Chapter 12
Asset Life Cycle Plans:
Twelve Steps to Assist Strategic Decision-Making in Asset Life Cycle Management

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ABSTRACT

Effective management of physical assets should deliver maximum business value. Therefore, Asset Management standards such as PAS 55 and ISO 55000 ask for a life cycle approach. However, most existing methods focus only on the short term of the asset's life or the estimation of its remaining life. These methods do not consider alignment to changing corporate objectives in a variable context, nor do they adopt a multidisciplinary perspective. This chapter argues that, to create maximum value, Asset Management should be a multidisciplinary and strategic practice that considers the complete life cycle of the asset: Asset Life Cycle Management. A practical twelve-step approach is presented to develop an Asset Life Cycle Plan (ALCP) in which expert sessions are used to identify the main lifetime impacts that influence the creation of business value from the use of the asset. The steps are illustrated with an example from practice. The chapter concludes that the ALCP supports asset managers in making long-term strategic decisions in a timely and effective manner.

INTRODUCTION

Physical assets are indispensable for society. Oftentimes, the assets are not noticed until a seemingly minor technical failure disrupts daily life. At these moments, it becomes clear that these assets fulfil vital functions in our lives. Examples include bridges and roads for transportation, the electricity grid to keep the lights on, and water treatment plants for drinking water. Next to their societal value, the

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financial (replacement) value of these assets is substantial as well. An estimate of this value in the Netherlands lies around 400 billion (milliard) euros (Veenman & Besselink, 2010), which is around 50% of the Dutch yearly GDP. This clearly shows the large financial value represented by physical assets in a modern Western country. Additionally, the costs of the maintenance needed to keep these assets fit for use are considerable. In the Netherlands, the maintenance costs amount to 30 to 35 billion euros per year (NVDO, 2015). Because such high financial and social values are at stake, the effective management of these assets is important for asset owners and society alike.

The fact that the end of the expected functional lives of many assets is approaching, increases the importance of effective Asset Management. This applies to Dutch infrastructure assets (de Leeuw & Pries, 2014; Jongepier, 2007; Wetzer & Bouwman, 2007). The same applies to Western Europe and the USA (Allan, 2005; Brown & Humphrey, 2005). Assets reaching the end of their useful life tend to need more intensive maintenance, and modernization or life extension may be worthwhile. On the other hand, timely disposal may be necessary to prevent excessive costs, or risks for health, safety, and the environment (Jongen, 2012; Rouse & Chiu, 2009). Additionally, these ageing assets often have to fulfil different functions than those for which they were designed, often decades ago. The assets have to comply with new regulations, satisfy changing market demands, and may be needed to produce higher quantities than anticipated (Al-Turki, 2011).

It is in this complex context that the asset manager operates. The management of ageing assets in a changeable context asks for strategic decisions, next to the daily work of maintenance and tactical planning. Strategic decisions directly impact corporate objectives by asking questions such as: How long can the operation of asset X be continued? What modifications need to be made to asset Y at the next overhaul? How can we convince management that the purchase of asset Z is worthwhile, even though its price is higher than all other alternatives? How can we keep the operation and maintenance of the assets aligned with changing corporate objectives? and What external developments may have an effect on the business value created with the operation of the assets?

Such a strategic focus on the complete life cycle of the asset is also required by recent Asset Management standards such as PAS 55 (IAM & BSI, 2008) and ISO 55000 (ISO, 2014). These require a life cycle approach. However, these standards do not provide much guidance as to how such a life cycle approach should be implemented. The same applies to well-known maintenance concepts, such as Reliability Centred Maintenance (RCM), which focus primarily on the short term (Coetzee, 1999; Murthy, Atrens, & Eccleston, 2002). In other words, there are many strategic Asset Management decisions to be made, but there is very little guidance available for asset managers who need to make these decisions. Therefore, the aim of this chapter is to present a tool to assist strategic decision-making in Asset Management.

The next section will present a theoretical background on Asset Management. It will conclude that Asset Management should be a strategic and multidisciplinary practice, focusing on the complete lifetime of an asset. Such an approach to Asset Management will be termed "Asset Life Cycle Management" (ALCM). Current maintenance approaches often just focus on the short term and do not adopt a multidisciplinary approach. These approaches do not address changes in the environment in which the asset operates, changes in regulation, or new corporate objectives. Hence, the concept of "lifetime impacts" will be introduced in the next section. These lifetime impacts are a key ingredient for an Asset Life Cycle Plan (ALCP), which is a tool developed to support strategic decision-making in Asset Management. An ALCP does this by presenting a holistic view of the current and expected performance, costs of the assets, and the main challenges that may affect performance over an asset's lifetime. An extensive and practical twelve-step approach will be presented to develop such an ALCP, illustrated with an ALCP

on distribution transformers from a Dutch network operator. The chapter concludes that the ALCP aids asset managers in making strategic decisions in a timely and effective manner. In the last section, the implications for further research and for practitioners will be presented.

BACKGROUND ON ASSET MANAGEMENT

It is worthwhile to investigate the concept of Asset Management in some more detail before presenting the tool that assists strategic decision-making in Asset Management. Pudney (2010) proposes an elaborate definition of Asset Management based on a study of Asset Management literature. He defines Asset Management as "an organisation's coordinated multidisciplinary practice that applies human, equipment and financial resources to physical assets over their whole life cycle to achieve defined asset performance and cost objectives at acceptable levels of risk whilst taking account of the relevant governance, geo-political, economic, social, demographic and technological regimes" (Pudney, 2010, p. 8). From this definition, five characteristics of Asset Management stand out. Asset Management (AM):

1. Is a multidisciplinary practice;
2. Takes the whole life cycle of a physical asset into account;
3. Achieves certain objectives;
4. Considers the limits of risk and relevant regimes; and
5. Determines the allocation of resources (Ruitenburg, Braaksma, & van Dongen, 2015).

Each of these five characteristics will be discussed in more detail.

Asset Management Is a Multidisciplinary Practice

Many different disciplines should be combined in Asset Management. This applies to technical disciplines such as engineering and maintenance. Additionally, a financial perspective on the assets should be included in Asset Management. However, there are additional disciplines that play a crucial role, such as data collection and analysis, planning and scheduling, operational excellence, rules and regulations, IT, human resources, and innovation (Smit, 2014). To create maximum value from the exploitation of an asset, all these disciplines may play a role. One should understand degradation processes that deteriorate the condition of the asset. One should know what maintenance actions may be performed to counter this deterioration. Based on the costs of the possible interventions, a choice has to be made for the most cost-effective solution. This intervention should comply with existing regulations and fit with the capabilities of the engineers and operators employed by the company. The innovation department may have sought out new technologies that can be implemented while making the intervention. And of course, the implementation of the intervention needs to be scheduled, taking the production planning into account to ensure a good fit with the ongoing operations.

In spite of the importance of the involvement of many disciplines in Asset Management, Haffejee and Brent (2008) conclude, "[t]he economic, environmental, social and technical dimensions of Asset Management are not explicitly depicted." Rather, approaches are often limited to the technical aspects of the asset (Frangopol, Saydam, & Kim, 2012; Garg & Deshmukh, 2006) or focus mainly on the financial

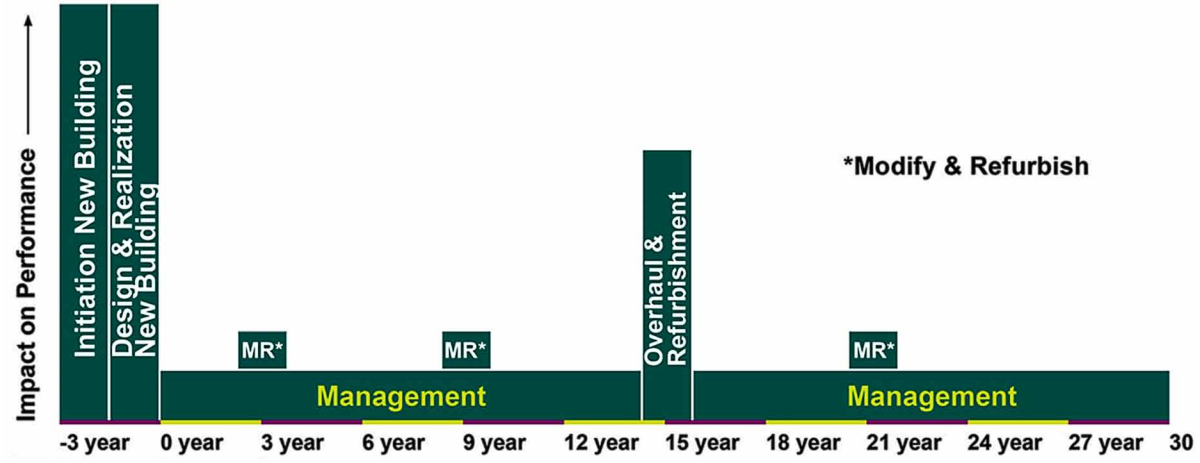
performance of the asset (Asiedu & Gu, 1998; Márquez, Márquez, Fernández, Campos, & González-Prida Díaz, 2012). To conclude, multidisciplinary approaches to Asset Management are scarce.

Asset Management Takes the Complete Life Cycle of the Asset into Account

Asset Management should consider the asset's complete life cycle. Different reasons for this are given in the literature. One of these is that most of the life cycle costs are already fixed in the design of the asset; hence, it is important to take the complete life cycle of the asset into account from the moment of design onwards (Schuman & Brent, 2005; L.A.M. van Dongen, 2011). In the design, a large part of the future performance of an asset is already fixed. One may be able to change the asset's throughput, operation speed, or safety during its service life, but often at considerably larger costs than if it had been part of the original design. L.A.M. van Dongen (2011) illustrates this with a figure (refer to Figure 1). The figure shows the influence the asset manager may exert over the performance of an asset during its life cycle (in this case the life cycle of a train). Future performance requirements should be considered as early as possible to prevent unnecessary high refurbishment costs later in the asset's life. In other words, the complete life cycle of the asset should be taken into account.

A second reason to consider the complete life cycle of the asset is the increasing market turbulence in many sectors. This requires the asset manager to make the right strategic decisions to ensure that the asset will remain valuable to the company even in a changed market (Komonen, Kortelainen, & Räikkönen, 2012). Additionally, many external developments (e.g. new regulations) may have an impact on the asset (Al-Turki, 2011) and should be taken into account as early as possible in the asset's life. However, the same authors stressing the importance of considering the asset's complete life cycle also state that a focus on the complete life cycle is often lacking. This also applies to well-known Asset Management methods, such as Reliability Centred Maintenance (RCM), which primarily focuses on the short term (Coetzee, 1999; Murthy et al., 2002).

Figure 1. Overview of a typical life cycle at NedTrain
(adapted from L.A.M. van Dongen, 2011)



Asset Management Aims to Achieve Specific Objectives

The third characteristic of Asset Management shows that Asset Management aims to reach certain objectives. These objectives should relate to the objectives of the asset owner and thus ultimately to the corporate strategy. The asset is not valuable to the company in its own right (apart from its potential resale or scrap value). The asset is valuable only if it fulfils a function that fits the strategic goals of the company, goals that may change over time. Combining this with the previous characteristic shows that the management of assets should not be considered a stand-alone process carried out in a vacuum. Rather, the operation and maintenance of assets should continuously be aligned to changes in corporate objectives and the operating environment (Komonen et al., 2012).

The importance of Asset Management with respect to the corporate goals is also shown by the PAS 55 definition of Asset Management: Asset Management consists of "systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan" (IAM & BSI, 2008, p. 2). This definition shows that Asset Management is inextricably connected to the achievement of the "organizational strategic plan" and therefore the corporate strategy. As assets are necessary means to reach the corporate objectives, the management of these assets is a strategic concern to a company. For example, the assets used by a chemical company facilitate the chemical processes that create the added value for the company. For a utility company, the infrastructure assets allow the company to deliver electricity, gas, or water to its customers. For an airline, the aircraft are indispensable to transport travellers to destinations all over the world. To summarize, since companies are highly dependent on the assets they operate to achieve their corporate objectives, the strategic aspects of maintenance and Asset Management should be emphasized. However, the connection between Asset Management and the corporate strategy is often lacking (Komonen et al., 2012).

Asset Management Considers the Relevant Risks and Regimes

Asset Management should take relevant risks and regimes into account. Risks can be failures or safety risks, the type of risks most maintenance methods focus on (e.g. RCM or Condition-Based Maintenance [CBM]). However, risks may also be related to topics as diverse as production errors, reputation, sustainability, or cyber security. Asset Management should also consider regimes, which relate to the external developments mentioned earlier: new regulations, changes in the labour market, social pressure to increase sustainability, or a lobby to improve working conditions.

The concept of risks emphasizes the inherent uncertainty related to Asset Management. Asset Management should consider the asset's complete life cycle, but our knowledge of the future is incomplete by definition. Additionally, often only limited information on the asset is available, and—as Asset Management is a multidisciplinary practice—this information may be dispersed over different people, departments, and software systems. In addition, the quality of data (e.g. failure data or condition data) may be unreliable (Braaksma, 2012). Nevertheless, decisions have to be made about the assets and the allocation of resources to the assets.

Asset Management Determines the Allocation of Resources

Ultimately, Asset Management is all about the allocation of resources. Where should money be invested? Where may a reduction of working hours be achieved? What maintenance tasks are necessary, and which may be postponed? Which activities do we do ourselves, and which can be carried out by service providers in a more cost-effective way? The allocation of resources applies to both the daily operations (e.g. production schedules, spare part availability) and the strategic management of the assets (e.g. the budget reserved for an overhaul or the purchase of a new asset). Many methods and tools exist that may be used to effectively allocate resources, especially for operational and tactical planning. The field of maintenance management addresses these topics (for two good reviews of this topic, refer to Frangopol, Saydam, & Kim, 2012; Garg & Deshmukh, 2006).

Asset Life Cycle Management (ALCM)

To conclude, Asset Management should be a multidisciplinary practice focusing on the achievement of changeable corporate objectives over the complete life cycle of the asset and taking into account the relevant external developments and risks. Such a strategic, multidisciplinary, and long-term approach to Asset Management will be termed Asset Life Cycle Management (ALCM) throughout the remainder of this chapter.

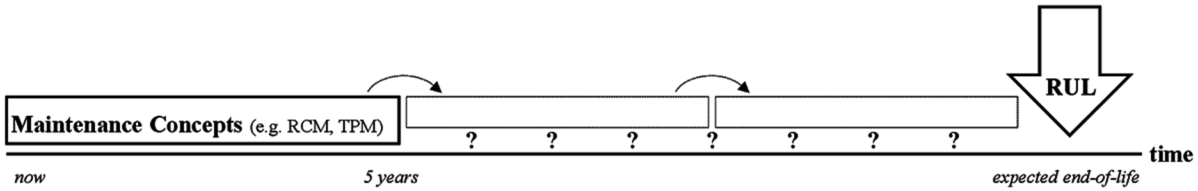
LIFETIME IMPACTS

Asset Management ultimately focuses on the realization of business value from the use of physical assets over their complete lifetime. For the short term, maintenance concepts such as Reliability Centred Maintenance (Moubray, 1997; Smith & Hinchcliffe, 2003), Total Productive Maintenance (Wireman, 2004), and many others exist (Waeyenbergh & Pintelon, 2002). These often produce an overview of maintenance tasks to be carried out in a certain time period, and these same tasks may be repeated over and over again. Additionally, there are many tools available to continuously improve the performance of assets, such as Pareto analysis or root cause analysis (e.g. Ishikawa diagrams) (for an overview, see Zaal, 2013).

Looking at the remainder of the asset's life, many approaches exist that focus on the estimation of the Remaining Useful Life (RUL) of the asset (e.g. Si, Wang, Hua, & Zhou, 2011). These tools and methods aim to estimate the point in time when the asset will cease to perform its function because of technical failures, for example, after a specified amount of operation hours.

Maintenance concepts and RUL estimation cover the short term and the end of the asset's life. What is lacking is a method that covers the period in between, a method that assists the asset manager in ensuring the asset remains valuable to the company in a changeable context (see Figure 2). After all, repeating the same maintenance tasks during the asset's lifetime may overlook internal or external changes to the company that may have an impact on the asset. These changes may present opportunities or threats that have an impact on the realization of value from the use of the asset. Therefore, they should be taken into account to ensure a maximum contribution of the asset to the business objectives. Additionally, both the maintenance concepts and RUL estimation primarily take a technical perspective on the asset, rather than the multidisciplinary approach that is important in Asset Management.

Figure 2. The gap in asset management between maintenance concepts—covering the short term and sometimes repeated periodically—and the outcome of RUL estimations giving the expected end-of-life of the asset



To fill this gap in the asset's life cycle, the authors have proposed the concept of "lifetime impacts" in earlier publications (Ruitenburg, Braaksma, & van Dongen, 2014; Ruitenburg & Braaksma, in press). Lifetime impacts can be defined as "probable (technical and non-technical) events or trends that may have a positive or negative influence on the value creation with the asset in the intermediate or long term" (Ruitenburg & Braaksma, in press).

The concept of lifetime impacts is explained most easily using an analogy of the Titanic. For a moment, imagine yourself as the asset manager responsible for the safe and reliable operation of the Titanic. From a purely maintenance perspective, you might carry out a sophisticated FMEA-analysis to create a maintenance program to keep this massive, valuable ship in optimum condition. Additionally, an RUL-estimation could give an idea of the projected end-of-life moment of the vessel, based on assumptions of operation hours, operation conditions, and knowledge of degradation mechanisms. However, it is well-known that neither the maintenance program nor the RUL-estimations would have prevented the Titanic from sinking. It was an iceberg that brought this massive, high-tech asset to a premature end, resulting in massive financial and reputational losses, not to mention the human tragedies caused by this event.

One of the many intriguing stories surrounding the Titanic disaster is about the lookout in the crow's nest (Salkeld, 2007). It is said that he did not have the key to open the locker with the binoculars. In the official inquiry, the lookout was asked about the consequences of the lack of binoculars. He stated that, with binoculars, "We could have seen it [the iceberg] a bit sooner." When asked, "How much sooner," he replied, "Well, enough to get out of the way."

Just as a single iceberg sank the Titanic, there are many proverbial icebergs that may impact the creation of business value with an asset (see Figure 3), for example, a large increase in the costs of spare parts or the ban of a certain toxic substance used in the asset. Only through timely identification of such icebergs can timely measures be taken to circumvent them. Knowing the remaining useful lifetime will only become relevant if the asset does not find a premature end-of-life due to the consequences of a lifetime impact.

Figure 3. Lifetime impacts[1]

For example, a plant in the process industry only produces business value as long as it complies with regulations on safety, emissions, hazardous materials, etc. If a change in regulation, which would be a lifetime impact, makes the operation of the plant illegal, the plant may need to be shut down. In such a case, the plant will be worthless to the asset owner, irrespective of its technical condition and remaining useful life.

Five Perspectives

As ALCM is a multidisciplinary practice, the lifetime impacts that are relevant for an ALCP should be multidisciplinary as well. Based on an industry project of Dutch asset owners (R. van Dongen, 2011) and a first application of the concept of lifetime impacts in practice (Ruitenburg & Braaksma, in press), five different perspectives have been identified. Using the Titanic analogy, there are five different types of binoculars to look into the future in order to identify the relevant opportunities and threats.

1. **Technical Perspective:** Technical lifetime impacts concern the ability of the asset to comply with the technical specifications set regarding its technical condition and performance. Reliability, availability, production quality, remaining useful lifetimes, and bathtub curves are all related to this perspective.
2. **Economic Perspective:** The economic perspective is concerned with the financial aspects of the asset and its operation. Does the asset still deliver financial value to its user or owner? Maintenance costs, operating costs, costs of spare parts, life cycle costing, and total cost of ownership are relevant concepts here.
3. **Compliance Perspective:** The compliance perspective asks if the company is still allowed to operate the asset. This perspective looks at all kinds of regulation (e.g. safety, environmental, worker conditions, or hazardous materials). Additionally, the social acceptance of the asset and its operation is relevant here since a decreasing acceptance may precede official regulation.
4. **Commercial Perspective:** The commercial perspective looks at the extent to which the asset still fulfils the demands of the market. An asset producing Discmans or mp3 players may be in great condition from a technical perspective, but it probably no longer fulfils the demands of the market.
5. **Organizational Perspective:** Finally, the organizational perspective concerns the ability and willingness of the company to operate the asset. There may be a lack of specialized knowledge limiting the ability of the company to maintain the asset in the desired condition, or the organization may aim for an increased standardization of its assets. This may make certain asset types redundant for the company, even though from the other perspectives there may be no reason to decommission these assets.

These five perspectives, abbreviated by the acronym TECCO, together give a multidisciplinary insight into the main lifetime impacts regarding the future of the asset. The perspectives are not intended to be mutually exclusive. For example, an incentive towards a more sustainable operation of the assets may come both from social pressure (Compliance) and from higher management (Organizational), or a certain degradation mechanism (Technical) may result in higher maintenance costs (Economic). Using these five perspectives to look into the future will help the asset manager identify the most important lifetime impacts for the asset.

Asset Life Cycle Plans

The identification of lifetime impacts is a crucial step to ensure continuous value creation with an asset over its complete lifetime. However, knowing these impacts in itself does not necessarily result in the desired performance of the asset, nor in an alignment of the operation with the asset and the corporate objectives. Therefore, in response to the required "life cycle approach" by ISO 55000, this paper proposes the concept of the Asset Life Cycle Plan (ALCP). In their earlier research, the authors carried out a case study on Asset Life Cycle Management (ALCM) using these ALCPs at a rolling-stock maintenance company (Ruitenburg et al., 2015). In this company, the ALCP was used as a means to align corporate objectives with the management of trains, as well as to communicate the expected performance and the associated costs of the train to the relevant stakeholders (idem). In this way, the ALCP can be a means to assist ALCM practices in a company and to support strategic Asset Management decisions.

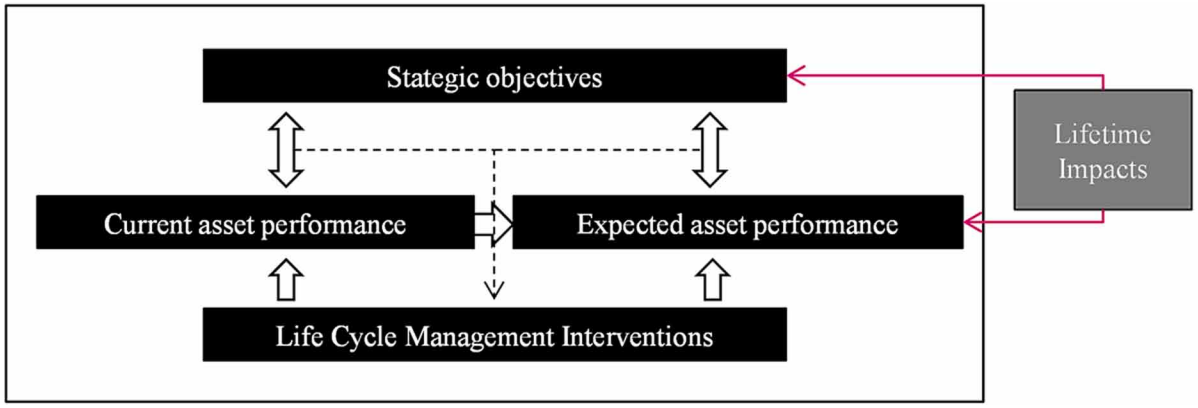
Figure 4 shows the main structure of the ALCP. This structure has been developed based on the means-end analysis (Holmström, Ketokivi, & Hameri, 2009), the Pyramid Principle for structuring texts (Minto, 2008), and the ALCPs in the case study on ALCM carried out by the authors (Ruitenburg et al., 2015).

The ALCP starts with the strategic objectives the company has for the asset. These are compared with the current and expected performance and costs of the asset. If the performance does not comply with the objectives, interventions may be needed to bring the performance into accordance with the goals. Lifetime impacts may have an impact on either the strategic objectives (e.g. goals for the reduction of CO_2 emissions) or the asset's future performance and costs (e.g. higher costs due to higher spare part prices). In the ALCP, the main focus lies on the value realized from the exploitation of the asset. This involves the continuous alignment of the asset's performance with the corporate objectives in a changeable context.

This general structure has been translated into the following chapter structure for an ALCP:

0. **Management Summary:** States the main message of the ALCP, aiming at higher management. This should answer the question, "What needs to be done to keep the asset (population) valuable to the company in the long term?"
1. **Introduction:** Gives a brief introduction to the ALCP, including its purpose, aim, the scope of the ALCP, and an outline of the document.

Figure 4. The structure of the ALCP



2. **Strategic Objectives and Function:** Lists the main corporate goals relevant for the asset and the main strategic developments and decisions that are relevant, for example, the aim to enter new markets. Additionally, it states how the asset contributes to these goals.
3. **Current Situation and Performance:** Gives an overview of the main characteristics of the asset (population), including its age, main components, replacement value, and a brief summary of the current maintenance policies. It lists the current performance of the asset related to the strategic objectives and relevant goals for the asset. Since ALCM is a multidisciplinary practice, the performance should be measured from different perspectives as well, for example, production output, availability, reliability, maintenance costs, and safety.
4. **Lifetime Impacts:** This chapter lists the main lifetime impacts that affect the value the asset will have for the company in the future. Lifetime impacts are listed for all five TECCO perspectives. Attention is paid to both positive and negative lifetime impacts.
5. **Expected Performance and Costs:** Based on the current performance and the effects of the lifetime impacts identified, an overview of the expected performance on the asset objectives and the costs of the asset is given. This may be by means of KPIs or other quantitative measures, but can be qualitative as well.
6. **Life Cycle Management:** Based on the analysis thus far, this chapter recommends actions be taken to keep the asset valuable to the company. This may include additional maintenance, design changes, overhauls, modernization projects, preventive replacement, and actions to collect information needed to manage the asset more effectively in the future.
7. **List of Actions:** Gives an overview of the main actions resulting from the ALCP, including projected start and end dates and the responsible person or department.

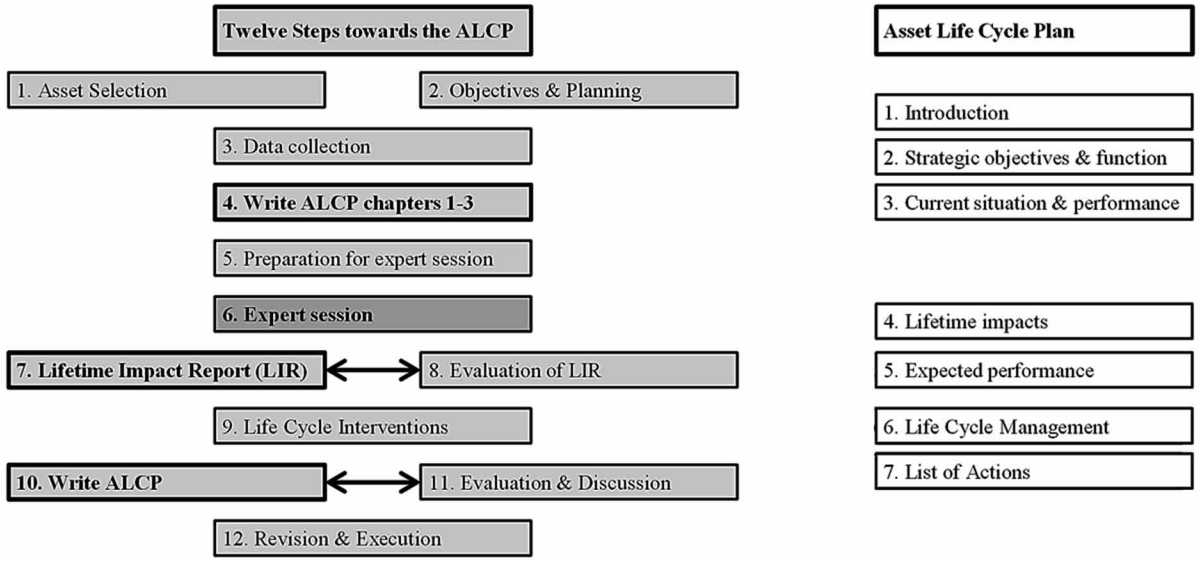
WRITING AN ALCP: STEP-BY-STEP INSTRUCTIONS

Writing an ALCP is not just a matter of writing a number of chapters according to a specific structure. It is not so much the structure that is important, but rather the process of creating an ALCP. One of the main challenges of writing an ALCP is to bring all the relevant knowledge, information, and expertise on the asset together in one document. As previously stated, Asset Management is a multidisciplinary practice. Many companies are used to organizing these disciplines in separate functional silos. This information is often scattered over different databases (e.g. failure data vs. maintenance budgets vs. outsourced maintenance), departments (e.g. regulation vs. operations vs. financial vs. purchasing), and documents (e.g. maintenance manuals vs. market trend reports vs. company strategies). Additionally, certain pieces of information may not be available in explicit form, but are rather stored in the heads of people working with the assets.

To structure this process, a twelve-step approach has been designed. The twelve steps are based on the Lifetime Impact Identification Analysis (LIIA) method, as presented in an earlier publication by the authors (Ruitenburg et al., 2014; Ruitenburg & Braaksma, in press), and on the experience of the first author with the writing of ALCPs.

The twelve steps can be used as a guide to develop an ALCP. Some of the steps may be carried out in tandem, but the order of the steps has been designed in such a way that each step produces the preconditions for the next steps (see Figure 5 for an overview of all twelve steps and their relation with the ALCP).

Figure 5. The twelve steps towards the ALCP, including its relation to the ALCP document. The three deliverables in the process are indicated in bold.



The description here is aimed primarily at the person responsible for the creation of the ALCP. Oftentimes this will be the asset manager. Not only should the asset manager take the lead over writing the ALCP, but they should also act as a director of the execution of the twelve steps that will be presented.

To illustrate the twelve steps, a case is presented from Liander, a Dutch network operator applying ALCPs in their Asset Life Cycle Management practices. Please refer to the illustration presented in Appendix 1.

Step 1: Asset Selection

The first step is the selection of the asset (population) as the topic of the ALCP. This may seem obvious, but it requires some thought. Depending on the availability of information and the depth of the analysis, the whole process of writing an ALCP may take one fully employed asset manager a couple of weeks. Therefore, only those assets should be selected that deserve such an investment of time. For example, assets with questionable performance or assets on the verge of an important life cycle event, like a modernization or overhaul, or maybe assets with a high criticality for the company or those representing a very large financial value. Additionally, a very dynamic environment may increase the desire for an ALCP to investigate the consequences for the asset.

Additionally, the level of detail of the analysis has to be determined. What are the system boundaries that will limit the analysis? Will the analysis cover the asset as a whole, or will it take the main functional components as the object of analysis? When a population of similar assets is taken as the subject, scoping decisions have to be made. What assets are similar enough to be treated as one population, and which are too different? It is important to reason from the function of the asset and the value it produces rather than the technical characteristics. Some assets may be different from a technical point of view but can be treated as similar in an ALCP because they have the same function and need to fulfil the same

objectives. Certainly, when differences between subpopulations are relevant, these should be reported, but only if necessary for the main message of the ALCP.

Step 2: Determination of Objectives, Target Audience, and Preliminary Planning

Now that the topic for the ALCP has been chosen, the main objective of the ALCP has to be determined. What questions does the ALCP have to answer, and what needs need to be satisfied? This clearly relates to the target audience of the document. This may be higher management or the asset manager for whom the ALCP can be a working document and a way to set the right priorities. Depending on the target audience, a short and preliminary answer to the main question(s) of the target group can be given. This may help the writer(s) of the document set the right focus for the document. Such a core message may be, "In the short term, the asset performs well, but due to changing market conditions a business case should be made to determine if the life of the asset should be extended."

Next to the content of the ALCP, the target audience may have special requirements for the presentation of the ALCP, for example, format, layout, length, or use of data. These requirements should be made clear at this stage to prevent potential rework later in the process. Throughout the remainder of these steps, the target audience and the company at large will not be discussed again. However, this is clearly important to effectively meet the demands of the target audience.

Additionally, this is the moment to set preliminary planning. Input is needed from other departments and people, and these dependencies should be managed to make the process of writing an ALCP as efficient as possible. Depending on the organization and the availability of information within the organization, the collection of information from different departments may take several weeks to months.

Step 3: Data Collection

Now that the goal of the ALCP has been set, the time has come to collect all the information that is needed to answer the main question(s) of the target audience. The information should cover at least three different topics:

1. **The Corporate Objectives Relevant for the Asset:** What are the business values the asset should contribute to (e.g. safety, reliability, costs, and customer satisfaction)? And what strategic decisions have been made that are relevant for the asset? An example would be the decision to enter new markets to increase quality or quantity of production, or maybe to become a front-runner in sustainability. These objectives set the stage for the remainder of the ALCP. The asset is only valuable insofar as it contributes to these objectives. Therefore, it is of crucial importance to align the management of the asset with these goals.

Next, these (often relatively broad and intangible) objectives should be translated to specific goals for the asset. What does the asset have to achieve? This can be done by means of KPIs or other quantitative measures. Alternatively, this can be qualitative descriptions of performance, such as a continuation of the contract with the main customers or a happy workforce. However, it may still be advisable to make these objectives measurable in some way since this will make it easier to determine if a goal has been reached.

2. **Static Asset Data:** The asset should be described in a way that gives the target audience a better background on the asset. As the ALCP may be used in departments not directly involved with Asset Management, for example, in the strategy department or the purchasing department, some of the most important facts and figures may be needed: at least function, age, (replacement) value, population size, projected date of decommission (if any), and a brief overview of the current maintenance policy.
3. **Dynamic Asset Performance Data:** Next to the static data, the current performance of the asset should be reported and related to the objectives relevant for the asset. The performance should be reported in a multidisciplinary way, covering, for example, the five TECCO perspectives. At least the production output of the asset, its reliability/availability, safety, and cost performance should be covered. Ideally, the performance should be given over a period of time (e.g. the previous five years) to give an indication of the trends visible in the performance. This will also allow a better prognosis of future performance.

It is important to note that this information will probably not be available within one department; hence, there is a need to cooperate with the relevant people to bring all the information together. This may very well cross functional boundaries within, and maybe even across, the organization. While this may be a cumbersome and time-consuming process, it is crucial to establish a multidisciplinary Asset Management. Additionally, it is a way to bring the relevant stakeholders together and to get them involved in the process of writing an ALCP. As a result, the ALCP can be positioned as a "shared understanding" of the performance of the asset and its future.

Additionally, one should realize that—especially when writing the first ALCP—not all relevant information may be available for the ALCP. This is an excellent opportunity to identify the relevant information gaps (see also Haffejee & Brent, 2008) and to discuss which information may be necessary for an effective management of the assets. Depending on the costs of collecting this information, new information may be collected for a future ALCP.

Step 4: Writing the First Chapters of the ALCP (Chapters 1-3)

With the work done thus far, the first three chapters of the ALCP can be written. The reason to start writing the ALCP is threefold:

1. It can serve as a first tangible milestone in the process of crafting an ALCP;
2. It allows a first discussion with the stakeholders on this fundamental part of the ALCP; and
3. It is an important input for the next steps, where the main lifetime impacts relevant to the asset will be identified using one or more expert sessions.

Please refer to the illustration presented in Appendix 2.

Step 5: Preparation for the Lifetime Impact Identification Expert Session[2]

As stated before, it is crucial in Asset Management to look ahead and to notice proverbial icebergs in the future. The identification of these lifetime impacts will be done in Step 6 by means of an expert ses-

sion. The current step prepares for this session. The preparation consists of content-related and practical preparation.

Content-Related Preparation

The main goal of content-related preparation is to collect the relevant information to identify the lifetime impacts. A large part of this information was already collected in Step 3 and reported in Step 4. But there is some additional information that may be relevant, since the information from Steps 3 and 4 predominantly describes the current and past situations while lifetime impacts relate to the future. Therefore, information should be collected regarding the future of the asset. This may include scenarios of market developments, analyses of failure data (e.g. bathtub curves), Remaining Useful Life (RUL) estimations of components, cost prognoses, or lists of upcoming changes in regulation. It may be useful to think about the information that may be available within the company on future developments from the five TECCO perspectives. The goal is not to get a full overview of every bit of information within the company but instead to facilitate an efficient and effective expert session. There is a trade-off to be made here: more time spent on the preparation of the expert session will reduce the time spent in the session.

Practical Preparation

Practical preparation mainly concerns the organization of the expert session(s). This starts with the selection of the experts to be invited. It is advisable to invite experts from the five different TECCO perspectives and to keep the group size limited to between four and eight persons. Since many experts have to be able to join the meeting, setting a date for the meeting should be done several weeks in advance. Additionally, the goal of the meeting should be explained, as should the uses of an ALCP. Some of the experts may have already been involved by providing information in Step 3; others may be new to the concept of an ALCP. Still others may have little knowledge of the asset (e.g. a financial or regulation expert). A level playing field should be created to allow them to join the discussion in the expert session. This can be achieved by distributing the first chapters of the ALCP, as written in Step 4. The experts may be asked to prepare themselves for the meeting, for example, by preparing a short statement to start the discussion on the TECCO perspective they represent.

Other than the experts, it is important to think of two other roles. The first is the chair or facilitator of the expert session. This person should guide the expert session, keep the discussions focused, keep track of the time, and may need to ask relevant questions that are overlooked in the session. These may, for example, be topics that were raised in the content-related preparation. It is recommended that a list of topics that need to be discussed be prepared for the facilitator. Additionally, the facilitator should make sure that sufficient attention is paid to both positive and negative lifetime impacts. It is not necessary for the facilitator to be an expert on the asset, but the facilitator must have the right chairman skills to keep the discussion efficient. The second role is the secretary or note-taker, who records the discussion.

Furthermore, the structure of the session should be prepared. This may include a time schedule and a presentation that guides the process and gives the necessary information inputs and a background on ALCM and lifetime impacts.

Step 6: The Lifetime Impact Identification Expert Session

The expert session lies at the heart of the process to write an ALCP. In the expert session, experts are brought together to share their knowledge and expertise. This resembles the expert sessions as used in the Failure Mode and Effect Analysis (FMEA) to develop maintenance plans in RCM (Moubray, 1997). Regarding the ALCP, the expert session is the means by which all the information collected in the previous steps is processed, combined, enriched with the tacit knowledge of the experts, and put to use in the identification of lifetime impacts. This section will present the main parts of the expert session. Additionally, two important topics related to the expert session—time and uncertainty—will be discussed at the end of the section.

Introduction

The expert session starts with an introduction. In the introduction, the experts should briefly introduce themselves since some may be from very different departments. Additionally, the ALCP, lifetime impacts, and the different TECCO perspectives are explained, for example, using the Titanic analogy.

Evaluation of the Current Maintenance Program

After the introduction, the expert session proceeds with an analysis of the current maintenance program because some lifetime impacts may be hidden in the current maintenance program. For example, the maintenance program may prescribe certain maintenance actions that are not carried out in practice or the work quality may be poor. Alternatively, a critical evaluation of the current maintenance policy may reveal opportunities for improvement, for example, by adopting new innovative techniques or by lengthening the maintenance intervals. After a critical discussion of the current maintenance program and its execution, the current maintenance program will be out of scope for the remainder of the expert session.

The Identification of Lifetime Impacts

After this evaluation, the time has come to look into the future and to identify the relevant lifetime impacts. This is done by means of the five TECCO perspectives, which are used as binoculars to look into the future from a certain perspective. Each perspective is discussed separately to ensure that explicit attention is paid to each of the perspectives. The goal is to identify the main lifetime impacts for each perspective, negative as well as positive. The discussion begins with an introductory statement from the expert representing the relevant TECCO perspective. Then, the other experts react to this statement while the facilitator facilitates the discussion in order to get a good overview of all the relevant positive and negative lifetime impacts. The focus should be on the likelihood of the impact, its effect, and the certainty of the expert(s) on the impact. The amount of discussion on a lifetime impact may be a useful indicator of the level of certainty: the more disagreement among the experts, the lower the certainty.

Each discussion ends with a brief summary by the facilitator or the note-taker to verify that the most important impacts have been identified. This may trigger additional discussion because it may take a moment to realize that something important has not yet been discussed.

If there are specific future scenarios available within the company (e.g. describing different demands from the market), these may be used to elicit additional lifetime impacts. In this case, after the discussion

of the TECCO perspectives, each scenario is discussed separately. Some scenarios may give rise to additional lifetime impacts while others may make certain lifetime impacts that were already identified more important while reducing the importance of others. Additionally, one may make use of brainstorming techniques to elicit the lifetime impacts. For example, the expert session may start off with a brainstorm using sticky notes where each expert can individually write down the lifetime impacts considered relevant.

Closure

At the end of the session—with an advised length of no longer than four hours, including one or two breaks—the session is closed. The closure should include an outlook on the remainder of the process. If a second expert session is needed, this can be planned. In addition, the next steps in the process should be explained, including the possibility to give feedback on the Lifetime Impact Report (see Step 8).

Two Notes on the Topics of Time and Uncertainty

The expert session may raise an important topic of discussion: the time horizon used in the identification of lifetime impacts. Are all lifetime impacts relevant, or does one limit the discussion to impacts within a certain timeframe (e.g. five or ten years)? This depends on the needs of the target audience of the ALCP: Do they want an overview of the lifetime impacts to expect during the next five years, or would they rather know all impacts to expect during the asset's remaining life? Either way, it may be advisable to pay attention to the complete life cycle of the asset. Some high-impact lifetime impacts may have an influence on short-term interventions. For example, in a modification of the asset, future changes in regulation should be taken into account. Additionally, the time horizon may depend on the flexibility of the organization compared to the changeability of its context. If the context is highly changeable while the organization needs a long time to adapt the asset or its operation to these new circumstances, there may be a need to look further into the future, and in more detail. If the organization is very flexible and the context is stable, the time horizon for a detailed analysis may be shorter. Irrespective of the time horizon chosen, the facilitator needs to ensure that the discussion covers the complete time horizon rather than just covering the lifetime impacts nearby.

Additionally, the topic of uncertainty may require some attention here. Some lifetime impacts are known to happen in the future (e.g. if a supplier has announced it will stop the production of spare parts); others are uncertain (e.g. changing regulations). For some, the effect on the asset's performance may be clear; for others, this is entirely unsure. It may be advisable to elicit all reasonably likely lifetime impacts. However, it may not be necessary to think of suitable interventions for all of these because some may not be worth the effort. Additionally, the interventions may depend on the certainty of the lifetime impact: those that are certain may need direct action while those that are uncertain may need to be monitored or to be studied in more detail.

Step 7: Writing the Lifetime Impact Report (LIR)

A second important deliverable in the process is the Lifetime Impact Report (LIR). The LIR lists all the lifetime impacts identified during the expert session. Additionally, it relates these to the performance of the asset. This gives a first idea of the future performance of the asset. Some impacts may, for example, only relate to the maintenance costs of the asset (e.g. higher price of spare parts) while others may

relate to many performance measures (e.g. technical degradation of a specific component may result in downtime, lower reliability, and safety risks). Additionally, some lifetime impacts may be very hard to directly relate to the performance but may be very important to register, for example, the realization that it becomes harder to find skilled technicians, which in the long term may reduce the maintenance capacity of the organization.

It is important to list all of these lifetime impacts, including the less likely or seemingly unimportant ones. These may not all find their way into the final ALCP, as the effect of some impacts on the value creation with the asset may be negligible. However, the asset manager may want to monitor these by revisiting the list periodically to see if new developments make one of these more important. In this way, the LIR can be viewed as a priority list for the asset manager: it lists all the potentially important lifetime impacts on the asset. Some may be considered very important, others may seem irrelevant, but depending on the future developments, all may require the attention of the asset manager at some point in time.

There are four other uses of the LIR that are worth mentioning. The first function is to get feedback from the experts in the expert session. Second, the LIR may be used as an input when decisions need to be made regarding life cycle events, such as overhauls or modernization. The LIR can then be used as an overview of everything that may be relevant and ensures that no important issues are overlooked in the decision-making process. Third, the LIR can be used as an input to the expert session for other ALCPs. Some impacts may not be very relevant for one asset but may have a large impact on others. In this way, the LIR facilitates information sharing. A final use of documenting these insights is that important expertise is made available on paper, which makes the company less vulnerable if knowledgeable employees leave.

Please refer to the illustration presented in Appendix 3.

Step 8: Evaluation of the Lifetime Impact Report (LIR)

Now that the LIR has been written, summarizing the lifetime impacts and their impacts on the asset performance, it can be discussed with the experts that were present in the session. One could organize a special evaluation session for this purpose, have short meetings with each of the experts individually, or just send them the LIR and ask for their feedback. Irrespective of how this is done, it is crucial to ask for the input of the experts again. They may think of additional impacts, may criticize the summary, or they may comment on the effects on the asset performance as described in the LIR. In addition, they may give different priorities to the lifetime impacts listed.

Additionally, the LIR may be used to involve other experts in the process, for example, those that could not be present at the expert meeting or those with a very specific expertise that may shed light on specific lifetime impacts.

By taking the time for an evaluation, the resulting ALCP will be more reliable. Additionally, the ALCP will become more of a shared understanding of the future of the asset, rather than just a view of the asset manager writing the ALCP.

Step 9: Think of Appropriate Life Cycle Management Interventions

After rewriting the LIR based on the feedback of the experts, a joint understanding of the main lifetime impacts relevant for the asset evolved. Based on this understanding, it may be necessary to take actions to prevent negative lifetime impacts from happening (or to reduce their effects) or to grasp the full potential

of positive lifetime impacts. In other words, there may be a need for life cycle management interventions. These interventions may range from changes in the maintenance program, starting pilot projects to test out new innovations, or the collection of additional information on particular lifetime impacts to design changes, overhauls, modernization projects, or even the preventive replacement of particular assets. Additionally, some lifetime impacts may be very uncertain and/or only materialize over time, and monitoring their progress may be sufficient.

Whatever the specific solution, it may be important to give a brief indication of the cost of the solution, its benefits, and the moment in time when actions will have to be taken. Still, for the asset manager, some actions may have a high priority and need to be listed.

Important to note here is that the ALCP is not meant to be a decision-making document. Rather, it is a document that gives an overview of the asset, the main future opportunities and threats, and the recommended actions to be taken. In most organizations, a specific decision-making process will exist, which needs to be followed to make large and high-impact decisions. Nevertheless, just giving an overview will probably not satisfy the needs of the target audience. Hence, it is important to think of the main actions that are necessary to produce maximum business value with the assets in the long term.

Step 10: Writing the ALCP

The tenth step is the actual writing of the ALCP. The first three chapters have already been written in Step 4. The information for Chapters 4 and 5 can be taken from the LIR. The information for the remainder of the ALCP was collected in Step 9. The chapter on life cycle management should list the main actions to be taken and their main consequences. Additionally, it gives an outlook regarding the future of the asset, for example, by means of a description of the situation in 10 or 20 years. In this way, the target audience can be prepared for decisions that may need to be made in the future, as well as their consequences. In this way, the ALCP is not just a document that gives an overview of the future of the asset. It is also a communication device to manage expectations and to create a shared understanding of the future of the asset.

Please refer to the illustration presented in Appendix 4.

Step 11: Discussion and Evaluation with Target Audience and Other Relevant Stakeholders

The ALCP itself is just a piece of paper, irrespective of the huge amount of effort, time, and expertise it has taken to produce. It has to be put to use. This happens by means of a presentation of the ALCP to the target audience and other relevant stakeholders and a discussion and evaluation of the main results. If the target audience is higher management, they may be especially interested in the financial implications of the ALCP and the main decisions that need to be made. The ALCP may help create a joint understanding of the future of the asset and facilitate decision-making on strategic issues relevant to the asset.

If the discussion and evaluation of the ALCP give rise to changes in the ALCP, these need to be made. Then the ALCP can be accepted and authorised by the target group and/or the management. This makes the ALCP not only a joint understanding of the asset's future but also the official view of the organization.

Step 12: Determine Revision Date

It is important to realize that the ALCP is not a one-time exercise. Rather, it is a way of doing Asset Life Cycle Management. This implies that every ALCP will need to be kept up to date. Depending on the internal and external dynamics relevant to the asset, this may need attention every one to five years. Updating an existing ALCP will of course take less time because only the changes to the previous ALCP will have to be processed. However, it is of crucial importance to carry out a new expert session because new lifetime impacts may appear on the horizon.

The revision date should be set already to make sure a revision will be carried out in time. Still, it may be necessary to do some updates before the revision date, for example, if a large life cycle event happens or a large decision needs to be made.

This is also the moment to start the execution of the actions listed in the final chapters of the ALCP. Their results can be reported in the next ALCP, and their impact on the performance can be evaluated. In this way, a loop is created, from objectives, current and expected performance, and the development and execution of lifetime interventions to the evaluation of the new performance. This loop results in a growing understanding of the asset and a more effective management of the asset.

Please refer to the illustration presented in Appendix 5.

CONCLUSION

Asset Management should aim to create maximum business value from the use of physical assets. To do so, it is crucial to take a multidisciplinary approach towards Asset Management, to be aligned with the corporate objectives, and to focus on the complete lifetime of the asset. Asset Life Cycle Management (ALCM) has been used to describe this "ideal" way of doing Asset Management.

To assist strategic Asset Management decision-making, an integrated insight into the remaining lifetime of the asset is necessary. This insight can be developed by the use of an Asset Life Cycle Plan (ALCP). An ALCP starts with the strategic objectives a company has for the asset in order to let it create business value. The current and expected performance of these objectives is reported to show how the asset delivers business value. Additionally, future impacts and trends on the value creation with the asset are identified, and their effect on the performance is estimated. Finally, the ALCP gives an overview of the Asset Life Cycle Management interventions that may be useful to secure or increase the asset's value for the company.

Current maintenance concepts and tools primarily focus on the short term of the asset's life and often do not take a multidisciplinary perspective; hence, these tools do not assist in the identification of future impacts and trends with an impact on the asset. To support strategic decision-making in Asset Management, the identification of these "lifetime impacts," as they have been called in this paper, is vital. Therefore, a twelve-step approach has been presented to identify lifetime impacts from a multidisciplinary perspective. Five different perspectives are used for the identification: Technical, Economic, Compliance, Commercial, and Organizational (TECCO) lifetime impacts result. The lifetime impacts from these perspectives are identified by making use of the knowledge and information available within the company, primarily by bringing experts together in an expert session. In such a session, a joint understanding of the asset and its future will develop, and the relevant lifetime impacts can be identified.

By following the practical twelve-step approach presented in this paper, an ALCP can be written. The approach is illustrated with an ALCP written by Liander, the largest Dutch network operator. This illustration shows how an ALCP supports asset managers in making strategic decisions in a timely and effective manner.

DISCUSSION AND IMPLICATIONS

This final section discusses the conclusions from this chapter as well as the implications for further research and for practitioners. A first topic of discussion concerns the prioritization of lifetime impacts. During the expert session, many lifetime impacts will be identified. Which of these are the most important and most relevant then becomes the question. In RCM, the failure modes identified in an expert session are prioritized based on likelihood and effect size, resulting in a Risk Priority Number (RPN) (Moubray, 1997). A similar approach may be applicable to lifetime impacts.

Second, further research may also address the question of how to mitigate negative lifetime impacts and to exploit the full potential of lifetime impacts. The twelve-step approach presented in this chapter does not offer much guidance on this topic. The identification of lifetime impacts will only deliver value if the right interventions are made in a response to the lifetime impacts identified.

A third topic to discuss is the generalizability of the ALCP and the steps presented in this chapter. While developing the method, the authors aimed for a general applicability in Asset Management. The focus on the creation of business value allows users to adapt the method to a specific industry. However, thus far the ALCP has only been applied in populations of similar assets in the energy sector.

A last issue concerns the title of this book: *Optimum Decision-Making in Asset Management*. The authors are of the opinion that optimum decisions do not exist in long-term Asset Management. Obviously, some decisions are better than others, and some may be plainly wrong. But as one never knows what the future holds, making optimum decisions on the long term is a myth. Rather than optimal decisions, good and timely decisions are needed. Therefore, this chapter has set out to assist asset managers with the difficult and uncertain decisions they often need to make.

IMPLICATIONS FOR PRACTITIONERS

Apart from the twelve practical steps to develop an ALCP, this chapter has four important implications for practitioners in Asset Management. Firstly, practitioners should focus on the complete lifetime of their asset(s) to produce maximum business value for their companies. Since decisions made now may have important implications for the remainder of the lifetime of the asset, maximum value can only be created by taking the full lifetime into account. It is crucial that higher management supports this approach to Asset Management. Because many of the benefits of the ALCP will only be visible in the long term, the long-term support of management is needed. Such lengthened support will allow the asset manager to keep working with the ALCPs until tangible results can be seen in a higher value created with the use of the asset.

Secondly, this chapter has shown that Asset Management should be a multidisciplinary practice. One may compare the disciplines represented in one's Asset Management practices with the TECCO perspectives to see if all important disciplines are covered.

As a third implication, practitioners in Asset Management may ask themselves if their Asset Management practices have closed the loop of objectives, performance, interventions, expected performance, and new performance figures. Closing this loop will facilitate a process of continuous improvement.

Finally, this chapter has stressed the importance of the knowledge of experts. Often, asset managers face limited data availability and/or data of a doubtful quality. Additionally, the future is uncertain by definition. Nevertheless, decisions need to be made. The use of the knowledge of experts, added to existing information and data, may allow for better decisions to be made.

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KEY TERMS AND DEFINITIONS

Asset Life Cycle Management: An approach to Asset Management with explicit emphasis on the multidisciplinary and strategic approach to the performance of an asset and the business value created with the use of the asset throughout its complete life cycle.

Asset Management: An organization's structured and organized practice to create maximum value with its assets.

Life Cycle: The complete lifespan of a physical asset from design and construction to decommissioning and recycling.

Lifetime Impact: A probable (technical and non-technical) event or trend that may have a positive or negative influence on the value creation with the asset in the intermediate or long term.

Long Term: Refers to the longest time horizon applied in an organization. Depending on the organization, the long term may commence from 3 up to 15 years into the future (after the short and intermediate term).

Multidisciplinary: A practice in which different fields and specialities are deliberately brought together.

Physical Asset: Any physical object having an expected lifetime of at least 10 years and representing a significant value to its owner, both in terms of money and the function it fulfils.

Strategic: Related to the corporate strategy.

Strategic Alignment: In agreement with the (corporate) strategy; the goals of the Asset Management department are tuned to the higher (corporate) strategy.

TECCO: Acronym to describe five important perspectives that need to be covered in order to make Asset Management multidisciplinary. TECCO is an acronym for Technical, Economic, Compliance, Commercial, and Organizational. TECCO is intimately linked to the identification of lifetime impacts.

ENDNOTES

[1] The picture of the Titanic is created by Boris Lux, available at Wikipedia (RMS Titanic, 2015).

[2] Earlier work of the author (Ruitenburg et al., 2014; Ruitenburg & Braaksma, in press) has introduced the Lifetime Impact Identification Analysis (LIIA), a method consisting of several steps. The twelve steps as presented in this chapter include and extend the steps of the LIIA.

APPENDIX 1

Illustration: An Introduction to the Use of ALCPs at Liander

Liander is the largest Dutch network operator, responsible for the safe and reliable distribution of electricity and gas to its 3.1 million customers. As shown earlier, the ageing of assets is a well-known issue in Western Europe. Liander experiences the same problem, as large parts of its networks were constructed in the 1960s and 1970s. Because many of the assets in the network have expected lifetimes between 40 and 60 years, large-scale replacement may be needed in the years to come. The current changes in the production and use of energy—often called the energy transition—offer an additional challenge. Distributed electricity production, for example, by means of solar and wind power, is on the rise, while new applications such as electric vehicles may cause a large increase in demand. This results in new demands on the existing electricity grid. To support the strategic decisions Liander has to make, the Asset Management department decided to start working with ALCPs.

One of the ALCPs covers the distribution transformers Liander operates. Its main question was, Is there reason to expect a large increase in the replacement rate of the distribution transformers? Since the population of distribution transformers consists of 28,000 assets, representing a replacement value of 200 million euros, this clearly is a strategic topic that has the interest of higher management. The twelve steps will be illustrated using both the process of developing this ALCP as well as the structure of the final document. The goal is not to show every detail of the ALCP, but rather to give the reader an idea of the scope and logic of such a document. For reasons of confidentiality, the numbers as well as some of the lifetime impacts presented in this example are fictive.

APPENDIX 2

Illustration: The First Three Chapters of the ALCP on Distribution Transformers

Chapter 1: Introduction

This ALCP describes the future of the population of distribution transformers for the coming 20 years. The main question it will answer is, Is there reason to expect a large increase in the replacement rate of the distribution transformers? The scope of this ALCP is limited to the 28,000 distribution transformers in the grid. The large majority of these assets transforms electricity from medium voltage (10 kV) to low voltage (400 V). Figure 6 shows a picture of a distribution transformer.

Chapter 2: Strategic Objective and Function

Liander aims to create maximum business value from the exploitation of its assets by achieving the required performance (i.e. availability, reliability, safety) at minimum costs and at an acceptable risk. The performance on each of the relevant KPIs should minimally remain constant in the next five years of operation.

Figure 6. A distribution transformer. In the interior the medium and low voltage coils are visible.

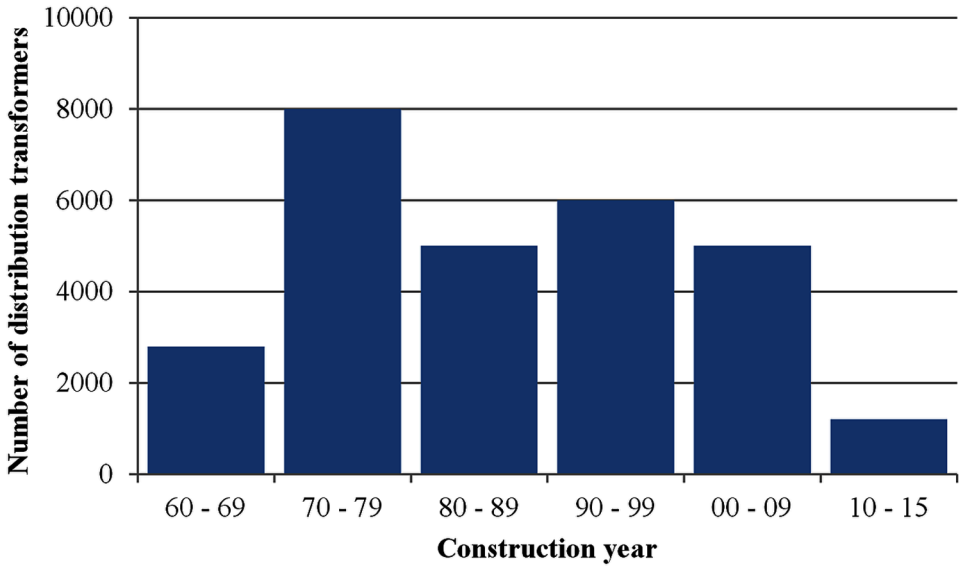
The main strategic developments relevant to the distribution transformers are energy transition and sustainability. The energy transition may cause temporal reversals of the electricity flow in residential areas with a high number of photovoltaic power cells or wind turbine generators. Since this is a new phenomenon, it is unknown if this will negatively influence the remaining service life of the asset. The corporate ambitions on sustainability aim for a strong reduction in CO_2 emissions. Because distribution transformers cause a significant part of the current CO_2 emissions through the energy losses inherent to the transformation process, the sustainability ambition may have implications for the distribution transformers. Additionally, Liander has decided to apply 20 kV on its medium voltage grids. This transition may take decades, but irrespective of its planning, which is currently unknown, the management of the distribution transformers should be aligned to its implementation since the 10 kV transformers will be obsolete in a 20 kV grid.

Chapter 3: Current Situation and Performance

Figure 7 shows the age of the distribution transformers of Liander (28,000 in total). The average age is 30 years, compared to an expected life of at least 40 years. Based on the current experience, this may be an underestimation of the life expectancy, which experts agree lies around 60 years. Currently, every year 600 transformers are replaced based on capacity (quality of the transformers is not yet a reason for preventive replacement). A preventive maintenance policy based on periodic inspections is used.

The current performance of the population is good. The reliability of the transformers is very high (99.98% reliability). Their contribution to the yearly outage per customer is less than 1%. Regarding safety, no incidents have been reported involving the distribution transformers. From a sustainability point of view, the energy losses of the transformers are substantially higher for older transformers.

Figure 7. Example of age distribution of distribution transformers (based on fictive numbers)



APPENDIX 3

Illustration: The Distribution Transformer Expert Session and the LIR

The Expert Session

The expert session was attended by eight experts from the departments of Asset Management, Innovation, Grid Planning, Purchasing, and Maintenance Execution. The session took four hours, which was barely enough time to discuss the five TECCO perspectives at sufficient length. Lifetime impacts were elicited in two ways: first, by means of an individual brainstorm using Post-it® notes, which were collected on five large sheets of paper (one per perspective). Second, each perspective was discussed in a plenary discussion. This yielded a total of 124 lifetime impacts. After filtering out double impacts and combining closely related ones, 34 unique lifetime impacts remained. The filtered-out lifetime impacts were retained on a list for safe keeping.

The LIR (Input for ALCP Chapters 4 and 5)

These 34 lifetime impacts were reported in the Lifetime Impact Report. Table 1 shows examples of the lifetime impacts reported in the LIR on the distribution transformers.

Based on the current performance of the transformers and the lifetime impacts identified, the performance is expected to remain at the current levels for the next five years. An increase in the amount of failures is not expected, even though the population is ageing. However, in the long term, three lifetime impacts may increase the need for replacement:

Table 1. Examples of lifetime impacts related to the distribution transformers for each of the five TECCO perspectives. Positive impacts (+) are listed on the left, negative impacts (-) on the right

Technical Lifetime Impacts	
+ Real-time load measurement may yield additional insights into the remaining lifetime of the assets. + The limited availability of condition data limits the insights into the remaining useful life of the transformers.	- The change towards 20 kV grids will render 10 kV transformers obsolete; the impact depends completely on the speed of this transition. - The energy transition may give rise to a need for power management in distribution transformers (On-Load Tap-Changers [OLTC]). Because modification of existing transformers is expensive and difficult, replacement may be necessary.
Economic Lifetime Impacts	
+ The use of aluminium coils may reduce the costs of new transformers (but this will increase the size of the transformers, limiting their suitability for existing stations).	- Increasing prices of materials (copper, aluminium) increases the price of transformers.
Compliance Lifetime Impacts	
+ None.	- New regulations on power quality and energy losses in transformers are under development.
Commercial Lifetime Impacts	
+ None.	- The energy transition may give rise to new demands, for example, power management in distribution transformers. - The use of DC (Direct Current) instead of AC (Alternating Current) in the grid would make transformers redundant.
Organizational Lifetime Impacts	
+ The use of bio oil in the transformers may increase their recyclability, fitting the organizational ambitions on sustainability. + Innovative amorphous transformers may reduce energy losses in new transformers.	- The technicians in the transformer workshop will all retire in the coming years, giving rise to potential capacity and knowledge problems. - Liander pays increasing attention to sustainability and energy losses, which may lead to the decision to preventively replace a substantial part of the population.

1. The energy transition may lead to new demands on the transformers (e.g. power management, additional monitoring), which may result in the modification or replacement of transformers in areas with a high local production of solar power.
2. The transition to 20 kV grids will make the existing 10 kV transformers obsolete.
3. The corporate ambition to reduce CO_2 emissions may lead to a replacement of the oldest transformers (which are still reliable but less energy efficient).

APPENDIX 4

Illustration: The Remaining Chapters of the ALCP on Distribution Transformers

Chapter 6: Life Cycle Management

Currently, there is no need for large changes in the current management of the distribution transformers. Innovations such as bio oil, OLTC, and amorphous transformers are being monitored by the innovation department. A business case will be developed to investigate if replacing old transformers for new

energy-efficient ones would be profitable. If so, this may have an impact on the older transformers in the population. This particularly applies to the transformers built before 1980. According to the fictive age structure given in Figure 7, this amounts to a total of 10,800 units.

The strategic decision of Liander to change existing 10 kV grids to 20 kV potentially has a large impact on the existing population. The size of the impact depends on the speed of this transition. To make this transition as cost-efficient as possible, the existing population of distribution transformers should be taken into account when planning this transition. Additionally, the new demands on the transformers caused by the energy transition need to be monitored closely since these may need to be modified or replaced in the future.

APPENDIX 5

Illustration: Evaluation and Discussion of the ALCP on Distribution Transformers

Evaluation

The ALCP has been evaluated with the asset manager responsible for the distribution transformers. He indicated that the ALCP is a foundation for further improvement. It gives an overview of the main topics relevant to the asset for its complete lifetime. This makes it different than existing maintenance policy documents, which often have a more limited focus both in time and in perspective. This makes it easier to identify the main priorities in the management of the transformers. Additionally, it is a communication device to share the expected performance of the asset with other stakeholders or departments.

The ALCP was presented to the management of the Asset Management department. It was well received. The strategic focus of the document and the discussion of the future replacement needs were stated to be strong characteristics.

Discussion

The application at Liander shows the potential value of working with ALCPs. The ALCP on distribution transformers allowed the company to get an integrated understanding of the asset's future from the different TECCO perspectives. Based on such an understanding, well-informed strategic decisions can be made. The experts joining the expert session regarded this session as useful and interesting. They especially valued the fact that experts from different departments were present, allowing an integrated and multidisciplinary view of the transformer's future to emerge.

By means of an ALCP, Asset Management may become proactive rather than reactive. It looks ahead, presents the main challenges and opportunities that lie ahead, and comes up with suitable solutions that can be implemented in time. This also implies that the chances are small that new problems will suddenly appear and ask for immediate and often less cost-effective solutions.