused by the lack of a competence documentation system in the land-based process organization, as there already exist plans to implement a solution. Consequently, the presentation of improvement areas will first involve the land-based manufacturing organization before proceeding to present the improvement areas of the O&G organization and the land-based process organization together.

Land-Based Manufacturing Organization

The improvement areas of the land-based manufacturing organization are the most identifiable, as it is currently lacking several essential elements and practices for its asset management practices to be regarded as anywhere near compliant with all the 24 clauses of ISO 55001 (2014) as presented in section 3.2.1-3.2.7, or reaching the performance levels of the O&G organization and the land-based process organization. Based on the results uncovered in the analysis of its asset management practices in section 4.3, there are three main areas that should be prioritized as improvement areas related to its asset management practices. The areas encompass undergoing a more formalized approach to asset management on top management level, prioritizing a more holistic perception of the value created by the organization's assets, and being more proactive in the search for root causes and mitigation of asset degradation and nonconformities. Additionally, the organization should also focus on making more use of the valuable components that are already in place within its organizational boundaries. The most valuable component in that regard is the existing management system implemented as a result

of its ISO 9001 certification (as presented in section 4.3.2). The existing management system forms an excellent basis for undergoing an adoption of an integrated management systems approach, as previously presented in section 3.2. By using the existing framework of the ISO 9001 management system to integrate such elements as a SAMP and an asset management policy, the land-based manufacturing organization would have an excellent foundation for developing and operating a functioning asset management system. The organization should also make more use of its existing communication channels, which have been established at a prominent level. As outlined in section 4.3.3, there have already been established good procedures for top management to conduct reliable and informative top-down communications. If these communication channels were used more actively towards communicating the importance of asset management, the content of an asset management policy, and the importance of having a whole-life approach to the management of assets, there is a good chance of creating a solid asset management environment over time. All in all, it is fair to say that there is already established a certain base for practicing asset management at an elevated level in the land-based manufacturing organization, it is simply a matter of acknowledging it and starting to use the foundation correctly.

As a final remark regarding the improvement areas of the land-based manufacturing organization, the author would like to point to a statement made by Bruce Hawkins, the Certification Director for the SMRP Board of Directors (SMRP, 2017). He states that *"the implementation of the ISO 55000 suite is not expected to be a herculean undertaking for most organizations; most companies we have worked with have some of the elements already in place, but the elements are not brought together in a cohesive plan that is linked to the overall business strategy of the organization"* (Hawkins, 2014, p.1). This statement fits very well with regards to the improvement areas of the land-based manufacturing organization, pointing towards the lack of a SAMP (the cohesive plan) and a formalized asset management approach.

O&G Organization and Land-Based Process Organization

Based on the results uncovered in the analysis of asset management practices, the improvement areas of the O&G organization and the land-based process organization are quite different to the improvement areas of the land-based manufacturing organization, as they both presented asset management practices that could be regarded as fully and nearly fully compliant with each of the 24 clauses of ISO 55001 (2014) as presented in section 3.2.1-3.2.7. Based on this, it is suggested in ISO 55002 (2014) that their improvement areas should be to seek further improvement of their asset management practices and work actively towards a level of asset management practices that can be regarded to be beyond the practices outlined in the ISO 55000 suite. This is based on the following statement contained within ISO 55002 (2014, p.6), which reads *"compliance with all the requirements of ISO 55001 should be considered as achieving only the minimum starting point for an effective asset management system and should not be seen as the final goal"*. The statement contained within ISO 55002 (2014, p.6) is further supported by Woodhouse (2014) who suggests that one should be careful of referring to the asset management practices included in the ISO 55000 suite as "best practices", as industrial organizations are encouraged to continually challenge, innovate and stretch the limits of what is considered "best practices" within asset management.

When entering the area of surpassing the asset management practices of the ISO 55000 suite and working towards what could be regarded as "best practices" within asset management, some key factors come into play. First, asset management practices will effectively become context dependent (Woodhouse, 2014). What this means is that it will require different measures to surpass the practices of the ISO 55000 suite, depending on an organization's operating sector and general context. For example, it is not likely that "best practices" within the O&G industry will be equal to "best practices" within the land-based process industry. In other words, one surpasses and loses the common ground and practices of the ISO 55000 suite. Another key factor is that the definition of "best practices" will be subjected to constant change, because of the development of innovative technology and practices. Due to these two factors and the fact that the analysis of asset management practices contained within this thesis was to be based on the common asset management practices of the ISO 55000 suite, there will not be included a comprehensive presentation of improvement areas that extend beyond the asset management practices included in the ISO 55000 suite. However, there were made specific references to some current developments within both the O&G organization and the land-based process organization during the interview sessions with the two industrial organizations that are of interest in that regard. The references were made during the part of the interview sessions that covered the 'Continual Improvement' clause of ISO 55001 (2014), as the interviewees from both organizations made specific references to current developments caused by an increasing focus on digitalization, and the benefits it may bring to their asset management activities. To remain true to both the scope of this thesis and the statement of ISO 55002 (2014, p.6), a short presentation of these developments will be made next. These developments should effectively be regarded as the improvement areas of the O&G organization and the land-based process organization, respectively.

Developments within the O&G organization:

In its quest for continual improvement, the O&G organization is actively studying what its Operations Engineering Manager referred to as "step changes". The organization is actively seeking new advantages and possibilities provided by innovative technology and digitalization of their processes, also with regards to asset management. A specific example that was brought up during the interview session was further development and improvement of the organization's use of Integrated Operations (IO). IO is a collective term used to describe the integration of people, organizations, work processes and information technology to make better decisions. IO is driven by remote access to real time data and allows for enhanced task integration, with tasks being solved by personnel at multiple locations simultaneously, both onshore and offshore (IO Center, 2017). The existing benefits of IO, with regards to asset management, include wider use of multidisciplinary teams, improved cross-functional cooperation and enhanced process integration. Kadiri, Raza and Liyanage (2015) specifically highlights the enablement of remote expert consultations related to operations and maintenance, which facilitates improved asset management decision-making. Although IO is already a well-established discipline within the Norwegian O&G industry, it still has tremendous development potential with regards to the continual development of innovative technological solutions. This is recognized by the O&G organization, having made it a specific improvement area in its asset management developments and future endeavors.

Developments within the land-based process organization:

The land-based process organization's developments are of a similar nature to the ones of the O&G organization, as it is also actively studying the implications of innovative technology and digitalization of its processes. The importance of doing so is underlined by the organization having included a designated clause in its one-page overarching organizational policy, which specifies that it shall actively utilize innovative technology and the possibilities that lies within increased digitalization of its processes, also with regards to asset management. To concur with the organizational policy, there was recently initiated a pilot project involving use of big data in relation to a selection of the organization's RCM processes. Big data is a term that is subjected to a wide range of definitions, but in short it can be explained as the processes of undergoing analytics of large volumes of data or complex datasets, using complex algorithms that are often facilitated by cloud-based technology (SAS, 2017). The implications of big data towards asset management is quite substantial. Asset information is, as previously discussed in section 2.4.4, a key factor in asset management, especially with regards to asset management decision-making and strategic planning processes. By utilizing big data in relation to the gathering of asset information, it is possible to analyze much wider and complex data sets. Instead of the organization performing separate condition monitoring measurements, for example related to vibration analysis and lubricant analysis (as presented in section 2.4.3), it can create more sophisticated data models, consisting of several variables at once (Dunn, n.d.). This facilitates the creation of improved prediction models related to the organization's assets, which allows the organization to optimize its maintenance operations and forecast faults and nonconformities in an improved manner. Doing so can lead to cost reductions, reductions of downtime, improved asset management decision-making and improved root-cause analysis processes (SAS, 2017). Even though the use of big data in the land-based process organization is currently in a pilot phase, it is believed that it will be implemented in a wider scale as time goes, thus it is made a specific improvement area in its asset management developments.

Chapter 6 – Discussions, Observations and Suggestions for Further Studies

6.1 Scope of Work and Objectives

The aim of this thesis was to perform an analysis to compare the asset management practices found in a selection of Norwegian industrial sectors, namely O&G, land-based manufacturing and land-based process. The analysis was to include an industry-leading organization from each of the industrial sectors and be based on the common asset management practices of the ISO 55000 suite. The results of the analysis were to end up in an uncovering of specific performance gaps and improvement areas related to the included organizations' asset management practices. To comply with the aim of this thesis and cover the scope of work presented in section 1.3, several tasks have been completed.

First, a comprehensive literature study on asset management has been conducted. The literature study covers a wide variety of areas such as important definitions, history and development, scope, asset management subjects and key benefits, thoroughly introducing the reader to the holistic, integrative discipline that is asset management. The comprehensive literature study on asset management forms a solid and necessary basis for understanding the content of the ISO 55000 suite.

Next, a detailed study of the ISO 55000 suite has been performed. The study covers an introduction to the ISO standard, its included requirements and clauses, and selected benefits of undergoing an implementation process of the ISO standard. The detailed study of the ISO 55000 suite forms an essential knowledge base that is required to properly understand and gain value from the analysis of asset management practices, especially with regards to requirements and clauses of the ISO standard.

Lastly, an analysis of asset management practices has been performed. The analysis was conducted using the common asset management practices of the ISO 55000 suite and included industry-leading organizations from three Norwegian industrial sectors, namely O&G, land-based manufacturing and land-based process. The analysis includes an establishment of quantitative indicators presented in radar charts and text-based comparisons against the seven requirements and 24 corresponding clauses of ISO 55001 (2014), the sub-standard included in the ISO 55000 suite that include specific requirements and clauses that must be met to successfully implement an asset management system. The results of the analysis ended up in an uncovering of performance gaps and improvement areas related to the included organizations' asset management practices.

Based on the above, it is the author's opinion that the defined scope of work and the objectives of this thesis have been fulfilled.

6.2 Observations and Findings

The analysis of asset management practices revealed several interesting findings regarding the individual organizations' asset management practices. First, the elevated asset management practices of the O&G organization reinforced the impression of the Norwegian O&G industry being an industrial sector that actively prioritizes asset management and a whole-life approach to the management of assets. During the interview session with the Operations Engineering Manager of the O&G organization, it quickly became clear to the author that he gave the best responses and had the highest familiarity with asset management of all the interviewees that participated in the analysis process. The general flow of the conversation and the accuracy of his answers were at a prominent level during the entire interview session, showing an extensive understanding of both the discipline of asset management and terms contained within the ISO 55000 suite. This led to a combination of the interview session being the shortest in duration and the most effective in terms of quality. The author suspects that if a more detailed or practical analysis approach was taken, either more detailed with regards to the ISO 55000 suite or by changing the analysis criteria to encompass the 39 asset management subjects (section 2.4.1-2.4.6), the performance gaps between the asset management practices of the O&G organization and the other two industrial organizations would be more significant compared to the performance gaps that were revealed by using the analysis criteria that were used in this thesis. Still, this is just a theory that is based on the impressions the author got from the interview sessions. It would have to be investigated further to be verified.

Next, looking at the practices of the land-based process organization and the land-based manufacturing organization, the author had few reference points of how their analysis results would turn out. It was therefore a surprise to see the land-based process organization performing as well as it did. It became evident that asset management is in fact an important focus area within the organization and that it is something that is gaining significant priority from its top management. The organization is proactive in its asset interventions, it actively prioritizes a holistic perception of the value created by its assets, and asset management is actively incorporated into its strategic planning processes. On the other hand, the land-based manufacturing organization presented asset management practices of a rather average overall level. As outlined in the section containing its improvement areas (section 5.3), it has built a solid foundation for creating a functioning asset management system and practice asset management at an elevated level, but several essential elements are currently not in place, such as a SAMP and an asset management policy. The author suspects that the land-based manufacturing organization's asset management practices is a relevant reflection of the current state found in numerous other industrial organizations in Norway. Most industrial organizations will have implemented some aspects of asset management, but the part where many of them will underperform is in the actual process of integrating the aspects and align their efforts towards a common set of strategic objectives (Edwards, 2010b; Hawkins, 2014). There may be many reasons for this, as it can be attributed to ignorance, awareness issues, lack of commitment of top management, or simply that the industrial organizations are fairly content with their current organizational state and overall performance level.

A final finding that was of great interest to the author was the incredibly low familiarity with the ISO 55000 suite that was observed within the three industrial organizations included in this thesis. The interview sessions revealed that the only interviewee that had prior knowledge of the ISO 55000 suite was the Technical Director of the land-based manufacturing organization, with this knowledge being of an academic type. None of the industrial organizations included in this thesis had implemented the standard specifically or expressed any interest in seeking a certification. The somewhat odd relationship between the current proficiency of asset management practices within the selected industrial organizations and the low familiarity and interest in the ISO 55000 suite, leads the author to believe that there exists a certain awareness issue regarding the ISO 55000 suite. It became evident during the interview sessions that other ISO standards that are also concerned with an introduction of management systems, such as ISO 9001 (quality management) and ISO 14001 (environmental management) have gained far more attention and widespread acceptance when compared to the ISO 55000 suite. This despite the ISO 55000 suite's obvious advantages and benefits (as presented in section 3.3), elevated level of applicability and the possibility of using existing functions introduced by other ISO management systems to adopt an integrated management systems approach (as presented in section 3.2).

An interesting aspect regarding the low familiarity with the ISO 55000 suite are the potential effects caused by the introduction of a translated Norwegian version. A translation of the ISO 55000 suite has been an ongoing process since the publishing of the ISO standard back in January 2014. The translated Norwegian version was recently finalized and published as late as November 2016 (Standards Norway, 2016). It shall be interesting to observe if a translated Norwegian version of the ISO 55000 suite is able to increase the interest in the ISO standard and facilitate a more widespread acceptance and perhaps also implementation of the ISO standard within Norwegian industrial sectors. An introduction to the discipline of asset management through the Norwegian version of the ISO standard could also potentially act as a door-opener for interested parties towards the wider selection of international academic literature concerned with asset management, which in turn may lead to even further improvements in their asset management practices.

6.3 Areas for Further Study

As revealed in the analysis of asset management practices in Chapter 4 and the presentation of performance gaps and improvement areas in Chapter 5, both the O&G organization and the land-based process organization presented excellent asset management practices. However, as previously elaborated upon in 'Delimitations' in section 1.5, the analysis in this thesis measures the degree of compliance with the 24 clauses of ISO 55001 (2014) as they are presented in this thesis specifically (section 3.2.1-3.2.7) and not with the clauses as they are fully described in the ISO 55000 suite, where they consist of a wider range of 72 "shall do" activities. An interesting area for further study in that regard, now that is has been established that both industrial organizations are in fact highly capable in their asset management practices, would be to conduct an even more detailed analysis within either of the two industrial organizations, to reveal how their asset management practices would align to the ISO 55000 suite in a more comprehensive form of analysis. Such an analysis could potentially prove valuable to the industrial organizations, as it might reveal several areas of improvement that were not unveiled in the analysis included in this thesis.

Another interesting area for further study could be to conduct an industry-specific analysis of asset management practices using the ISO 55000 suite. It would be interesting to see how the asset management practices of the O&G organization included in this thesis would fare against other, similar organizations that are operating within the same industrial sector. Such an analysis could also be centered around the other industrial sectors covered in this thesis, namely land-based manufacturing and land-based process.

A final area for further study, and perhaps the most interesting, could be to further investigate the improvement areas/development areas that were outlined for the O&G organization and the land-based process organization in section 5.3. The increasing focus on digitalization is an area that will have major implications towards industrial organizations' asset management practices and the value-creating abilities of their assets. It could for example be interesting to study a project that is of a similar nature as the big data project that were recently initiated within the land-based process organization, to investigate the actual effects it will have on an industrial organization's asset management capabilities, both from a qualitative and quantitative point of view.

6.4 Challenges Encountered

There have been some challenges encountered during the work process with this thesis.

The author had no familiarity or previous experience with the ISO 55000 suite when starting the work with this thesis. The process of getting to know the ISO standard and its included requirements and clauses proved to be a challenging task. It took a lot of effort to get a sufficient overview of the standard and to be able to extract the content of the standard into this thesis.

It also proved a challenging task to create the basis for the analysis of asset management practices. The author had few prior reference points regarding the current standing of asset management practices within both the land-based process industry and the land-based manufacturing industry, especially with regards to the practices outlined in the ISO 55000 suite. It was challenging to determine the level of detail that would yield the best foundation for comparing the individual organizations' asset management practices. The given timeframe of this this thesis did not permit the author to do a detailed comparison against the complete content of the ISO 55000 suite. This forced the author to make some generalizations with regards to the content of the ISO 55000 suite. It was determined that the best approach would be to cover the essence and main components of each of the 24 clauses of ISO 55001 (2014) in Chapter 3 (section 3.2.1-3.2.7) and build the analysis of asset management practices around this. Both the interview guide (Appendix A) and the complete analysis of asset management practices in Chapter 4 (including the radar charts, the scorecards and the written text sections) are consequently built around the 24 clauses of ISO 55001 (2014) as they are presented in section 3.2.1-3.2.7. The selected approach proved successful as there was uncovered several interesting performance gaps and the author was able to present improvement areas with regards to all three organizations' asset management practices. In retrospect, the author would probably have made the interview guide even more comprehensive or conducted multiple interviews within each organization to reveal performance gaps that might not have been revealed by the analysis in this thesis. However, it is easy to point at such details now that the author has some actual reference points regarding the state of asset management practices within the selected organizations and their associated industrial sectors.

Lastly, it proved challenging to determine the best method for setting the quantitative indicators included in the radar charts. This was specifically included in the scope of this thesis and something the author was required to do. Initially, a questionnaire-based five-level Likert scale was considered. However, this would not have revealed the actual asset management practices as included in the written text sections of the analysis, which is facilitated through the semi-structured interview approach. It would also have required the involved personnel to have prior knowledge of the ISO 55000 suite to receive contextually relevant information, which it turned out that most of them did not have. It was therefore determined to use the approach consisting of the indicator scale adapted from the IAM (2016) and create scorecards as basis for the radar charts and their quantitative indicators. This proved to be an approach of sufficient technical consistency and validity, which effectively outlined performance gaps and improvement areas.

Chapter 7 – Conclusion

This thesis set out to perform an analysis to compare the asset management practices found in a selection of Norwegian industrial sectors, namely O&G, land-based manufacturing and land-based process. The analysis was to include an industry-leading organization from each of the industrial sectors and be based on the common asset management practices of the ISO 55000 suite. The results of the analysis were to end up in an uncovering of specific performance gaps and improvement areas related to the included organizations' asset management practices.

First, literature studies of both the discipline of asset management and the ISO 55000 suite were conducted. The studies act as important contributors towards forming the knowledge base that is required to gain benefits and understanding of the analysis of asset management practices and the results that were uncovered. Next, the analysis itself was conducted. The analysis is based on information gathered by the author through a series of semi-structured interview sessions with proficient and knowledgeable personnel from each of the industrial organizations that are included in the analysis. The interview sessions were all conducted by using the same interview guide, which is based on the seven requirements and 24 corresponding clauses of ISO 55001 (2014), the sub-standard included in the ISO 55000 suite that specifies requirements and clauses that must be met to successfully implement an asset management system. The analysis approach was chosen based on ISO 55002 (2014, p.5), which states that *"an initial review of the organization's current processes against the requirements of ISO 55001 will determine the areas that need to be developed to support the functioning of a compliant asset management system"*.

The analysis of asset management practices revealed several interesting findings with regards to the three industrial organizations' asset management practices, including a set of specific performance gaps and improvement areas. It became especially clear that the land-based manufacturing organization struggled in several areas when compared to both the O&G organization and the land-based process organization, which the author found to be caused mainly by a lack of commitment from its top management, short-termism, and the lack of a formalized asset management approach. Both the O&G organization and the land-based process organization presented excellent asset management practices when compared to the criteria set for the included analysis, clearly illustrating that asset management is in fact a focus area and an important priority within both organizations. It should be noted that the analysis of asset management practices within this thesis is based on the essence and main components within each clause of ISO 55001 (2014) to facilitate a reliable analysis within the given timeframe and workload of this thesis. The author believes that a more detailed or practical analysis approach would have yielded more significant performance gaps between the asset management practices of the O&G organization and the two organizations representing the other Norwegian industrial sectors. Lastly, the analysis of asset management practices also revealed that the included industrial organizations had an almost non-existing familiarity with the ISO 55000 suite. Based on the feedback the author received during the work with this thesis, there seems to exist certain awareness issues related to the ISO 55000 suite in the selected Norwegian industrial sectors.

Bibliography

Assetinsights, n.d. *Functional silos will defeat the organization*. [image online] Available at: <http://www.assetinsights.net/Concepts/Peeps_Functional_silos_will_defeat_the_organization.JPG> [Accessed 28 March 2017].

Aven, T., 2015. *Risk Analysis (Second Edition)*, Wiley.

Biahmou, A., 2015. Systems Engineering. In: Stjepandic, J., Wognum, N. and Verhagen, W.J.C., (eds.), 2015. *Concurrent Engineering in the 21st Century – Foundations, Developments and Challenges*, Springer.

Birolini, A., 2014. *Reliability Engineering: Theory and Practice (Seventh Edition)*, Springer.

BSI PAS 55-1, 2008. *Asset Management: Specification for the optimized management of physical assets*, British Standards Institution.

Burns, P., 2010. Asset management strategy: Leadership and decision-making. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Business Dictionary, n.d. *SWOT analysis*. [online] Available at: <http://www.businessdictionary.com/definition/SWOT-analysis.html> [Accessed 21 February 2017].

Campi, J.P., 1993. Breaking the Paradigm of Performance Measurement. In: Christopher, W.F., Thor, C.G., (eds.), 1993. *Handbook of productivity measurement and improvement*, Productivity Press.

Dunn, S., n.d. *Big Data, Predictive Analysis and Maintenance*. [online] Available at: <https://www.assetivity.com.au/article/maintenance-management/big-data-predictive-analytics-and-maintenance.html> [Accessed 3 May 2017].

Edwards, R., 2010a. Regulating asset management. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets,* Thomas Telford.

Edwards, R., 2010b. Asset management in the rail and utilities sector. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Elkington, J., 1997. *Cannibals with Forks: Triple Bottom Line of 21st Century Business*. Capstone Publishing Ltd.

Ensor, P.S., 1988. *The Functional Silo Syndrome*. [pdf] Available at: <http://www.ame.org/sites/default/files/documents/88q1a3.pdf> [Accessed 10 March 2017].

Frankel, E.G., 2008. *Quality Decision Management – The Heart of Effective Futures-Oriented Management*, Springer.

Gardiner, P.D., 2005. *Project Management: A Strategic Planning Approach*, Palgrave Macmillan.

GFMAM, 2014. *The Asset Management Landscape (Second Edition)*. [pdf] Available at: <http://www.gfmam.org/files/ISBN978_0_9871799_2_0_GFMAMLandscape_SecondEdition_English.pdf> [Accessed 26 January 2017].

Hastings, N.A.J., 2010. *Physical Asset Management*, Springer.

Hawkins, B., 2014. *A Vision of an ISO 55000 Compliant Company*. [pdf] Available at: <http://www.plantservices.com/assets/Media/1401/white-paper/iso-55000.pdf> [Accessed 26 January 2017].

Hodkiewicz, M.R., 2015. The Development of ISO 55000 Series Standards. In: Tse, P., Mathew, J., Wong, K., Lam, R. and Ko, C., (eds.), 2015. *Engineering Asset Management – Systems, Professional Practices and Certification. Lecture Notes in Mechanical Engineering*, Springer.

IAM, 2015. *Asset management – An anatomy (Version 3)*. [pdf] Available at: <https://theiam.org/what-is-asset-management/anatomy-asset-management> [Accessed 18 January 2017].

IAM, 2016. *Asset Management Maturity Scale and Guidance (Version 1.1)*, Institute of Asset Management.

Institution of Civil Engineers, 2015. *BIM and Asset Management*. [pdf] Available at: <https://www.ice.org.uk/getattachment/disciplines-and-resources/briefing-sheet/bim-and-asset-management-factsheet/BIM_and_Asset_Management.pdf.aspx> [Accessed 1 May 2017].

IO Center, 2017. *What is Integrated Operations?* [online] Available at: <http://www.iocenter.no/info/what-integrated-operations> [Accessed 3 May 2017].

ISO 55000, 2014. *Asset management – Overview, principles and terminology*. International Organization for Standardization.

ISO 55001, 2014. *Asset management – Management systems – Requirements*. International Organization for Standardization.

ISO 55002, 2014. *Asset management – Management systems – Guidelines for the application of ISO 55001*. International Organization for Standardization.

Jay, P. and Hamer, K., 2015. *Quantified Benefits from Asset Management – The Sodexo Journey*. [pdf] Available at: <http://www.twpl.com/wp-content/uploads/Case-Study-Sodexo-2015-1.pdf> [Accessed 2 March 2017].

Johnson, C., 2010. Creating an asset management culture. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Kadiri, O.O., Raza, J. and Liyanage, J.P., 2015. Current Status and Innovative Trends of Asset Integrity Management (AIM): Products & Services in the Norwegian Oil and Gas Industry. In: Tse, P., Mathew, J., Wong, K., Lam, R. and Ko, C. (eds.), 2015. *Engineering Asset Management – Systems, Professional Practices and Certification. Lecture Notes in Mechanical Engineering*, Springer.

Kaplan, R.S. and Norton, D.P., 1996. *The Balanced Scorecard: Translating Strategy Into Action*, Harvard Business School Press.

Liyanage, J.P., 2012. Smart Engineering Assets Through Strategic Integration: Seeing Beyond the Convention. In: Van der Lei, T., Herder, P. and Wijnia, Y., (eds.), 2012. *Asset Management: The State of the Art in Europe from a Life Cycle Perspectiv*e, Springer.

Lloyd, C., 2010a. Introduction. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Lloyd, C., 2010b. Developing the competence of asset management staff. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Markeset, T. and Kumar, U., 2000. Application of LCC techniques in selection of mining equipment and technology. In: *Proceedings of the 9th International Symposium on Mine Planning and Equipment Selection, Nov 6-9, Athens, Greece.*

Markeset, T. and Kumar, U., 2003. Integration of RAMS and risk analysis in product design and development work processes: A case study. In: *Journal of Quality in Maintenance Engineering, Vol. 9, Issue: 4, pp. 393-410.*

Mobley, R.K., 1990. *An introduction to predictive maintenance*, Van Nostrand Reinhold.

Moubray, J., 1997. *Reliability-Centered Maintenance (Second Edition)*, Industrial Press Inc.

Parnell, G.S. and Driscoll, P.J., 2011. Introduction. In: Parnell, G.S., Driscoll. P.J., Henderson, D.L., (eds.), 2011. *Decision-making in systems engineering and management*, Wiley.

Petroleum Safety Authority Norway, 2013. *Principles for barrier management in the petroleum* industry. [pdf] Available at: <http://www.ptil.no/getfile.php/1319891/PDF/Barrierenotatet%202013%20engelsk%20april.pdf> [Accessed 16 March 2017].

Pilling, M., 2010. Beyond BSI PAS 55 compliance. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Powerhouse Growers, 2013. *The Triple Bottom Line*. [image online] Available at: <http://www.powerhousegrowers.com/wp-content/uploads/2013/10/the-triple-bottom-line.jpg> [Accessed 3 April 2017].

Ratnayake, R.M.C., 2010. Asset Integrity Management: Operationalizing Sustainability Concerns. In: Gunasekaran, A. and Sandhu, M., (eds.), 2010. *Handbook of Business and Information Management Systems*, World Scientific Publishing Company.

Reece, B., 2015. *Annex SL: What's It All About*. [online] Available at: <http://www.insidestandards.com/annex-sl-whats-it-all-about/> [Accessed 23 February 2017].

SAP, 2017. *Asset Management*. [online] Available at: <https://www.sap.com/solution/lob/asset-management.html> [Accessed 7 March 2017].

SAS, 2017. *Big Data: What it is and why it matters*. [online]. Available at: <https://www.sas.com/en_us/insights/big-data/what-is-big-data.html> [Accessed 3 May 2017].

Savitz, A.W. and Weber, K., 2006. *The Triple Bottom Line*, Jossey-Bass.

Skybrary, 2016. *Risk Assessment Matrix*. [image online] Available at: <https://www.skybrary.aero/images/FAA_RA_Sample.JPG> [Accessed 5 April 2017].

SMRP, 2017. *Board of Directors.* [online] Available at: <http://smrp.org/About/Board-of-Directors> [Accessed 13 May 2017].

Standards Norway, 2016. *NS-ISO 55000: Forvaltning av anlegg og verdier – Oversikt, prinsipler og terminologi*. [online] Available at: <http://www.standard.no/no/Nettbutikk/produktkatalogen/Produktpresentasjon/?ProductID=860929> [Accessed 13 April 2017].

Statistics Norway, 2017. *Et krevende år for industrien*. [online] Available at: <http://ssb.no/energi-og-industri/artikler-og-publikasjoner/et-krevende-ar-for-industrien> [Accessed 20 April 2017].

Statnett, 2013. *Statnett er PAS 55 sertifisert*. [online] Available at: <http://www.statnett.no/Media/Nyheter/Nyhetsarkiv-2013/Statnett-er-PAS-55-sertifisert/> [Accessed 30 January 2017].

Woodhouse, J., 2010a. Asset management: The way forward. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Woodhouse, J., 2010b. Asset management in the oil and gas, process and manufacturing sectors. In: Lloyd, C., (ed.), 2010. *Asset management: Whole-life management of physical assets*, Thomas Telford.

Woodhouse, J., 2014. *ISO 55000 – What, Why and How: An introduction to the first international standard for asset management.* [pdf] Available at: <http://vision-aeam.com/wp-content/uploads/2014/04/3-1-Brief-intro-to-ISO55000.pdf> [Accessed 2 March 2017].

Appendix A – Interview Guide

Included below is the interview guide that was used in all the interview sessions. Note that some of the questions include basic explanations and some guiding examples for the interviewees. These were added to provide clarity to the interviewees and to explain some of the ISO 55000-specific terminology that might not have be familiar to the interviewees prior to the interview sessions. The explanations proved useful as they would in some cases act as talking points and opened for a deeper and more informative conversation. Both the author and the interviewees had their own physical copy of the interview guide during the interview sessions. Also note that the questions that encompass the ISO 55001 (2014) clauses 'Asset Management System' and 'Determining the Scope of the Asset Management System' are gathered in one header in the interview guide.

#	QUESTIONS	EXPLANATIONS
	CONTEXT OF THE ORGANIZATION	
	Understanding the organization and its context	
1	Can you outline some of your organization's current organizational objectives?	
	Understanding the needs and expectations of stakeholders	
2	How do you ensure that needs and expectations of stakeholders* are being regularly incorporated into decision-making processes and strategic planning processes?	**Stakeholders include employees, shareholders, customers, local communities, etc.*
	Asset management system & Determining the scope of the asset management system	
3	Were you aware of the discipline of asset management or the ISO 55000 standard for asset management prior to this interview?	
4	Has there been implemented an overarching management system* to control your organization's asset management activities?	**A management system for asset management, as described in the ISO 55000 suite, helps to direct, coordinate and control asset management activities.*
5	Have you defined a strategic asset management plan (SAMP)* in your organization? If so, how does the SAMP contribute in linking your organizational objectives to specific asset management objectives?	**A strategic asset management plan (SAMP) is a plan that documents the role of asset management in supporting the achievement of organizational objectives.*
6	Which measures have been taken to define and document the scope* of your organization's asset management activities?	**The scope of an organization's asset management activities should be defined and documented, to optimize control of performance, risk and costs.*

LEADERSHIP		
Leadership and commitment		
7	To what degree would you say that top management and leaders in your organization actively promote cross-functional collaboration*?	**Cross-functional collaboration is referring to measures such as open communication across organizational departments and use of multi-disciplinary teams.*
8	To what degree would you say that top management and leaders in your organization communicate the importance of having a whole-life* approach to the management of assets?	**Whole-life approach meaning management of cost, risk and benefits throughout an asset's complete life cycle (from its creation through to its disposal).*
9	Which measures have been taken to ensure that top-down communication from top management and leaders in your organization reach all levels and departments?	
Policy		
10	Has top management in your organization defined and established an asset management policy*?	**An asset management policy is a short statement that clarifies which principles an organization intends to use to achieve its organizational objectives, using asset management.*
Organizational roles, responsibilities and authorities		
11	To what degree would you say that top management and leaders in your organization have clearly established responsibilities and authorities for key roles, with regards to asset management activities?	
PLANNING		
Action to address risks and opportunities for the asset management system		
12	How are risks related to your organization's assets being addressed?	
Asset management objectives & planning to achieve them		
13	Have there been defined and established specific asset management objectives* in your organization? If so, to what degree would you say that these objectives support the organizational objectives defined in your organizational strategic plan?	**Asset management objectives are objectives that reflects the desired results of an organization's asset management activities. Included aspects may include asset performance objectives, maintenance objectives, financial objectives, etc.*
14	Have there been established and created specific asset management plans* to support the achievement of the aforementioned asset management objectives? If so, what are the specific content and the expected outcome of such plans?	**Asset management plans are asset-specific plans containing specified life-cycle strategies, expected performance, maintenance strategies, risk analyses, budget requirements, etc., needed to achieve specified, corresponding asset management objectives.*

SUPPORT		
Resources		
15	Do you have procedures of mapping required resources* against available resources before undertaking planned activities related to your assets? If so, how is this done?	**Resources in this case can be financial resources, human resources, competence, equipment, etc.*
Competence		
16	How do you ensure that specific activities related to your assets are performed by personnel with the correct competence?	
17	***Ref Q.16:*** If competence requirements have been defined, which procedures do you have for documenting and continuously updating them?	
Awareness		
18	Which measures have been taken in your organization to raise awareness regarding how each employee's personal contributions affect both asset performance* and the achievement of organizational objectives?	**Asset performance referring to actual output level/production efficiency of the assets, as well as asset availability and asset reliability.*
Communication		
19	Which measures have been taken to ensure that both internal and external communications related to your assets reach the relevant parties and are of relevance to the recipients?	
Information requirements		
20	Have there been established specific information requirements related to your assets, to ensure that collected asset information* supports enhanced asset performance and contributes towards the achievement of organizational objectives? If so, how is this done?	**Asset information referring to operational data, maintenance data, performance indicators, risk, technical properties, etc.*
Documented information		
21	Which routines do you currently have on documenting and continually updating collected asset information?	
OPERATION		
Operational planning and control		
22	How do you ensure that implementation of planned activities to your assets occur as intended?	
Management of change		
23	How do you deal with planned and unplanned change that may affect the performance and/or health of your assets?	
Outsourcing		
24	How do you ensure that outsourced activities are being performed in a way that supports both the performance of your assets, as well as regular achievement of organizational objectives?	

PERFORMANCE EVALUATION		
Monitoring, measurement, analysis and evaluation		
25	Can you briefly describe some of your existing processes for measuring asset performance?	
26	To what degree would you say that there exists a clear link between asset performance measurements and the achievement of your organizational objectives?	
Internal audit		
27	Do you conduct internal audits at regular time intervals? If so, to what degree does such audits consider your assets and the quality of asset management activities?	
Management review		
28	Does top management conduct regular management reviews of organizational processes and objectives? If so, to what degree would you agree that your assets and their performance play a part in such management reviews?	
IMPROVEMENT		
Nonconformity and corrective plan		
29	Can you briefly describe some of your existing routines for dealing with a nonconformity or incident in one or more of your assets?	
Preventive action		
30	To what degree would you say that your organization have a proactive approach to identifying potential failures or degradation of asset performance?	
Continual improvement		
31	How is continual improvement (both with regards to assets, asset management and other organizational processes) being promoted in your organization?	