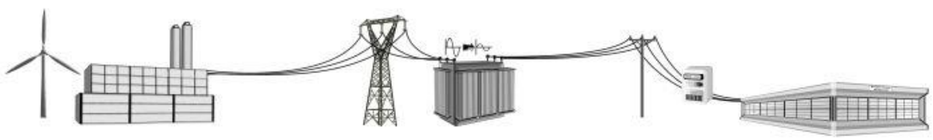
A sustainable procurement policy proposal for distribution system operators



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Date August 29th 2017

A sustainable procurement policy proposal for distribution system operators

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Engineering and Policy Analysis**

Faculty of Technology, Policy and Management

by

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To be defended in public on September 12th 2017

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Preface

In front of you lies the graduation report that concludes my Master of Science degree in Engineering and Policy Analysis. The diversity of topics covered in the academic courses of the past two years have educated me on more than just academic know-how. Most interesting and challenging has been the expansion of my daily thinking patterns by acknowledging the complexity of the world we live in instead of neglecting it in order to understand a simplified version of reality.

Concluding my master's programme with the development of a policy proposal on sustainable procurement at Alliander, a large Dutch electricity and gas distribution system operator, created the opportunity to align a range of research disciplines that were complementing each other. I have made it my personal goal to acknowledge the complexity of the 'world of sustainable infrastructure asset procurement' without getting lost in the interesting details of isolated research areas that simplify their scientific environment.

I wish to sincerely thank Co den Hartog, my company supervisor, for his inexhaustible enthusiasm with which he has shared his knowledge and critical ideas. My gratitude is also expressed to Jaco Quist who, as my first university supervisor, has provided me with constructive suggestions in order to complete this report, as well as Bert Enserink and Els van Daalen who complemented by TU Delft graduation committee and provided valuable feedback in order to complete my research. I would also like to thank Leo Posthuma and Michiel Zijp (National Institute for Public Health and the Environment, RIVM), Piet Soepboer and Tjeerd Broersma (ENEXIS BV) and Phil Brown (TU Delft) for their openness and knowledge sharing which has been a useful contribution to my research. I also wish to thank my colleagues at Alliander for a pleasant work atmosphere, interesting discussions and tasty cups of coffee, and Camiel Oremus on behalf of the management team for the opportunity to complete my graduation thesis at Alliander. And last, but certainly not least, my sincere appreciation and thanks to my dear friends, partner and family for their suggestions and motivational support throughout what sometimes felt as a lonely thesis crusade.

This graduation project has been a valuable contribution to my development as a policy analyst and as a person and for that I am very grateful.

Arnhem, 2017

Thomas Hajonides van der Meulen

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Executive summary

The environmental and social impact of the energy generation and distribution industry on the biosphere is negative or unknown due to a lack of supply chain transparency. For electricity and gas distribution system operators (DSOs), the opportunity to contribute significantly to more environmental and social sustainable development in the energy industry is large. DSOs own and use large amounts capital assets that consist of finite materials, are focal actors in large global supply chains, and are able to make large purchases due to their public role and their financial means.

The long (20-80 years) useful lifetime of infrastructure assets puts great emphasis on asset risk management, and operation and maintenance strategies to optimize technical and economic performance. As a result, the purchase decision of the assets mainly focusses on technical and economic requirements and criteria. This purchase moment can be considered to be the start of the assets' life cycle and its outcome thereby determines to a large extend the design and use of the asset. To reduce the social and environmental impact of the asset, environmental and social demands must thus be incorporated in this procurement process. Currently, a matured approach to sustainable procurement is unavailable within the infrastructure industry. Alliander, a large Dutch DSO, attempts to include sustainability as an addition to the existing procurement process. However, procedural integration in the existing processes is required to successfully and effectively integrate sustainability in asset procurement.

Infrastructure asset management, and DSO asset management in particular, are embedded in a risk-averse culture with high emphasis on technical, legal ,and economic values. Introducing innovative and more sustainable asset alternatives in daily decisions generates resistance among actors as no compromise on existing technical and economic values is desirable. This actor resistance needs to be overcome as procurement decisions are made by a team of actors. Decisions therefore require group consensus rather than actors that unwillingly agree to the decision. The long asset lifetimes, dispersed and interdisciplinary knowledge, and uncertain need for specific DSO asset functions and services in the future complicates optimal decision-making even further.

The infrastructure procurement process is an assessment process in which multiple suppliers and their asset alternatives are appraised using a large set of demands. By adding environmental and social sustainability demands to this assessment, procurement becomes partly value-based. Actor-dependent prioritization of demands leads to divergent and/or contradictory objectives. The subsequent trade-offs between individual (actor) and mutual (organizational) objectives are therefore embedded in a multitude of different interests, perspectives, and values. To overcome this decision-making difficulty, effective and goal-oriented collaboration among the actors that are involved is required.

Multiple scientific and corporate sustainability assessment and decision frameworks are currently available. However, a proven approach that can facilitate interdisciplinary group decision-making in the procurement processes is not yet available. A general sustainable procurement policy needs to be developed to provide formal guidance in the complicated procurement. Developing such a policy will provide an answer to the research question in this report:

How can sustainability goals be incorporated in the multi-actor decision-making process of infrastructure asset procurement by Dutch distribution system operator Alliander?

To develop the sustainable procurement policy and answer this question, four procedures were followed. Firstly, problems related to sustainability in (public) procurement were explored via an explorative and systematic literature study, as well as 23 informal expert interviews. Policy development goals, constraints, and criteria were taken from this first procedure into the second procedure, namely: the development of the policy. Developing a robust and suitable policy was done by merging the insights from the following five knowledge areas: sustainable development, asset life cycle management, multi-actor networks, multi-criteria decision-making, and (sustainable) procurement. The third procedure validated the policy through two case study applications at Alliander. Insights from these practical cases and the consultation of Alliander experts served as input for the final procedure: the evaluation of the policy. In this procedure, the added value and compliance with the policy constraints and criteria were evaluated.

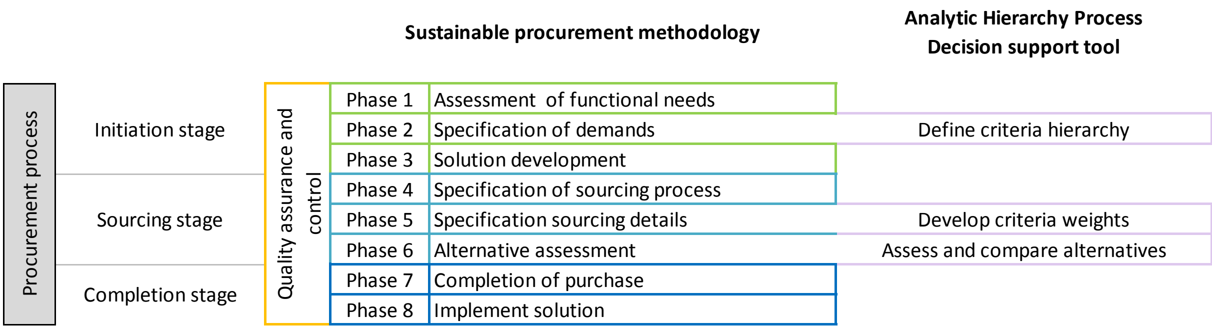


Figure 1 Sustainable procurement policy overview

The resulting policy, depicted in Figure 1, discusses the methodological steps that are required for successful sustainability-focused procurement in eight sequential phases. The core elements of this methodology are four-fold: (I) Collective formulation of procurement goals and the function of the asset; (II) Formulating technical, economic, environmental, and social demands throughout the complete asset material life cycle; (III) Expanding the perceived added value concept from technical and economic values to equally important environmental and social values; and (IV) Establishing unanimous consensus in decisions with diverging actor priorities to put the interests of the organization above those of individual actors, and to make long-term actor collaboration possible.

In addition to the methodology, a decision support tool was developed, based on the matured Analytic Hierarchy Process and pairwise comparison weighting method, which facilitates essential dialogue within the multidisciplinary procurement team throughout the procurement process. The tool offers a structured and logic-based decision-making approach: actor-specific value judgements, drivers, and priorities are made explicit by transparent documentation and visualization of individual criteria weight distributions. The differences between individual and group priorities regarding asset demands hereby become clear. The actor dialogue can thereby be limited to major differences in actor priorities rather than discussing numerous minor or non-existent differences.

Future scientific research is required on how to deal with interrelations between high amounts of procurement demands from different knowledge disciplines. To make sustainable procurement business-as-usual within the infrastructure industry, committed and inspiring leadership is required. A crucial step is the acknowledgement and of environmental and social added value, in addition to the current appreciation of technical and economic added value. Expanding the concept of added value creation, and thereby the core values of infrastructure organizations, makes sustainable procurement more accepted within asset management and incentivises supply chain actors throughout the supply chain to act more sustainably.

Chapter 1: Introduction

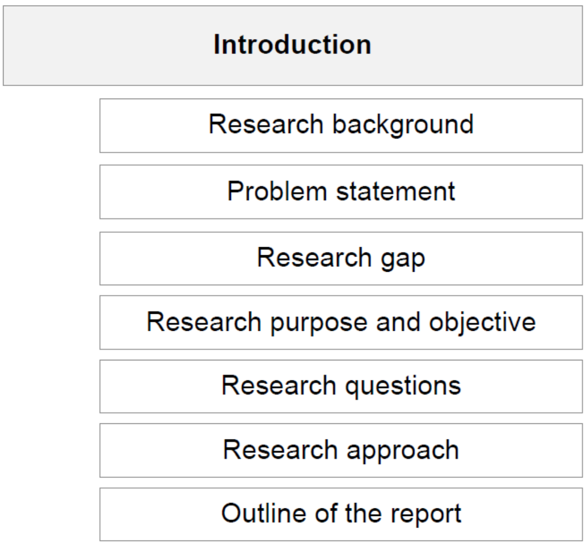


Figure 2 Content structure Chapter 1

In the introductory chapter of this thesis report, the *background* of the research *problem* (§1.1, §1.2) and reasons to solve this problem are outlined as well as the *research gap* and *purpose* of the conducted research (§1.3, §1.4). Furthermore, the *research questions* answered throughout the report to meet the research objective are presented (§1.5). The *research approach* chosen (§1.6) and the structural *outline of the report* (§1.7) conclude this chapter. Figure 2 sums up the content of the chapter.

1.1 Research background

It is becoming increasingly normal to consider long-term environmental and social sustainability in daily life decisions. This driver for global sustainability has not yet been incorporated effectively in the Dutch electricity and gas distribution sector. In the Netherlands, the technical reliability and capacity of the electricity and gas distribution network is considered to be self-evident, however the environmental and social sustainability in this sector is in its infancy. The potential contribution of distribution system operators (DSOs) to a more sustainable energy infrastructure is significant. Large quantities of (scarce) materials are used, and a global supply chain networks with low levels of transparency regarding working conditions is linked to the procured assets. In order to better understand the opportunities and challenges of adopting sustainability drivers in the procurement investment decisions and asset management practises of DSOs, the complexity of sustainability in this sector (§1.1.1) and in the procurement process (§1.1.2) is discussed.

1.1.1 Complex challenges of the transition towards a sustainable energy industry

The energy industry is a large and global extractive industry with many major unsustainable consequences to our planet and its people. Finite resources are extracted and either converted into electricity and heat, or processed into capital assets. Each stakeholder of the energy supply chain, from resource extractors, electrical power and gas generators, power and gas distribution system operators to the energy consumers, puts pressure on the boundaries of planet Earth. These boundaries should not be exceeded in order to maintain a healthy ecosystem globally and include, among others, ozone depletion, biodiversity loss, climate change and fresh water use. Major socio-technical transformations on a global systems level are required to reduce the negative impact of the energy industry. Examples of transformations are on the rise and include renewable power generation, smart electricity grids and applications of the Circular Economy concept which closes the loops of materials to prevent and reduce wasting valuable resources.

Three major challenges in decision-making obstruct the transition to a sustainable energy industry. Firstly, energy industry stakeholders face an *unknown demand and supply* of centralized energy generation and distribution. The uncertainties and different roadmaps for future energy production exacerbates these challenges even further. Secondly, *costly long-term investments* are associated with the interventions that are needed to reduce the environmental impact of stakeholders. And lastly, *hyperbolic discounting* (also known as *the present bias*, describing the preference of short term benefits over long term prosperity) is a deeply rooted psychological and cultural pattern in human behaviour. It becomes apparent that economic drivers play a major role in the willingness to act more ecologically and socially responsible.

The challenging transition to a more sustainable energy industry aims to solve current and future socio-economic and environmental issues. When sustainability (long term economic, environmental and social prosperity) and economic profits (short term economic benefits) become conflicting interests, sustainability is often omitted from the decision. A change is needed in order to secure human well-being and the well-being of the biosphere within the fundamental drivers of corporate decision-makers. Multidimensional sustainability should therefore be connected inseparably to business models of organizations rather than the add-on responsibility of a corporation, commonly known as Corporate Social Responsibility (Porter & Kramer, 2011).

Thinking in terms of sustainable business models and business operation while also providing the usual products or services requires a change in the way we see successful business operation and formulate corporate visions, missions and goals. An increasingly successful guideline for acting more sustainably in physical asset industries is the Circular Economy paradigm. In this paradigm, multiple boundary conditions of successful sustainability-focussed business operation are merged. Witjes & Lozano (2016, p. 42) describes that “systemic multi-level change, including technological innovation, new business models, and stakeholder collaboration” are pre-requisites for a successful Circular Economy. The implications of the shift towards a sustainability-focus, and the Circular Economy concept in particular, within the electricity and gas distribution operation sector is discussed in more detail below.

1.1.2 Procurement as a means to more sustainable infrastructure asset management

For many individuals and organizations, consequences of the current transition to a more sustainable society are relatively small and uncluttered. However, for infrastructure operators (e.g. DSOs, railway operators, telecommunication network operators), the need to operate more sustainable is more complex and demands ***direct action***. Infrastructure assets typically are designed for specific predictable performance envelopes for a long period of time. The major resource investments and technical complexity associated with these assets hinder the flexible and short-term anticipation of changes in the service they provide. Investments in unsustainable assets may thereby yield large negative societal impacts. Examples of negative impacts are the use of scarce and/or hazardous materials in infrastructure assets, the unknown or intolerable labour conditions of organizations of whom asset suppliers purchase their materials, and the absence of transparency throughout the supply chain regarding both environmental and social impacts of assets.

The negative impact reduction potential and positive impact increase potential of an infrastructure operator, and an electricity and gas distribution system operator (DSO) in general, is high: large amounts of (virgin) materials are used to create and maintain reliable networks of assets, and these assets are used for considerable amounts of time (typically 20-80 years). As a public service provider, DSOs have significant investment power and a clear social responsibility. The Dutch electricity and gas grid is operated by multiple DSOs, of which Alliander operates over 5 million connections. Alliander has the ambition to take a leading role in the Dutch ambition regarding sustainable infrastructure operation by becoming a Circular DSO (Den Hartog, 2016). Alliander’s activities include the purchasing of assets, operation and maintenance of these assets and, at the end of their functional lifetime, dispose of these assets. The growing awareness and recognition of asset life cycle thinking has led to the consideration of all life cycle phases within the purchasing phase.

Taking on the challenge of sustainable development within strategic DSO asset purchase decisions while dealing with (1) the unknown future demand and supply of electricity and gas, the (2) need for long-term investments and (3) overcoming the hyperbolic discounting principle require a strong and vivid ambition and the means to translate this ambition into results. Inspiring policies can help to materialize sustainable goals and decision-making drivers. This master thesis proposes a procurement policy to aid infrastructure operators to incorporate sustainability in their procurement process. ‘Policy’ hereby refers to a collective set of ideas, procedures and guidelines that can be adopted by an individual or an organization to offer (decision) support.

1.2 Problem statement

The problem focussed on throughout this research can be formulated as: the transformation of the current procurement policy into a sustainable procurement policy, while acknowledging the complications of the affected multi-actor network and consideration of asset performance requirements throughout their operational lifetime. Where assets are defined as capital infrastructure assets with long lifetimes, technical specification, and are fulfilling a public service.

Procurement decisions are made by a group of experts, each representing different interests and contributing their share of expert knowledge in the procurement process. The challenge in solving the aforementioned problem is the incorporation of the lack of consensus on value and knowledge during decision-making throughout the procurement process. This lack of consensus on values and knowledge among decision-makers is rooted in the three challenges of sustainable infrastructure asset management discussed in the previous paragraph: an optimal decision needs to be made in a costly and uncertain decision environment.

The complexity of making procurement decisions in an organization largely depends on the different perspectives and value judgements among individual actors in the organization. If consequences of a decision are not significant, actors with diverging values may be more willing to focus on shared organizational values and give in on their individual values. It is the decisions with potentially large impacts that are challenging: how does one include diverging sustainability-related values in purchasing decisions of expensive capital assets with a long lifetime?

To conclude, the focal problem in sustainable procurement of DSO infrastructure assets lies in making investment decisions regarding a product or service that complies with a large amount of multidimensional demands while representing all the needs and values of the individual actors involved, and the procuring organization as a whole, simultaneously.

1.3 Research gap

Solutions to the problem of sustainability assessment in procurement gain traction in scientific fields and the industry. However, a standardized integration of sustainability assessment criteria in the decision-making processes of procurement of capital (infrastructure) assets is still absent. Conceptual academic contributions are increasing in a variety of different research disciplines. The development and testing of theory in practise is now required to explore the complexity of sustainable procurement within the industry from an interdisciplinary point of view (De Bakker, Groenewegen, & Den Hond (2005); Hoejmose & Adrien-Kirby (2012)) and overcome the observed difficulties of implementing sustainability-related requirements and their measurement in the procurement processes (Walker, Miemczyk, Johnsen, & Spencer, 2012).

Organisational culture, psychological mind-set barriers and lack of ideologies, ambition, strategy and leadership are often addressed to be crucial drivers for successful implementation of sustainability in procurement (Allee, 2011; Antoinette, Paul, Soosay, & Hyland, 2015; Cao & Zhang, 2013; Rauter, Jonker, & Baumgartner, 2017). Hoejmose & Adrien-Kirby (2012) stress there is a need to address the complexity of sustainable procurement in the wider management context instead of single disciplinary research and applications.

There is a need to gain an objective and value-independent understanding of how well products, processes or services score on environmental and social performance besides the conventional technical and economic performance. Asset impact and performance goes across boundaries of single life cycle phases and thus a systems view on alternative assessment in procurement is needed. In the context of energy infrastructure asset management, no suitable methodology is available to evaluate assets on:

1. Technical and sustainable (i.e. social, environmental and economic) performance
2. while acknowledging their unique asset characteristics and demands
3. and also acknowledge the uncertain socio-technical system in which assets will come to operate

The research gap is formulated as follows: There is a need in academia and in the industry to make the assessment of sustainability performance of infrastructure assets through their entire life cycle measurable to be able to make purchasing decisions in line with the procuring organizations goals and demands.
This research takes a multidisciplinary view on the research problem to fill this research gap. The problem scope touches an extensive amount of potentially relevant areas of study. Choices regarding a more narrow scope are therefore required. Figure 3 illustrates this scope. Five knowledge areas are explored and aligned in the development process of the sustainable procurement policy: **sustainable development**, **sustainable procurement**, **multi-criteria decision-making**, **multi-actor networks**, and **asset life cycle management**.

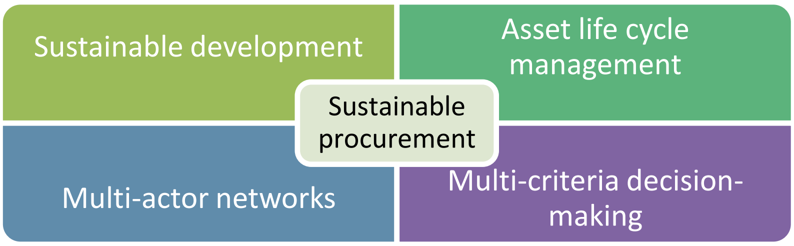


Figure 3 Research scope

The five areas of interest are interrelated: A multitude of actors represent sustainable development goals and asset life cycle management goals that need to be met through the procurement process. Both sets of goals together provide a multidimensional set of procurement criteria and requirements. These criteria and used by a team of multiple actors to assess the sustainability of the asset alternatives offered by the market.

1.4 Research purpose and objective

The result of this research project aims to make a contribution to scientific developments on the operationalisation of sustainability, the industrial developments towards more sustainable asset management and the general transformation of infrastructure industries and society towards a more sustainable system. The scientific, industrial and societal purpose are briefly discussed below:

The **scientific purpose** is to contribute to a necessary maturing step in the field of sustainability science. By combining state-of-the-art developments in a variety of disciplines, their isolated contexts are recognised and their role in the bigger picture of is acknowledged.

The **industrial purpose** of this research is to increase the decision process quality and the compliance of the procured end result with the organizational goals and demands.

The **societal purpose** of this thesis is to offer public infrastructure organizations a hands-on stepping stone for applied sustainable procurement with a scientific foundation. Those organizations capable of leading by example need to know *how* they can lead by example before society can benefit from the more sustainable practises of public infrastructure operators.

The scientific, industrial and societal purposes are translated into one objective: This research sets out to give both academia and Alliander insights in the necessities and organizational challenges of incorporating multidimensional (i.e. technical, economic, environmental and social) sustainability in the procurement process of DSO assets.

1.5 Research questions

By answering the following main research question, the research will achieve the research objective:

How can sustainability goals be incorporated in the multi-actor decision-making process of infrastructure asset procurement by Dutch distribution system operator Alliander?

To find answers to separate elements of the main research question, six sub questions are defined that, together, provide the necessary inputs to develop a sustainable procurement policy that suits the asset management and procurement environment of Alliander and thereby answers the main research question.

In the first part, the interdisciplinary nature of sustainability in infrastructure asset procurement and at Alliander is explored:

A. *What is the state-of-the-art of academic literature on sustainable procurement and associated research area's?*
B. *How do DSO asset life cycle management and multi-actor decision-making relate to sustainable procurement?*
C. *What are Allianders current sustainable asset life cycle management goals, sustainable procurement practises and actors involved in asset procurement?*

Sub-question A, B and C provide the policy inputs needed to develop the policy in the second part of the report. A suitable policy development method need to be defined to develop and validate the sustainable procurement policy:

D. *What steps can be taken to develop an effective sustainable procurement policy for infrastructure asset operators, and for Alliander specifically?*
E. *What sustainable procurement policy allows for a sustainability-focussed procurement process within the DSO infrastructure industry?*
F. *To what extend is the sustainable procurement policy able to successfully integrate sustainable asset material life cycle management in the procurement process?*

During the course of this research, a constant iteration process based on theoretical and practical input stimulates the development of a practical policy based on state-of-the-art literature. To structure the policy development process, the research is set up following the steps discussed in the next paragraph.

1.6 Research approach

Developing and validating a policy requires an appropriate research methodology. The policy analytic steps and topology of Dunn (1994) and Van de Riet (2003) are partly suitable to develop the sustainable procurement policy. Originally, the steps and topology suggests to develop multiple policy alternatives, from which the best policy is then selected. In this research, only one policy alternative is developed that aims solve the problem. No other policy alternatives are considered. Therefore, the policy design steps are adapted to use for this single policy development process. Figure 4 illustrates the development process in which four main procedures are shown. By following the four procedures and by including the iteration loop between theory and practise, the research delivers a single policy that complies with the development inputs.

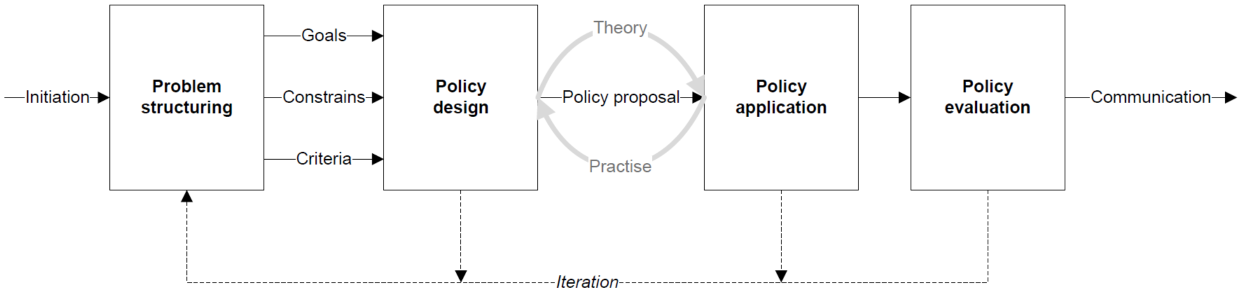


Figure 4 Policy development process visualizing the methodological procedures (adapted from Van de Riet (2003, p. 11))

1.6.1 Problem structuring: The need for a change

The global awareness of the need for sustainable development makes the identification of specific problems in sustainable procurement increasingly difficult. Many points of views make the problem structuring procedure an important step to analyse the large amount of academic and corporate contributions are published recently. Problem structuring is therefore essential to be able to make a clear contribution to recent scientific developments. Scoping of the problem is considered a continuous process. Scientific literature review and practical application of the theory aids this scoping process, resulting in a well-defined problem for which this research proposes a solution.

1.6.2 Policy development: Literature review feeding into the conceptual policy

The policy inputs are defined based on the literature review conducted. The context of the model suggests the need for a wide variety of inputs, rooted in the five knowledge areas: Sustainable development, asset life cycle management, multi-actor networks, multi-criteria decision-making and (sustainable) procurement. To structure these inputs and consider them into the development process, they are grouped per knowledge area and structured according to Dunns policy *goals*, *constrains* and *criteria* (Dunn, 1994). The policy consists of a methodology and a decision support tool that operationalizes this methodology.

1.6.3 Policy application: Case study validation

Practical implementation of the policy proposal by means of case studies enables the author to apply the conceptual policy. Insights in the feasibility and practical fitness are acquired by expert judgement consultation. These insights are used to improve the conceptual which results in an iterative development process.

1.6.4 Policy evaluation: Evaluation of design input compliance and performance

After the policy application and final iteration of the policy, the end result is evaluated using the policy inputs to determine the extent to which the policy is able to facilitate sustainability in the DSO asset procurement process.

1.6.5 Embedding the academic research in the industrial context

The thesis project is executed at Alliander, which creates a mutually beneficial situation: academic and industrial points of view are combined resulting in the conversion of theoretical ideas into practical results. Alliander offers multiple opportunities that add value to the project: Insights in the state-of-the-art DSO asset management practises and the procurement activities of capital assets as well as the strategic collaboration with actors are gained. Alliander also offers the opportunity to perform case studies as the required (sustainability) information and knowledge regarding sustainable procurement is internally available. Informal interviews and the daily collaboration with

Alliander employees serves as a source of information as skilled experts on a wide variety of relevant disciplines are physically present.

1.7 Outline of the report

The holistic need for more sustainable DSO infrastructure procurement is discussed in this chapter. Figure 5 below visualizes the report outline and the interrelation between Chapters 1-8. In chapter 2-5, five knowledge areas are discussed through an extensive literature review. These five areas are Sustainability in procurement (Chapter 2), Strategic DSO infrastructure asset management (Chapter 3), Decision-making in multi-actor networks (Chapter 4), the industrial Alliander context and procurement methodology (Chapter 5) and Multi-criteria decision analysis (Chapter 6). Four existing decision-making frameworks are selected and a set of policy inputs is established throughout this first part of the research. To transform the current procurement policy into a more sustainability-focused policy, a policy development methodology is set up (Chapter 6). The scientific and industrial inputs and frameworks are then combined into the sustainable procurement policy (Chapter 7). Two case studies are conducted to validate the improvements of the sustainability-focused policy compared to the current procurement policy (Chapter 8). Chapter 8 also presents the evaluation of the policy. The conclusion and recommendations (Chapter 9) conclude this report.

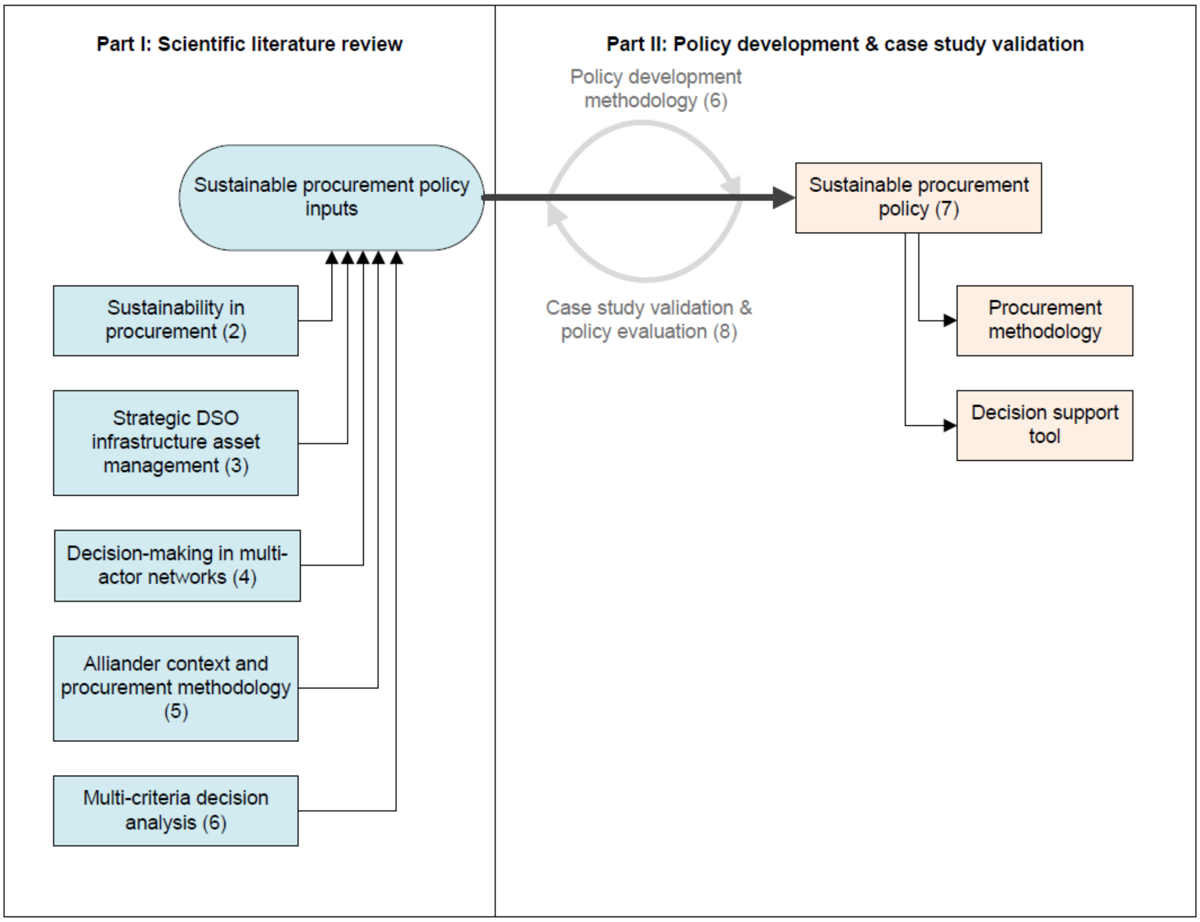


Figure 5 Visualisation of the report structure

Part I: Scientific literature review

Chapter 2: Sustainability in infrastructure asset procurement

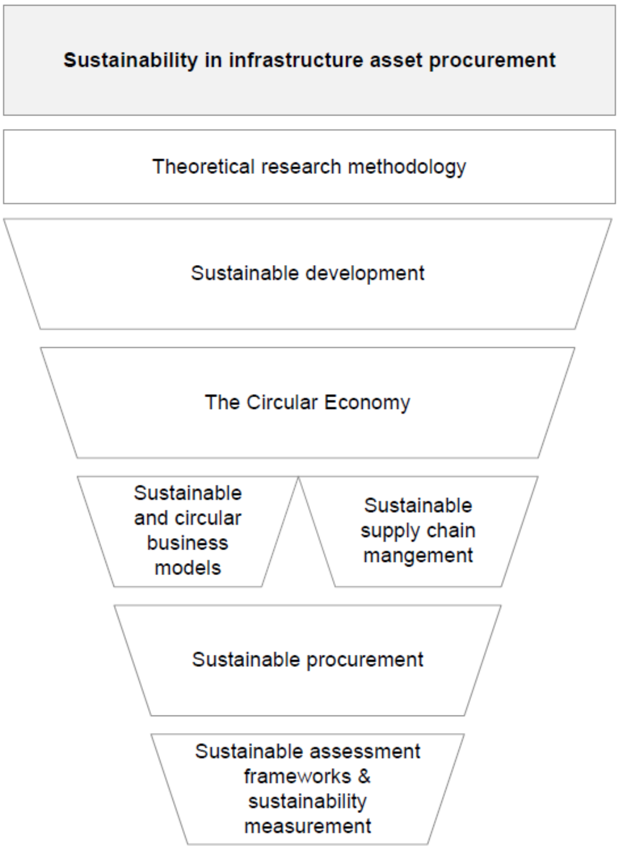


Figure 6 Content structure Chapter 2

Understanding the role sustainability plays in capital asset management and procurement requires the understanding of multiple research areas within sustainability science. To systematically cover these research areas, the topics are discussed from largest scope and least concrete topic, to smallest scope and most concrete topic (§2.2) as illustrated in Figure **6**6. Firstly, the philosophy and visionary direction of *sustainable development* needs to be understood. Secondly, the paradigm of a *circular economy* in which sustainable development is discussed from resource utilization point of view. Thirdly, two topics enable this circular economy to be successful: (1) *sustainable (and circular) business models*, and (2) *supply chain management*. Fourthly, *sustainable procurement* connects the demand and supply of sustainable assets. Lastly, sustainable procurement involves the assessment of sustainable performance, which is formalization by three topics: (1) *sustainability assessment frameworks*, (2) *sustainability norms and standards*, and (3) *sustainability measurement* using principles, criteria and indicators. Chapter 2 starts by discussing the research methodology used in Chapter 2, 3 and 4 (§2.1).

2.1 Literature research methodology

Multiple research methods are selected that enable the author to ultimately answer sub-questions A, B and C in Chapter 2, 3 and 4 respectively. This literature review method is motivated below. The complementary empirical research methodology that provides insights in the Alliander context is discussed in Chapter 5. The policy development method and the case study validation is discussed in Chapter 6.

The interdisciplinary context of the research problem urges the need for a well-defined scope. Putting limits on the depth of relevant research areas and the amount of areas considered is a prerequisite for a successful completion of the research within the timeframe available. An *explorative literature review* is suitable to be able to decide on this scope. Subsequently, a more *systematic specific literature study* is conducted to gain a deeper understanding of selected research disciplines. The focus in this second literature study lies on fundamental contributions and recent state-of-the-art publications in academic literature. The latter is explicitly relevant as the research topic is currently maturing. The two literature review approaches are used for different purposes and which is discussed below (University of Toledo, 2016).

First, the explorative literature review is performed to gain an understanding of the broad research areas, with a specific aim on the topics of sustainable development, circular economy, procurement and sustainable supply chain management. As a basis for the explorative literature study, both publications recommended by experts in the specific topics and fundamental, commonly cited publications are studied. By taking this literature base as a starting point and following up on other cited publications or relevant papers, more literature within or related to the topics studied is explored to gain a more complete picture of the diversity of potentially relevant research disciplines for this thesis. The literature studied is mainly found at large online repositories, including Scopus (www.scopus.com), EmeraldInsight (www.emeraldinsight.com), Google Scholar (www.scholar.google.com) and Elsevier's ScienceDirect (www.sciencedirect.com). The explorative and broad level of reviewing of literature is found suitable for this initial review stage as it allows for drawing conclusions about topics by criticizing and summarizing multiple bodies of knowledge. However, the disadvantage of researcher bias needs to be acknowledged: The large number of publications found by this so-called snow-balling effect makes that the process has the tendency to be biased: The author makes choices to study a publication based on his judgement on the possible relevance of the publication. This judgement is subjective and could therefore eliminate highly relevant publications from the literature study. Therefore a second literature review is conducted.

The second literature review has a more systematic character: based on keywords from the explorative literature review, and a specified aim on infrastructure asset life cycle management, a structured and objective research in the academic online library of Scopus and ScienceDirect is conducted. Subjective selection of the first literature review is omitted and leading publications are the basis of this research. Focussing on literature reviews, bibliometric analysis and synthesis results in an overview and understanding of existing research. This review approach aids the author to find similar research in the topics of interest and strengthens the analysis of the scientific knowledge gap. Input of similar research is highly relevant to guarantee the unique contribution of the research done. Careful selection of keywords is hereby essential as these keywords determine the scope of the review. A high correlation with keywords is needed to narrow down the results. By selecting publications based on the following steps, the keyword results are systematically narrowed down.

The more search results, the more steps are taken:

1. Keyword-based search commands, based on explorative research findings
2. Limiting results to *review* (and occasionally *article*) types of document to remove specific and in-depth research contributions
3. Review the title, abstract and sources on suitability, selecting the literature on: its ability to present an overview of the state-of-the-art developments in the topic, or directly relevant research considering the *sustainable development of infrastructure asset management* and/or *sustainability related decision-making in asset management*.
4. Well cited (50+) publications
5. Recent contributions (2007 until now)

The literature research methods above have a complementing role: The explorative research is an input to the more focussed systematic literature research by giving insights in the relevant disciplines and areas as well as corresponding keywords. The literature found initially is subjected to the bias of personal preferences, which is countered by the systematic second review that identifies the fundamental literature objectively.

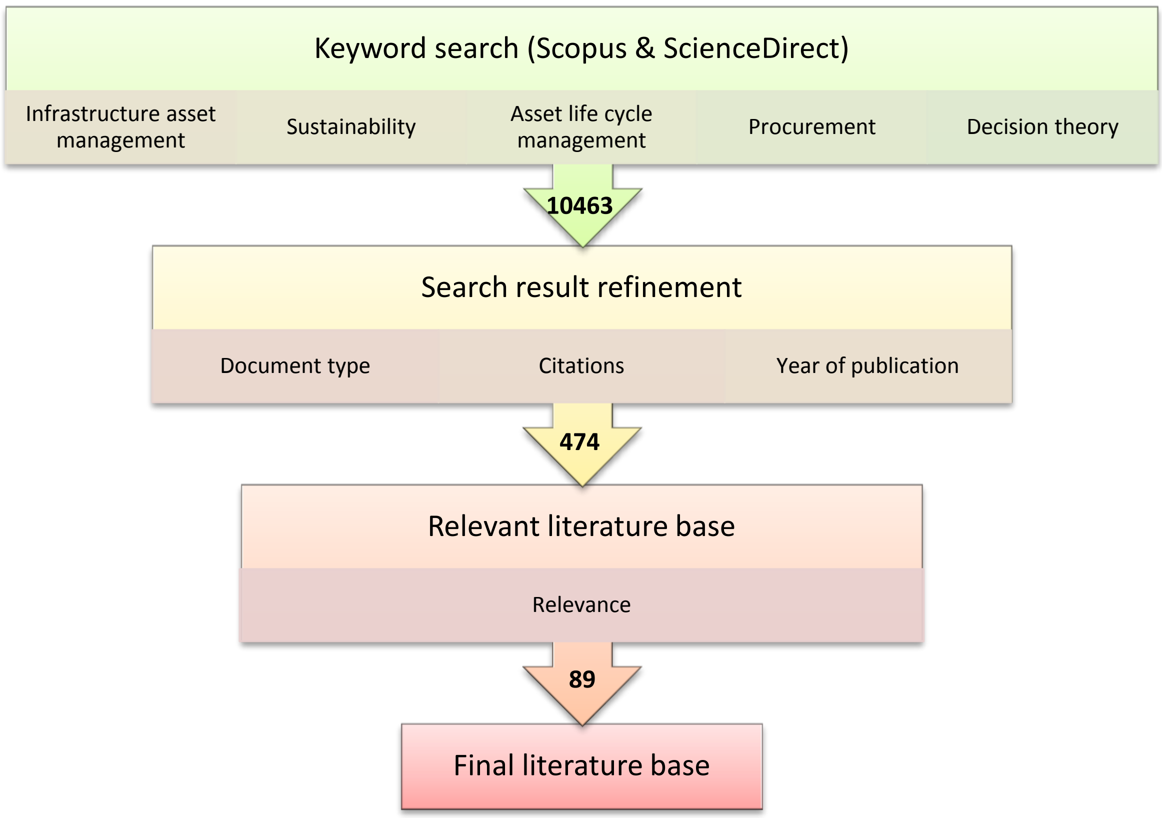


Figure 7 Literature research methodology

The drawback of a focus on fundamental literature is omitting the less known and more specific publications. The field of interest in this thesis is a research gap that has invited other researchers to actively contribute to. It is thus expected that work is currently published related to the scope of this research. By using detailed keyword searches, these publications are therefore looked for in a the systematic literature research. Figure 7 depicts the literature research process and the results found using the above mentioned systematic approach. Search results are listed for two literature bases for each search query, using the following notation: (number of Scopus hits/number of SciendeDirect hits). The literature search overview in Appendix A extensively lists the search steps taken during the systematic literature study.

2.2 Multidisciplinary theory on sustainability in procurement

Sustainability and procurement are topics that both can cover a wide range of literature. To systematically explore both topics, the literature of the concept of sustainable development provides a background in terminology and the ideology of sustainable development. The follow-up topics of Circular Economy, business models, and supply chains translate that concept in smaller chunks of literature that are directly related to sustainable procurement. Sustainability measurement then wraps up the paragraph by discussing the means to measure sustainable performance.

2.2.1 The need for sustainable development

Global world population is rapidly growing and consumer patterns are changing as societies evolve towards a higher welfare state, which subsequently leads to over-consumption worldwide. By 2030, the middle class consumer group will increase with another three billion consumers (Jackson, 2016). To secure our current and future wellbeing on planet Earth, the inter-linkages between population, consumption and our environment need to be considered and we need to change: new socio-economic systems are needed (Sulston et al., 2012).

The troublesome future scenario in which the current global economy depletes our planet asks for a drastic change in the form of sustainable developments. Sustainable developments (SD) are 'developments that meet the needs of the present without compromising the ability for future generations to meet their own needs' (Brundtland, 1987, p. 16). Many definitions of sustainability can be found in academic and business literature (Cabezas, Pawlowski, Mayer, & Hoagland, 2003) that all discuss acting responsible for current and future wellbeing. Commonalities between these different definitions are found in the multiple dimensions of sustainability, often categorized in social, environmental and economic sustainability. This tripled is referred to as the Triple Bottom Line (TBL) (Elkington, 2001), or the three Ps: People, Planet, Profit.

The awareness and commitment of (large) public and private organisations to behave more sustainably is increasing significantly nowadays. As an example, Corporate Social Responsibility (CSR) is adopted as a way organisations tend to show the outer world they take their responsibility to the public besides focussing on their own gains. However, as Porter & Kramer (2011) argue, CSR can be seen as an add-on to the daily business operation. Actual impacts are made only when social responsibility and sustainable business operation is taken into the core of the organisation (see Accenture 2016; Porter & Kramer 2011; Short et al. 2013). Integrating sustainability in the core of the organisation may be complicated due to practical changes in daily operation and, less tangible, cultural changes in mind-set and priorities of stakeholders internal and external to the organisation.

To accomplish such a cultural change, a prerequisite to moving forward is understanding each other and thus speaking the same language. The wide variety of interpretations of sustainability disrupts the communication between actors as the interpretation of the word and associated topics varies among actors. One can think of sustainable development as the direction chosen by an actor to contribute to 'a better world'. The large spectrum of opportunities to act sustainably is also reflected in the Sustainable Development Goals (SDGs) published by the United Nations (2016).

As 'acting sustainably' has a different meaning depending on the context or the actors involved, the next paragraph addresses the terminology used throughout this document.

2.2.2 The diversity and terminology of the topic of sustainability

The multiple dimensions, different scales of sustainable development and the interdisciplinary character of global challenges have led to a situation where sustainability related research is scattered and many different terminology is used for practically similar sustainable development ideology. CIRAIG (2015) did an attempt to create an overview of the variety of research and terminology which illustrates the diversity and difficulty of speaking one language. Throughout this document, the terminology in Figure 8 is used:

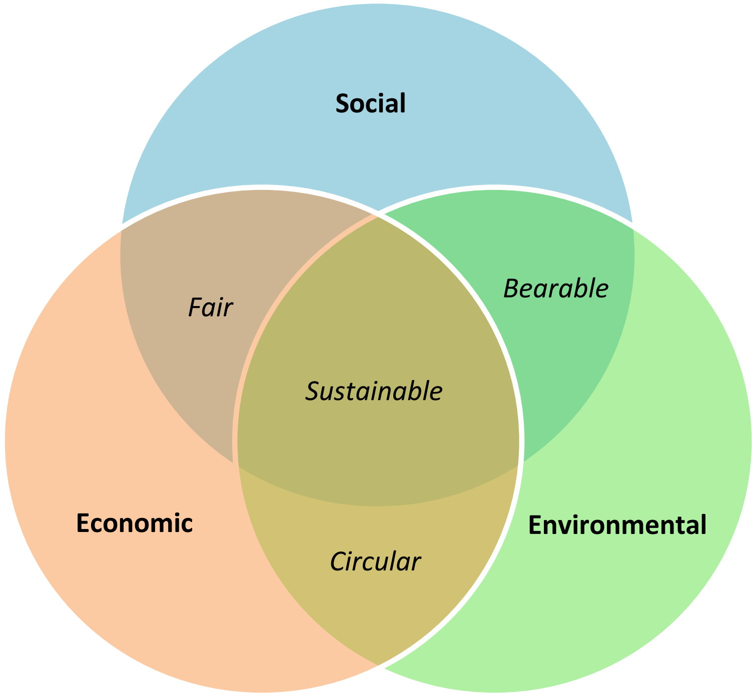


Figure 8 Visualisation of sustainability terminology

While well-established definitions and terminology may assist in the communication between actors, a common understanding of the principle of SD on a more abstract level is essential to achieve a higher state of welfare globally. As Ban Ki-moon addresses: "It [the 2030 Agenda for Sustainable Development] seeks (…) to integrate and balance the three dimensions of sustainable development—economic, social and environmental—in a comprehensive global vision" (United Nations, 2016a, p. 4). Connecting the sustainable procurement policy developed in this document to the SDGs underlines the holistic and visionary objective of the policy. The following paragraph will therefore briefly discuss a sustainable worldview, the SDGs and their relation to sustainable development in the infrastructure asset context.

2.2.3 The Doughnut Economy and the UN Sustainable Development Goals

Raworth (2014) presents a visionary compass for future (economic) policy makers in which she defines a social foundation with 11 essentials for inclusive and sustainable development (see Figure 9). Raworth (2014) connects this social foundation to the environmental ceiling, defined by Rockström & Et al. (2009) as the planetary boundaries, to illustrate the highly complex system of which our society is part. This foundation and ceiling combined become the illustration of *the safe and just space for humanity*. Raworth discusses that our global economy needs to operate within this doughnut shaped space. Using the resources of our planet is inevitable when the needs of each individual human being on the planet is to provided. The environmental ceiling, defined by nine categories, gives us the maximum level of pressure that can be put on the planet to secure long term sustainability. Appendix B illustrates the current pressure on our ecological ceiling.

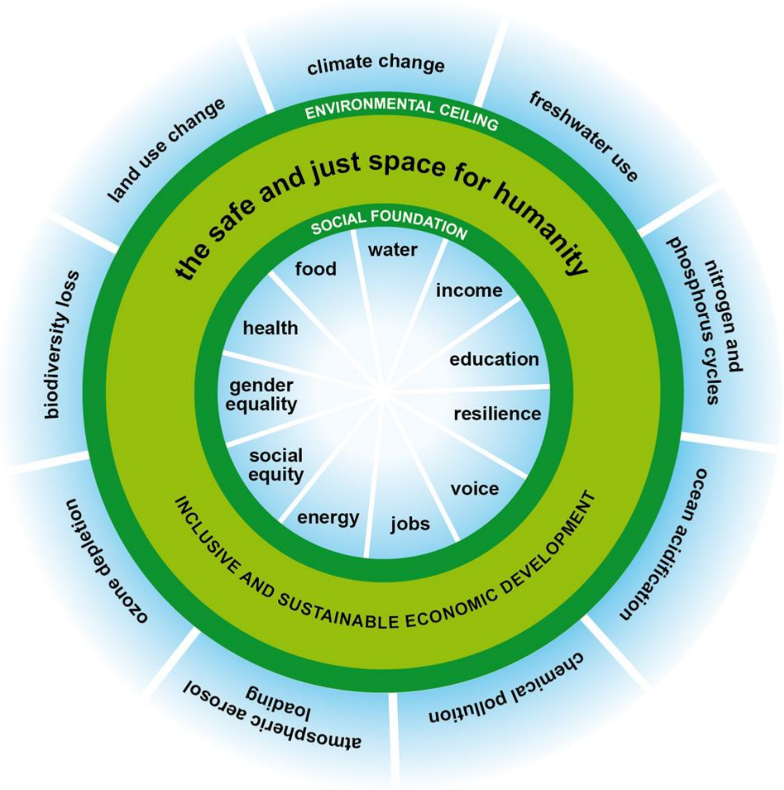


Figure 9 The Doughnut Economy, adapted from Raworth (2017, p. 44)

For each organisation and individual there are plenty of opportunities to contribute to the transition to a better world for us and our future generation. The Sustainable Development Goals (SDGs) are a set of objectives formulated by the United Nations that aim to address global challenges until 2030 (United Nations, 2016a). In total, the SDGs consist of 17 urgent undesirable matters of social, environmental and economic character in both developing countries as well as wealthy countries. A description of the 17 SDGs can be found in Appendix C. Contributing to each of the 11 social foundations or 17 SDGs may not be realistic or effective. Focusing on a selected few can already lead to valuable contributions to the transition to a balanced global system. The SDGs are specific goals for humanity. However, they embody a vision of a fair, safe and just life for every living being on our planet and SDGs can therefore be considered a compass to make decisions that contribute to sustainable development.

The Doughnut Economy and the SDGs deliberately lack the inclusion of practical means to operationalize the ideology in order to allow each individual and each organization to find its own way of contributing to the sustainable development of society. The Circular Economy concept offers a range of principles and business models that guide its practitioners towards more sustainable daily businesses as the Circular Economy (CE) concept strives for a balanced and closed-loop resource system. The following paragraph discusses this Circular Economy into more depth.

2.2.4 The Circular Economy Concept

The need for a large scale transition to a sustainable economy lead to the emerging paradigm of a Circular Economy: An economic system in which the impact on the environment is minimized by adoption of a wide range of sustainability concepts, business philosophies and means. One out of many definitions that attempts to summarize what the Circular Economy is, is the definition of the Ellen MacArthur Foundation (2012, p.7): “a Circular Economy is an industrial system that is restorative or regenerative by intention and design”. The Circular Economy (CE) paradigm redefines the current view on the global economy. By significant effort of a multitude of authors and organisations the emerging concept of CE is rapidly evolving and developing in the academic and business context.

The Circular Economy is an alternative to our present economy which is characterised by its *linear* design: products are produced, used and discarded, with major extraction of finite resources and large impacts on the environment as a consequence. In the circular concept, the basic principle of the economy is to minimize the impact of the existence of the human society on planet Earth and thereby to strive for a sustainable living environment, now and in the future. As large amounts of materials are currently extracted from the lithosphere, material scarcity can be expected in the near future. A strong emphasis on careful use of rare earth elements and metals (e.g. copper, gold) is desirable as these materials are used for many industrial applications and should be re-used if possible as.

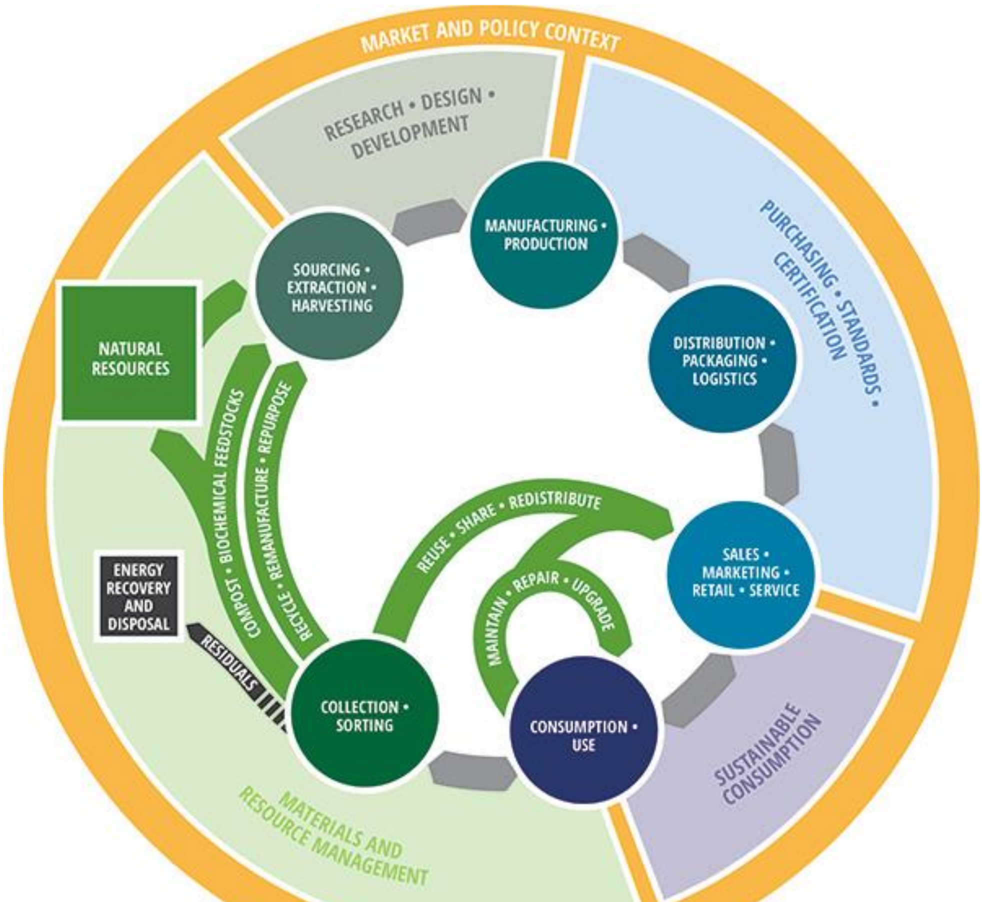


Figure 10 Visualisation of the Circular Economy concept and material loops, adapted from CircularEconomyLab (2017, p. 1)

often and long as possible. The CE thus strives for a closed system in which minimal resources are permanently extracted from the resource base (our planet). Figure 10 illustrates this closed system. The inner circles show the life cycle phase of a product, the green loops present the different loops that can close the circles, and the context in which decisions are made is illustrated by the outer circles. The electricity and gas distribution network comprises of large amounts of assets that are required to deliver the high reliability of the Dutch networks. Publications as mentioned above do not necessarily lead to the transition to the sustainable operation of these assets. However, realizing that the Circular Economy offers not only a reduction of ecological impact but also a more consciously managed material circulation opens doors from the DSOs perspective: Many kilograms of critical materials are processed and used in the industries related to the DSO asset base (i.e. metal industry and electronics industry) (CBS, 2013). Keeping the asset materials in functional loops instead of disposing such materials creates the opportunity for new business models but also a reduction in material (supply) dependency (CBS, 2013). By identifying specific (high) impact areas within the context of the DSO assets most suited for a more circular design and use.

Another stimulus to consider a fundamental integration of the CE concept in infrastructure operation is the recent technological developments that enable the sustainable transition. As Lacy et al. (2014, pp.10–11) points out, "wide-spread adoption [of the circular economy] is now possible due to the disruptive technologies that allow massive and fast change. To conclude, CE is both needed from sustainable development point of view and possible as well as attractive from a long term corporate strategy point of view. The latter introduces the need for a brief introduction of sustainable and circular business models.

2.2.5 Sustainable and circular business models

A sustainable business model can be described as "a business model that creates competitive advantage through superior customer value and contributes to a sustainable development of the company and society" (Lüdeke- Freund 2010, p.23). Bocken et al. (2013, p.44) extends this definition by describing sustainable business models as models that "align interests of all stakeholder groups, and explicitly consider the environment and society as key stakeholders".

The opportunities for changing a business model largely depend on the products and services involved. Disruptive innovations may change business models rapidly, while minor changes may be hard to notice. However, by changing business models, the relationship between procurer and supplier also changes (Lay, Schroeter, & Biege, 2009). Industries with a strong risk and uncertainty averse culture (typically applicable to public infrastructure operators) may find it more difficult to change than flexible and rapidly developing industries (e.g. consumer goods). Jonkers (2016) discusses the need for new business, organizational and earnings models in the transition to a circular economy. In his quest to a useful typology for the multiple conceptual publications on sustainable business models for a circular economy (BMCE), Jonkers (2016) focused on three of the most clearly described SBCEs: the *Waste to Wealth* typology developed by Accenture (Lacy et al., 2014), *Products that last*, by Bakker, Den Hollander, Van Hinte, & Zijlstra (2014) (updated by Nancy M P Bocken et al. (2016)) from the TU Delft and *REsolve*, a typology from the hands of the Ellen MacArthur Foundation in corporation with McKinsey & Company (Ellen MacArthur Foundation, 2015). Commonalities can be identified in the proposed variety of business models that fits in the concept of the circular economy. Therefore, a generalization of the three topologies is proposed by the author. See Table 1 for this generalization.

Sustainable business models align well with the philosophy of the waste hierarchy Rs (King, 2015): Refuse, Reduce, Reuse, Recycle, Recover, Rot. The higher the R, the desirable the waste is processed from a sustainability point of view.

Changing from a conventional business model to a sustainable business model does not necessarily lead to substantially different business operation (Rauter, Jonker, & Baumgartner, 2015). Enabling those changes does require company leaders (i.e. corporate management) to effectively reorganize processes and core business values to secure the prominent role sustainability plays (Rauter et al., 2015). To create intrinsic motivation at corporate management level, substantial drivers are needed.

Table 1 Generalized typology of sustainable business models

Generalization	Applicable R	Waste to Wealth	Products that last	REsolve
Dematerialization	refuse, reduce	-	Encourage sufficiency	Virtualize
Dispossession	refuse, reduce, reuse	Sharing Platform	Access and performance model	Share
		Product as a Service	-	Virtualize
Prolong lifetime	reduce, reuse	Product Life-Extension	Classic long-life model	Share
Optimize functionality	reduce, reuse	Sharing Platform	Encourage sufficiency	Optimize
		-	-	Exchange
Circularity & material loops	reuse, recycle, recover	Circular Supply-Chain	Extended product value	Regenerate
		Recovery and Recycling	Extending resource value	Loops
		-	Industrial symbiosis	-

Developing sustainable business models by Dutch DSOs needs to be done in collaboration with the many stakeholders involved in the supply chain and asset material life cycles of the assets operated. It is common that an infrastructure operator does not produce any of its assets himself, and thereby relies on the supply chain and stakeholders. The sustainable development of infrastructures is therefore not limited to the activities of the operator of the infrastructure, but reaches far beyond this individual responsibility. Connecting sustainable business models to procurement, both in scientific literature and in practise, is therefore highly relevant.

Direct and indirect suppliers are therefore part of the network that needs to be mobilized by the DSO in order to successfully apply sustainable business models and act more sustainably. Discussing sustainable supply chain management will provide insights that are crucial for the development of the procurement policy.

2.2.6 Value creation and sustainability in supply chains

To have an environmental and social impact on an (inter)national scale, the collaboration between actors throughout the supply chain and actor network is needed: the interdependency of actors in a supply chain network needs to be utilized. This multi-actor situation increases the complexity of the transition to sustainable business operations due to a diversity of agendas, objectives and visions.

Achieving large scale and long-term sustainability requires changes at the core of company strategies (Porter & Kramer, 2011). In many industries, including these of the infrastructures that are currently the backbone of our society, such fundamental changes are difficult. The main reason is the large amount of stakeholders that are connected in supplier networks. And the dependence of DSOs on these supplier networks. Acknowledging that the transition to a sustainable and circular economy is a group effort introduces the supply chain of the assets to the context of sustainable development. This supply chain can be defined as "… all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows" (Seuring & Müller, 2008, p. 1700). The interdependent shackles, or companies, of the chain all have their strategies to generate revenue and make profit from company operations. Fundamental changes in a business model of one company, may initiate or require a chain reaction throughout the supply chain. It becomes evident that global sustainable developments are complex and will encounter significant resistance when stakeholders expect a decrease in personal value gain. Allee et al. (2011) and Porter & Kramer (2011) therefore discuss that the concept of value needs to be extended explicitly. This involves "understanding tangible and intangible value flows between stakeholders […] for greater collaborative mutually beneficial value creation" (Bocken et al., 2013, p. 485).

A focal company may be held, to a certain extent, responsibility for the sustainable performance throughout a supply chain. Focal companies are "those companies that usually (1) rule or govern the supply chain, (2) provide the direct contact to the customer, and (3) design the product or service offered" (Seuring & Müller, 2008, p. 1699). Supply chains are becoming increasingly complex due to their exponential growth and globalization of upstream tiers.

In supply chains there are limitations on the impact that single actors can generate regarding sustainability goals. The more individual actors cooperate with other actors, the higher the impact potential. The potential benefits of productive collaborations are to be recognized. As Lambert et al. (2004, p.22) state: ''A supply chain partnership is a tailored business relationship based on mutual trust, openness, shared risk and shared rewards that results in business performance greater than would be achieved by the two firms working together in the absence of partnership.'' More insights on value networks and collaboration can be gained from Allee et al. (2011), a pioneer in this field of study.

Supply chain collaboration is often perceived as difficult (e.g. Troy, Hirunyawipada, & Paswan, 2008). Witjes & Lozano (2016) address that physical and socio-cultural proximity is a prerequisite for successfully collaboration. Socio-cultural proximity hereby refers to similar beliefs and attitudes and equal amounts of interaction of individuals towards the group, physical proximity is the propinquity of actors (Borgatti & Foster, 2003). Witjes & Lozano (2016, p. 41) states that "long term collaboration during the procurement process requires a shift from the technical specifications set up by the procurer to a more collaborative discussion on, and definition of, the proposed technical and non-technical specifications between the supplier and procurer". The traditional demand-supply procurement process hereby becomes a more interactive process in which the dialogue between supplier and procurer shapes the specifications according to the capabilities of the supplier market and the procurer needs. The collaboration thereby shifts from the sourcing phase to the preparatory phase of procurement. In short, the long term collaborations that can be contracted in the infrastructure industry offer a mutual potential benefit for all stakeholders.

Supply chain collaboration is agreed upon and legally confirmed in the procurement phase of an assets lifetime. A strong focus on sustainability in procurement may thereby lead to contracting more sustainably manufactured assets, as is discussed in more detail in the next paragraph.

2.2.7 Sustainable public procurement

Public procurement is an activity of governments and public sector organizations, including DSOs, that refers to the acquisition of goods and services (Kiiver & Kodym, 2014). The United Nations Environment Programme describes the procurement process with four stages and corresponding actions, listed Table 2, which can be considered as the general sequence of procurement activities.

Table 2 Procurement process as specified by the United Nations (UNEP, 2014)

Phase	Actions
Preparatory stage	Define problem, inventory of demands of internal and external stakeholders, first specification set leading to first concept of product or service
Specification stage	Analyse and develop first product or service and subsequent definite specifications
Sourcing stage	Communicate final specifications to potential suppliers, evaluation of offers from suppliers, selection of supplier(s), signing of contract
Utilization stage	Supply product or service, use of product or service

Traditionally, the procurer sets specifications and the amount of products or services that are required. The suppliers then determine the resources and processes (i.e. raw materials, production processes, electricity mix, labour quantity and quality) and present their offer to the procurer who then selects the best suited offer. The EU has regulations regarding the selection and contracting of offers. The selection has to be based on (1) lowest price, (2) lowest overall cost or (3) the best price-quality ratio (UNEP, 2014). It is this third selection type that is taken as a basis to include environmental and social criteria into product or service in recent practises of sustainable procurement (Kiiver & Kodym, 2014).

The shift towards sustainable public procurement also implies a shift towards sustainable business models. The inclusion of sustainability in product and service specifications leads to the need for suppliers to rethink their current business models and create competitive advantages for their company, customers and society as a whole (Lüdeke- Freund, 2010; Porter & Kramer, 2011).

The comprehensive review of literature on Socially and Environmentally Responsible Procurement (SERP) by Hoejmose & Adrien-Kirby (2012) offers a systematic analysis of the literature (a total of 188 articles) on sustainable procurement between 2000 and 2010. In their review, the immaturity of this research field as well as the increased traction in practical and academic settings are discussed. The diverse and fragmented literature on SERP discusses the complex and dynamic nature of the topic. Based on the work of Pedersen & Andersen (2006) and Zhu, Sarkis, Cordeiro, & Lai (2008), Hoejmose & Adrien-Kirby (2012, p. 232) conclude that "implementing sound SERP practices is complicated and comes with a range of challenges at both the corporate- and supply chain-level". To effectively operationalize SERP in an organization, internal resources, skills and support is required. Because the top management of an organization is responsible for the organizations culture, activities and the (strategic) resource allocation to meet corporate goals, Hoejmose & Adrien-Kirby (2012, p.236) conclude that top management support is one of the key drivers for SERP: "literature consistently finds top management support and employee initiatives as fundamental for a firm's commitment to socially and environmentally responsible procurement and supply chain management". Another value-based driver is the rooted organizational values of an organization: intrinsic motivation to adopt SERP in the business activities is a prerequisite for its success (Carter & Jennings, 2004).

A different perspective on 'resources' is presented by Carter (2005), who suggests to achieve organizational learning in collaboration with suppliers which makes suppliers 'resources' from which a procuring organization can benefit. Such collaboration requires a high level of mutual trust and commitment as information transparency is often a tough topic. Building the relationship of stakeholders on trust, collaboration and communication may also be effective in achieving SERP, using procedural justice approaches (Boyd, Spekman, Kamauff, & Werhane, 2007). Such relationship also can promote innovation and reduce risk, leading to an improved performance and consequently higher profits due to an effective relationship (Zhu, Sarkis, & Lai, 2007)

The readiness of supply chain actors to collaborate effectively can be linked to the organizational culture of actors. The organizational culture at an organization influences the behaviour of its employees and stakeholders (Cambra-Fierro, Polo-Redondo, & Wilson, 2008). Top management support for SERP can thus influence the required intrinsic value perception of individuals to systematically adopt environmental and social value creation. The comparative study of Brammer & Walker (2011) also confirms leadership to be highly relevant in the implementation and operationalization of sustainable procurement. This study expresses its concerns regarding costs being a dominant barrier if only values are only considered from a short-term perspective.

Short-term value creation mainly focusses on tangible (economic) performance that can be acquired through procurement decisions as decision makers are often reviewed on their KPI-related (tangible) performance. Explicit inclusion of intangible environmental and social performance in the formal goals and annually reported performance of the organization can stimulate decision makers to incorporate such intangible costs and benefits in their cost-benefit analysis (Preuss, 2005). Additional critical success factors and underlying obstructions are discussed by Kruisbergen (2016) and included in Appendix D. Appendix D also discusses the problems and solutions in sustainable procurement in more detail.

To make the next step in formalizing sustainable procurement, academics work on structured methodologies that are embedded in recent literature. Two relevant academic works are the publication of Witjes & Lozano (2016) who propose a framework that links sustainable public procurement and business models together, and the Solution-focused Sustainability Assessment (SfSA) methodology developed by Zijp, Posthuma, Wintersen, Devilee, & Swartjes (2016). The publications are discussed into more detail in the sub paragraph below.

2.2.8 Sustainability assessment and decision-making frameworks

The field of assessing sustainable development is rapidly emerging and a large amount of frameworks, methodologies, methods, models and tools are developed to aid these measurements. Reviewing these tools gives insight in the recent developments. The generalized objective of these tools is to stimulate and/or facilitate the sustainable development of its practitioners. Multiple attempts are done to structure these tools, for example by Gasparatos & Scolobig (2012; Sala et al. (2015); De Ridder et al. (2007), Hacking & Guthrie (2008), & Zijp et al. (2015). An incomplete overview of recent works is included in Appendix E. Ultimately, the tools listed are instruments aiding the decision makers by providing and evaluating information about social and environmental (and economic) effects of the proposed alternatives. Information that would otherwise be omitted from the scope of the decision maker. The ProBiz4CE framework (Witjes & Lozano, 2016) and the Solution-focussed Sustainability Assessment framework (Zijp et al., 2016) have found to be of significant added value in the context of sustainable infrastructure asset procurement and are discussed in the sub paragraphs below.

2.2.8.1 ProBiz4CE framework

The framework of Witjes & Lozano)2016) has integrated sustainable public procurement with sustainable business models in order to stimulate stakeholder collaboration and thereby integrate the Circular Economy concept in product procurement. Their framework "can lead to a better collaboration and conflict resolution between parties, alignment of specifications, understanding of the possibilities and challenges in delivering the product/service combination, and closing loops that will reduce the amount of raw materials needed and waste generated, thus better contribution to CE" (Witjes & Lozano, 2016, p. 42). The ProBiz4CE framework specifically addresses both environmental and socio-economic issues in addition to technical and economic demands and is based on actor collaboration to increase both the contribution to a circular economy and the economic benefits of the supplier and procurer. However, the focus lies on public procurement of consumer products with short life spans (e.g. an office desk) and long lifetime capital assets provide a different set of procurement demands that may not be suitable for the dispossession-type of business models. The applicability of this framework for products less suited for this type of business model is not yet discussed. The shift of collaboration to the start of the procurement process is also discussed by (Zijp et al., 2016) in their Solution focused Sustainability Assessment framework discussed below.

2.2.8.2 Solution-focused Sustainability Assessment framework

The Solution-focused Sustainability Assessment (SfSA) framework of Zijp et al. (2016) focusses more on solving unique wicked problems in an environmental management context compared to the ProBiz4CE framework. Its stepwise character, consideration of multiple potential sustainability metrics and the basic foundation originating from the solution-focused risk assessment concept makes the SfSA framework a valuable assessment method to consider in the policy development process. Figure 11 shows the six basic steps of the SfSA.

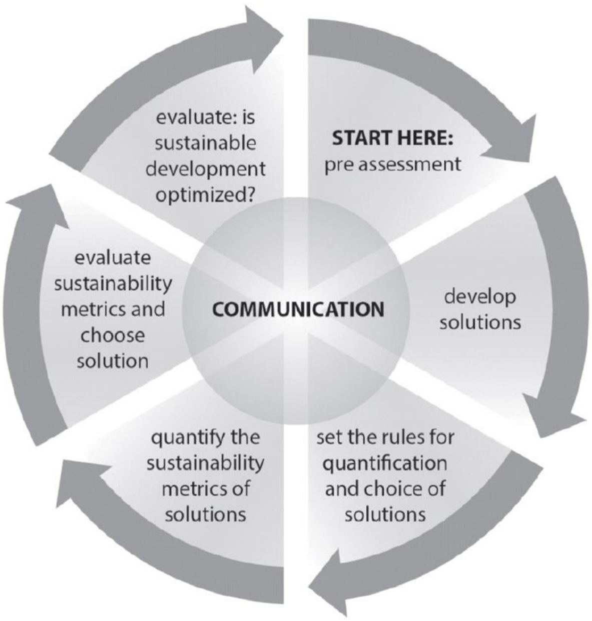


Figure 11 Visualisation of the Solution-focused Sustainability Assessment steps, adapted from Zijp (2017, p. 15)

In the framework the focus lies on both the problem at hand and the solutions available. "Solution focused, clear definitions on sustainability, participative, iterative, innovative" principles lie at the core of SfSA (Zijp et al., 2016, p. 321). The philosophy of a solution specified as a functional demand, instead of a set of technical specifications that need to be complied with, applies to the SfSA framework as well as the recent shift in (sustainable) public procurement. While the SfSA framework offers useful insights and inspiration that fits a procurement context, it is developed explicitly for large and wicked problems. Deciding on solutions for such problems is often a time intensive process with multiple iteration 'rounds'. Where in procurement decision-making, significantly less time is available. Also, the wickedness of problems tend to be less and political and resource constrains in the process limit the scope of the decision process. This results in a less open specification of the problem (functional demand) that needs solving (product offered). The inclusion of sustainability to the asset procurement process, however, increases the need for collaboration and consensus building among actors with different needs and perceptions of the problem. The SfSA framework is therefore considered highly relevant in the policy development process.

2.2.9 Sustainability related norms and standards

As concluded in the previous paragraph, the incentive for companies to take social and environmental responsibility of their own activities and supply chains still lies in economic competitiveness. Environmental and social codes of conduct or standards become more common. However, the intrinsic drive to change business strategies sustainably is not stimulated or adopted through these codes of conducts. Multiple standards are available to more structurally integrate sustainability in an organisations supply management. The multitude of standards with different criteria increase regulatory complexity and which does not stimulate mutual understanding between companies and the standards they use. Müller et al. (2009) compares different sustainability related standards (i.e. ISO 14001, SA 8000 and FSC Standard for Chain of Custody Certification) and discusses that, especially from a supply chain perspective, each standard has its own shortcomings. However, from a sustainable development point of view, the type of standard should not matter as long as the objective, being the formal compliance to more sustainability goals, is met. In DSO asset management, the ISO standards may be most suitable as the ISO offers both the well-known quality management system norm ISO9000, the ISO55001 norm for asset management as well as norms for an environmental management system (ISO14001) and also suggestion for socially responsible operation (ISO26000). The norm families related to sustainability are introduced in Appendix L together with ISO55001.

2.2.10 Measuring sustainable development in asset life cycle management

Measuring the performance of a procurement alternative and predictions of future developments with respect to that performance can be done based on qualitative or quantitative parameters. The most important pre-requisite of measurements is the objectivity and reproducibility of the measurement. Achieving objective measurements instead of subjective judgement and opinions becomes increasingly more difficult when measurement data is scarce, uncertain or cluttered, as is often the case with sustainability-related measurements. A structured measurement approach is therefore required to cope with these difficulties. A so-called 'hierarchy of assessment tools' (FAO, 1996) can be used to structure these measurements (Figure 12).

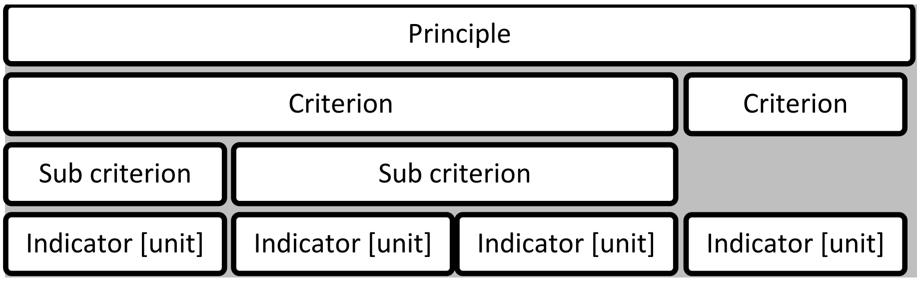


Figure 12 Visualisation of the hierarchy of assessment tools, adapted from FAO (1996, p.1)

2.2.10.1 Sustainable decision principles

As discussed in §2.2.2, the large spectrum of definitions and interpretations of sustainable development makes measuring SD a challenging task. The holistic sustainability ambitions (i.e. Doughnut Economic model, SDGs) need to be translated into sustainability *principles* applicable to a specific procurement process. Four questions can be used to formulate what sustainable development entails in the procurement process (NRC, 1999, p. 1658):

1. What is to be sustained?
2. What is to be developed?
3. What is the relation between what is to be sustained and what is to be developed?
4. Over what scales in space and time are those relationships meant to hold?

The procurement project scope and perspectives of actors involved in the project directly influences the interpretation of the more static corporate principles that form the basis of measurement criteria and thereby sustainability measurement as a whole. An issue often faced is the formulation of multiple sustainability principles that, when considered simultaneously, appear to be mutually exclusive due to the lack of resources (e.g. time, financial means, commitment, knowledge). Sustainability principles should not change over time to ensure their guiding function. Appendix F provides additional background information on sustainability principles.

To operationalize principles and assess alternative compliance with the principles, criteria are required that connect the alternative under consideration to the overarching principles. Defining suitable criteria is a difficult process that is discussed in the subsequent subparagraph.

2.2.10.2 Sustainable decision criteria

Sustainability principles sketch the direction of sustainable development, while criteria are the factors that are used "to make a judgement about the relative sustainability of a set of options" (Foxon & McIlkenny, 2002, p. 288). Criteria can thus be considered the operationalisation of principles. While principles do not change over time, criteria may change depending on the situation, values or goals until a definite and suitable set is chosen. The more specific criteria are formulated, the easier it becomes to make decisions or judgements based on that criteria as there is less room for (mis)interpretations. To cover a large amount of relevant topics, many criteria may need to be formulated which often results in an overload of criteria, and thus an increase in decision-making complexity.

Sustainable procurement criteria can have a variety of dimensions as the criteria originate from the entire life cycle of assets and materials. An organization can only make decisions in line with their sustainable ambitions when sustainability-related criteria are present and representative for the sustainability goals of the organization. In short, defining sustainability criteria requires a multidisciplinary approach. Methodologies that analyse and facilitate decision-making when multiple criteria from multiple disciplines/dimensions are to be considered are referred to as multi-criteria decision analysis (MCDA) methods. §6.1 discusses the relevance of MCDA in more detail.

Multiple authors have worked on sustainability criteria (e.g. Hallstedt 2017; Bratt et al. 2011; Halog & Manik 2011). However, a proven set of criteria incorporating all aspects of the triple bottom line of sustainability in infrastructure asset material life cycle management processes is currently unavailable. In practise, criteria are defined by means of expert judgement. Foxon & McIlkenny (2002) developed a set of five guidelines to assist the formulation and selection process of criteria, describing the required *comprehensiveness, applicability, tractability, transparency* and *practicability* of a good criterion. The supportive guidelines are included in Appendix F and are recommended to be used in the criteria definition process during the procurement process as well.

A general set of criteria may not be desirable due to the unique character of each procurement process. However, a set of overarching criteria is needed to serve as a starting point in the sustainable procurement policy developed. This set can be altered, revised or replaced based on the procurement project. Table 3 presents the generic set of criteria.

Defining criteria requires great care as criteria are capable of steering the alternatives offered into directions and criteria may also invite suppliers to deliver a large amount of (un)wanted information (Liyanage, 2012). It is thus of importance to consider the consequences of the adoption of a criterion as well as the scope (e.g. level of detail of data) of a criterion. The collection of large amounts of useless information on undesirable topics, while relevant asset material topics or procurement goals remain underexposed should be prevented.

A criterion requires a (set of) qualitative or quantitative parameter(s) that can be measured to define the performance of an alternative related to the criterion. The next sub paragraph discusses these measurement parameters, referred to as *indicators*, into more detail.

2.2.10.3 Sustainable decision indicators

Indicators are the parameters or variables that can be considered the 'data' of a criterion and thus the actual performance regarding a specified sustainability principle. When formulating indicators that define their criterion, the capability to measure past, current and future performance need to be considered. Reliable sources of this data or information and appropriate means to make this data or information available for each alternative under consideration are required to be able to measure the indicator. Sustainability indicators require appropriate units of measurement that represent the underlying sustainability principle. It is thus important that inappropriate simplifications do not triumph in cases of measurement complexities. As an important conclusive remark on indicator formulation, Clift (2003, p. 261) states that "**Aggregation across the dimensions, for example expressing ecological indicators in monetary form, is unnecessary and undesirable"**.

Zijp, Van der Voet, Huijbregts, & Posthuma (2015b) present a methodology to determine which sustainability data generation method is appropriate and how to select that method. For the extensive introduction to this instrument the reader is forwarded to the open access article of Zijp et al. (2015b). As with criteria, indicators largely depend on the desired function of an asset and the sustainability principles and set of (sub-)criteria that are considered. Sustainability indicators have the important task to steer the asset supplier market into the direction of sustainable development as corporate strategies of supply chain actors are mostly guided by profitable business models and cases. Correctly formulated sustainability principles, criteria and indicators may thus be able to show what is considered profitable and desirable from the perspective of the procuring organization. Care must be payed, however, to 'false' sustainability performances as discussed below.

Table 3 General sustainability criteria (based on Foxon & McIlkenny (2002, p. 292), European Forest Institute (2013) and Martín-Gamboa, Iribarren, García-Gusano, & Dufour (2017, p. 169))

Sustainability dimension	Criterion	Description
Technical	Technical performance and feasibility	The technical performance and technical feasibility encompasses the quality of the service or function the asset delivers during its use phase (e.g. asset efficiency and capacity)
	Reliability, Availability, Maintainability and Safety (RAMS)	RAMS includes the operational reliability, robustness and ease of (part) maintenance of the asset during its use phase.
	Flexibility & adaptability	The flexibility & adaptability of an asset refers to its ease of transportation, installation, use and decommissioning (e.g. level of modularity)
	Technical risk assessment	Technical risks mainly discuss the maturity level of an asset. Risks hereby refer to possible undesirable events during the asset use phase.
Economic	Life cycle costs	The life cycle costs of an asset generally refers to the total costs of using an asset throughout its full life cycle, from raw material extraction to end of use.
	Economic risk assessment	Economic risks are associated with the purchasing and operation of an asset throughout the full life cycle (e.g. uncertain return on investment)
Environmental	Resource utilization & material source	The resource utilization & material source criteria describe the origin and efficient use of resources and raw materials in three asset life cycles (i.e. raw material, use, end of use phase). This includes, among other characteristics, the percentage of virgin and recycled materials, the geographical origin of materials and the amount of material wasted or not suitable for re-use or recycling.
	6Rs waste hierarchy	Criteria related to the 6Rs of the waste hierarchy, referred to as the preferred order of asset waste at the end of use of an asset: Refuse, Reduce, Reuse, Repair, Recycle, Re-think. Hazardous properties of materials could also be included in this criteria category.
	Environmental impact	The environmental impact of an asset throughout its complete asset material life cycle is described by criteria in this category (e.g. CO_2 , CO, NO_x , SO_2 emission, biodiversity loss and land use change)
	Environmental risk assessment	Environmental risks throughout the complete asset material life cycle are categorized under this criterion. An example of environmental risk is the risk of ground water pollution during the asset production process.
Social	Supply chain participation	Supply chain participation encompasses the level of supply chain actor cooperation and collaboration throughout the complete asset material life cycle (e.g. innovation development partnership).
	Social impact	The social impact of an asset during the asset material life cycle is described by the social impact criterion. Social impact can, for example, refer to the number of persons employed in total and by gender to manufacture the asset.
	Social risk assessment	Social risks related to infrastructure assets mainly refer to health and safety risk in the Raw material phase, production phase and end of use phase (e.g. risk of child labour during the virgin material extraction).

2.2.10.4 Greenwash and the need for absolute measurement of sustainability

Major differences can be identified between (regulatory) compliance and setting (and achieving) ambitious goals in sustainability. Sustainability criteria have the crucial role to complement asset management guidelines (e.g. ISO standards) and to incentivise suppliers to shift from 'complying to standards in asset management', to setting out (and meet) ambitious goals through intrinsic motivation to perform more sustainable.

Absolute guidelines (i.e. regulations, norms and standards take a considerable amount of time to be developed and approved. And once approved, their content usually is a static 'measurement tape' of sustainable performance, or the guideline merely offers a framework that allows stakeholders to interpretations "compliance" as they deem fit. Both situations stimulate greenwash[1]. Two examples illustrate the limitations of standardized static guidelines in sustainable development, and the need for absolute criteria:

> *Example 1: Measuring relative performance*
>
> *The (environmental) performance of cars, fridges and houses is often measured using a measurement scale of G (lowest) to A (highest). Car X receives an A-label on the environmental performance scale as car X performs 20% better than comparable cars Y and Z in its product class. Due to product innovations, car Y and Z may end up performing better. This change in circumstances make car A only 10% better, resulting in a replacement of the A-label with a B-label. Measuring sustainable performance of cars should therefore be done using an absolute performance scale to communicate transparently and uniform about performances. Relative classification may stimulate continuous (competitive) innovation, however it does not provide an objective measurement of sustainability.*
>
> *Example 2: Sustainability standard certification*
>
> *Free interpretation of the ISO14000 Environmental management system standard enables practitioners to freely select their means to become ISO14000 certified. Due to the large spectrum of approved means, differences in ISO14000 performance are inevitable. ISO14000 certified organizations may have done the bare minimum and still appear to be as environmentally aware as much more ambitious organizations. The value of the ISO14000 certificate is thereby not set and depends on the interpretation and willingness to set ambitious environmental management system goals.*

To overcome greenwash situations and stimulate continuous sustainable development, sustainability criteria should be as relative to the current situation as possible and not based on normative compliance. To successfully utilize relative criteria, a point of reference is crucial: What is the base line performance? What or who is the performance on a criterion is compared to?

Utilizing relative criteria can offer a set of distinctive criteria throughout the evaluation of alternatives when assessing sustainability in contrast to demanded normative compliance.

[1] Greenwash is the activity that "makes people believe that your company is doing more to protect the environment than it really is" (Univercity of Cambridge, 2017, p. 1)

2.3 Conclusion and policy input

The knowledge area of sustainable development provides a way of thinking, value preferences and broadening the scope of factors considered that is of crucial importance within a sustainable procurement policy. The literature studied emphasizes the need for recognition and acknowledgement of explicit incorporation of sustainable development rather than considering it an important side effect. Adding an environmental and social sustainability-focus to asset procurement affects the interaction, collaboration and priorities among interdependent actor networks as different business models come into play that enable actors to contribute to a more Circular Economy, and sustainable development as a whole. The role and asset characteristics, as discussed in the next chapter, determine to a large extend the capabilities of infrastructure assets to be more sustainable. To be able to have an increase positive impact and decreased negative impact on the biosphere and human society as a whole, actors throughout supply chains need to adopt the focus on systems thinking and the expanded concept of value creation collectively. Only then, the Short-term individual gains become subordinate to the long-term collective gain of an organization and society.

The extensive background on sustainable procurement and interrelated sustainability-topics, as discussed in this chapter, provide highly relevant input to the sustainable procurement policy developed in Chapter 7. Based on the literature review a set of policy development goals, constraints and criteria that provide guidance in the development and the validation process.

Drafting the set of goals, constraints and criteria in this chapter, as well as in Chapter 3, 4 and 5, follows the policy analysis framework and definitions of Van de Riet (2003) and Walker (2000). The diversity of goals, constraints and criteria from multiple research disciplines enables a policy proposal based on multiple perspectives. These perspectives are expected to increase the complexity of the policy proposal and priorities in goals, constraints and criteria. However, the different perspectives and disciplines are considered complementary and are therefore required.

Policy goals: A policy is set out to solve a (perceived) problem. The underlying objectives that would resolve that problem once met are considered policy goals. Policy goals can be conflicting, making the design and implementation of a policy while complying with all goals at once a complex endeavour (Walker, 2000). Policy goals may be based on assumptions and may need to be altered during the policy development process.

Policy constraints: The range of policy alternatives is limited by a set of boundaries, referred to as policy constraints. This set of constraints define the solution space of the policy and the policy needs to comply with the constraints set in order to be a feasible and desirable policy alternative. Constraints are often based on assumptions. More constraints may introduce themselves, or perceived constraints may disappear. Active evaluation of constraints throughout policy development iteration cycle(s) is therefore required.

Policy criteria: Evaluation of a policy requires clearly defined measures that describe the policy performance. The policy is to be developed in order to resolve the problem as effective as possible, based on the performance measurements. Prerequisites for criteria are their direct relation to specified policy goals and their capability to be measured and scored quantitatively or qualitatively (Walker, 2000). A policy criteria can also be a constraint, resulting in a minimal or maximal performance score to be achieved (the constraint) and the (un)desired overshoot performance (the criteria).

From the literature review on sustainability in procurement, the conclusive nine goals, thirteen constraints and fourteen criteria used in the policy development process the are included in Appendix G.

Chapter 3: Strategic DSO infrastructure asset management

Figure 13 Content structure chapter 3

The environment in which the current procurement policy is the strategic *DSO infrastructure asset management* context. Understanding this context and how it affects sustainable procurement is essential to the development of a useful policy. The asset management context consists of a set of contextual factors dictated by the current knowhow and matured practices of the Dutch DSO infrastructure operation. Figure 13 shows the topics of interest to the sustainable procurement policy that are discussed: *infrastructure asset characteristics (§3.1)* and *infrastructure material life cycle management (§3.2)* to *asset strategies (§3.3)*, *risk assessment (§3.4)* and *expert judgement (§3.5)*. The chapter concludes by discussing the applicable *legal and regulatory frameworks (§3.6)* and the *asset market implications (§3.7)* on procurement procedures.

3.1 Infrastructure asset characteristics

Infrastructure assets (e.g. road, rail, water, electricity, gas and telecom assets) have specific characteristics that require specific attention. These assets and related services distinguish themselves from production related assets with their functional characteristics. Herder & Wijnia (2012, p.32-33) list the following characteristics that describe infrastructure assets:

- Very long lifespan (50-100 years)
- High probability of changing societal demands over time
- Uncertainty about those future demands
- Passive operation that requires almost no attention to function
- Robust technical design
- Networked systems
- Penetrating or structuring the public domain, making failures highly visible and undesirable

Managing such assets thus requires compliance to high performance demands over an uncertain and long time span. Effective asset management needs a sociotechnical system's perspective to anticipate on the complex dynamics of today's world (Liyanage, 2012). Appendix H illustrates the complex environment of asset management due to social, political and economic dynamics when the diversity of contextual influencers is acknowledged. This environment affects the function demanded from an infrastructure asset. The ability of an asset to carry out its main function during operation depends on the original design, production, installation, as well as the operation and maintenance strategies and activities of the asset. It is therefore relevant to consider the entire life cycle when striving for operational excellence.

3.2 Infrastructure asset material life cycle management

Asset management, when defined as "the systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems (…) for the purpose of achieving its organizational strategic plan" (The Institute of Asset Management, 2008, p. 2), is able to focus on the total life cycle of an asset in theory. In practice, considering the complete life cycle is difficult as infrastructure assets tend to be used for a very long time.

The main activities and decisions made to optimally and sustainably manage infrastructure assets are dependent on a specific asset as they have different functions and specifications. Infrastructure operators construct and maintain networks of different types of assets. Infrastructure assets are moderately to highly technical complex products. To ensure operational excellence of these assets while also provide economic stability to the asset operator, asset managers need to deal with challenges on both (strategic) corporate and operational level. Wenzler (2005) defines four key challenges in infrastructure asset management activities:

1. Alignment of strategy and operations with stakeholder values and objectives;
2. Balancing of reliability, safety, and financial considerations;
3. Benefiting from performance-based rates
4. Living with the output-based penalty regime

To address each of these challenges, general and asset-specific strategies and activities are required to create a balance between operational excellence and maintaining a healthy business climate of the organization. The causal relations between activities of an infrastructure operator can be visualized using a causal loop diagram (J. Schneider et al., 2006). Figure 14 shows this diagram.

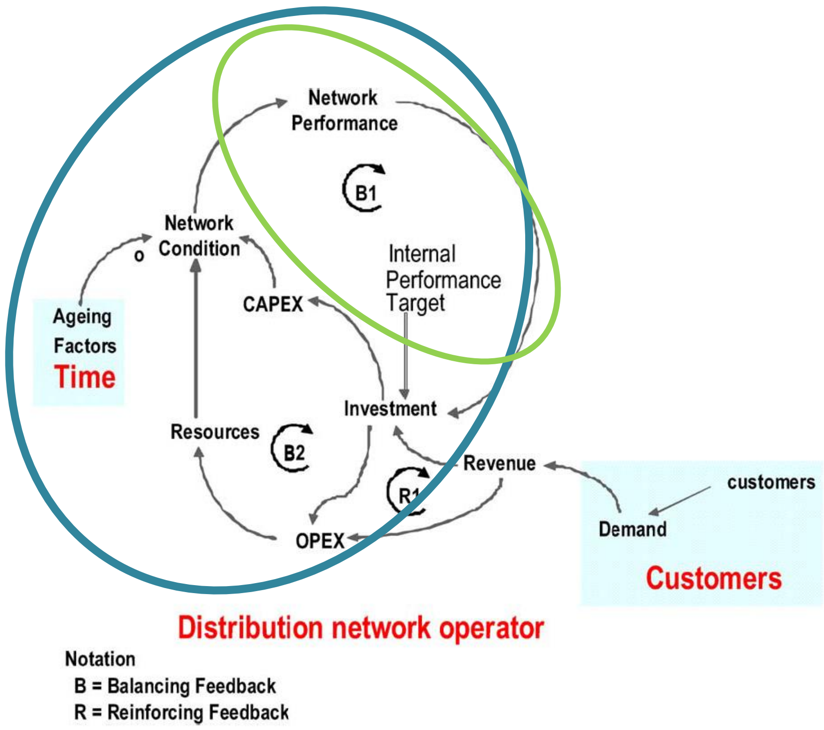


Figure 14 Causal loop diagram of DSO asset management investment and activities (adapted from J. Schneider et al. (2006, p. 644))

> *Description of the causal loop diagram (*Figure 14*): the network performance depends on the network condition: the better its condition, the better the network performance. The network condition is negatively influenced by aging factors over time and positively influenced by operational expenditures (OPEX) and capital expenditures (CAPEX). The network performance relates negatively to the investments made: a better performance results in a lower investment in asset management activities as long as the internal performance targets are met. The investment power (CAPEX and OPEX) depends on revenue, which on itself depends on the customers demand of services provided by the network operator. Two causal loops balance the asset management activities: The "CAPEX loop" keeps the asset base in a desired condition by investing in new assets, while the "OPEX loop" performs operation and maintenance tasks to slow asset degradation.*

Throughout its lifetime an asset is subjected to many decisions. From its fertilization (the decision that the function of the asset is needed) to its birth (design and production) and subsequently the operation and maintenance decisions during its, what should be, very long useful life. And even after decommissioning, multiple end-of-use options present itself (e.g. reuse, recycle, landfill). In each life cycle phase, decisions can have an impact on the multidimensional value of the asset.

Two life cycles can be defined: the **asset life cycle**, and the **asset material life cycle**. Both are shown in Figure 15. The asset life cycle considers the physical existence of the asset under consideration, starting when the asset is produced and finishing when the asset is taken out of service. When an asset is considered 'a combination of materials with a function', the life cycle expands to seven phases. The theoretical design and the collection or mining of materials indicate the beginning of the material life cycle, and the end of use decision marks the end of this life cycle.

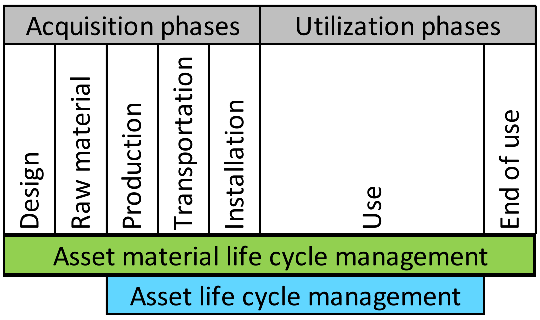


Figure 15 Visualisation of the asset (material) life cycle phases, adapted from Schuman & Brent (2005, p. 574)

The activities below characterise the corresponding phase:

Phase 1: Design	In the design phase, the asset product specifications are defined through conceptual design, preliminary design and detailed design
Phase 2: Raw material	The raw material phase considers the collection and/or mining, extraction and processing of material. Both virgin and recyclate (recycled materials in a second, third or higher life) materials are required to start the production of the designed asset.
Phase 3: Production	The development and production of the asset happens in the production phase. The production phase also includes certification and approval for commercial use (excluding innovative pilot programme assets).
Phase 4: Transportation	In the transportation phase the asset is transported from the production facility to the asset operator.
Phase 5: Installation	Asset construction and commissioning, as well as testing and calibration happen in the installation phase.
Phase 6: Use	The use phase focusses on asset utilisation and asset support. This includes asset operation, maintainance, performance monitoring, and execute asset modifications and upgrades.
Phase 7: End of use	The asset retires and is decommissioned in the end of use phase. Different waste management options are available and the asset can also be integration in other/new supply chains.

Asset (material) life cycle management can offer a systematic approach to applications of sustainable business models (see §2.2.5) due to a systems view and asset strategies with long time horizons. Generating economic profit while at the same time minimizing negative environmental and social impacts become possible when strategic decisions throughout the life cycle are made based on technical, economic, social and environmental factors simultaneously.

*For example: investments can be minimized by **reusing** an asset, which leads to CAPEX cost reduction, a lower demand for (virgin) materials and a more accurate asset maintenance plan due to (more) knowledge of the actual technical state of the asset.*

A recent shift towards more business and society centred asset management objectives, and thus a broader scope of conventional asset management, is discussed by Van der Lei (2012). The industrial sector, however, has a strong cultural influence on the acceptance of a broadened scope of objectives: The more safety-critical and reliability-driven the sector, the stronger the emphasis on "by the book" decisions and priorities.

The long life cycles of infrastructure assets offer the possibility to asset managers to shift their focus towards short term objectives (e.g. performance targets or financial cuts) rather than to focus on the long term. Consequences of short term decisions on long term asset degradation are subjected to major time delays, creating perverse incentives (present bias) in asset management decision-making. Heavy regulations and formalized (impersonal) procedures aim to counter negative consequences of a short-term target focus. Schneider et al. (2006, p. 644) therefore concludes that "in order to make the right decisions it is very important to develop the ability to analyse the complex dependencies between maintenance and renewal actions and the costs and the quality of service".

Consideration of the (often large) variety of short, intermediate and long term goals in procurement decision-making requires insights in the events or factors that could have an impact on the asset material life cycle performance. An impact, often referred to as an effect or influence, on the life cycle performance should be interpreted on a high level of abstraction. Impacts can be an improved technical asset reliability during the asset use phase, as well as the stimulation of forced labour during the extraction process of rare earth materials in the raw material phase. As the life cycle is long and multiple dimensions are considered relevant when sustainability goals are adopted, the establishment of a complete set of asset material life cycle impacts may be a daunting task. Three tools are found in recent literature that provide guidance in the life cycle impact identification process:

- **PESTLE** (acronym for Political, Economic, Socio-cultural, Technologic, Legal and Environmental) offers six categories of factors that may potentially impact the asset material life cycle positively or negatively (Jurevicius, 2013). The tool is commonly used on a macro level to determine and analyse risks and SWOTs (Strengths, Weaknesses, Opportunities and Threats). The PESTLE approach can be used throughout all life cycle phases.
- **TECCO** (acronym for Technical, Economic, Compliance, Commercial and Organizational) is a set of five perspectives that can be used to identify asset lifetime impacts. Lifetime impacts are defined as the "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, & Van Dongen, 2017, p. 265) and are thus mainly relevant during the asset use phase.
- **Asset lifetime impact factors** are a set of CAPEX and OPEX investment 'driving forces' that can be used to describe the exogenous or internal changes that affect an asset to compliance with the functional need over time Komonen et al. (2012). The impact factors are applicable to the use phase an end of life phase.

The PESTLE analysis categories and TECCO perspectives are discussed into more detail in Appendix H.

3.3 Development of an asset strategy

Most of the difficult decisions that involve the complete asset life cycle are dealt with on a strategic asset management level rather than an operational level. To guide the decisions involving the course of the asset material life, an asset strategy is needed. One can consider this asset strategy a product of four factors (see Figure 16). Prior to the design phase of the asset, the strategy already needs to be clear as without a strategy, wrong managerial and operational decisions could be made. An extensive overview of external and internal asset strategy inputs by Komonen, Kortelainen, & Räikkönen (2012) is included in appendix I. Setting up asset life cycle plans, which is an example of an asset strategy plan, is discussed by Ruitenburg et al. (2017).

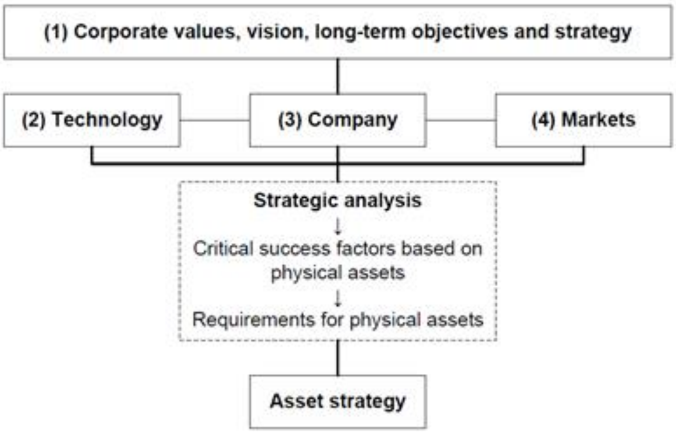


Figure 16 Information flow of asset strategy development adapted from Komonen et al. (2012, p. 50)

The asset strategy describes, in essence, what function the asset has and how that asset needs to fulfil that function. Generally speaking, infrastructure assets fulfil their function through continuous operation. Planned and unplanned maintenance becomes inevitable and the majority of the asset management activities are therefore focussed on maintenance. Asset management techniques and strategies include different types of *maintenance strategies* (e.g. "condition-based maintenance, reliability-centred maintenance, corrective maintenance and time-based maintenance), asset simulation, statistical fault analysis and asset life cycle extension" (Schneider et al., 2006, p. 645). These maintenance strategies and activities focus on technical performance. Adding economic, environmental and social factors are required to integrate sustainable asset management goals on a strategic level.

During the use phase, and operation and maintenance in particular, continuous trade-offs are made between acceptable and unacceptable risks. Unacceptable risks need to be mitigated as they may interfere with the service that is provided. Asset operation and maintenance management hereby essentially becomes risk management. Subsequent paragraphs discuss risk management in general, and (subjective) expert judgement in risk management specifically, to understand the importance of multidimensional risk assessment considering the entire asset material life cycle within the procurement process.

3.4 Alignment of risk assessment and sustainability

Asset management decisions are often based on risk rationale to make trade-offs between least harmful or most beneficial choices. Risk is a complex phenomenon and is generally defined as the product of three questions: "(1) What can go wrong? (2) What is the likelihood of that happening? and (3) What are the consequences?" (Rausand, 2011, p. 46). A risk assessment describes the systematic identification and mitigation of risk events for a given situation. As discussed in §3.1.2, dimensions and objectives beyond the conventional technical and economic drivers are increasingly accepted and incorporated in general asset management. However, translating environmental and social dimensions to risk management introduces major challenges (Liyanage, 2012).

Risk and sustainability principles can be considered comparable to a large extend: both aim to minimize the adverse consequences of a decision while dealing with (a) the inevitable complexity of aleatory[2] and epistemic[3] uncertainties in data and methods and (b) different humanitarian perceptions on the subject matter. Connecting risk-based decision-making to sustainability-focussed asset management can thus be considered an expansion of the decision-making rationale rather than a different approach.

As the risk assessment body of knowledge is matured throughout the past decennia, risk-based decision-making principles offer valuable lessons learned to the field of sustainability-based decision-making. Incorporation of sustainability-related events in risk assessment techniques and methods however requires a careful approach. Frequently used risk assessment tools have limitations when applied to sustainability-related risks (e.g. the consideration of time when assessing the environmental impact of polluted waste water). Appendix J discusses two commonly used tools and their applicability to sustainability: The ALARP risk acceptance principle and the risk matrix.

Adding additional dimensions of objectives to risk-based decision-making creates so-called multi-attribute and multi-objective decisions. Decision-making hereby becomes a process of trade-offs as multiple objectives from multiple dimensions are considered at the same time while. While a variety of methods exist in decision theory to deal with multi-objective decisions (e.g. Cinelli et al., 2014), Faber & Stewart (2003, p. 181) stress that "…these methods do not themselves provide any answer as to how the different attributes and/or different objectives should be weighted". Trade-offs between risk mitigation measures, or the general prioritization of one objective over the other, thus still requires a suitable solution that aligns multiple perspectives on values. An approach to simplify multi-objective analysis is often to convert attributes to comparable denominators or units of measurements. While this may seem to reduce multi-objective complexity, converting may not be desirable (Clift, 2003; Faber & Stewart, 2003).

Risk-based decision-making, being fundamental to infrastructure asset maintenance management, is a complex endeavour that is made significantly more difficult by adding sustainability-related risks. Coping with this increased complexity requires all actors involved in the multi-dimensional risk assessment to be aware of their role and responsibility towards a credible, complete and informed outcome on which strategic decisions can be based. The emphasis on expert judgement is hereby made as rational decision logic is not able to make value-based priorities.

3.5 Expert judgement in risk assessment

Risks are generally divided into two types: *'risk as is'* (objective risk, actual risk) and *'risk as perceived'* (subjective risk). It is discussed extensively that a 'risk as is' differs in many situations from a 'risk as perceived' by the public. Skjong & Wentworth (2001) discuss that this deviation also applies to experts who are consulted throughout the risk assessment process in case of insufficient, unavailable or non-existing statistical or historical data. *Expert judgement*, defined as "an informed opinion based on the experts training and experience" (Skjong & Wentworth, 2001, p. 1) thus also has its limitations when utilized in risk and/or sustainability assessments. In both assessments, situations are assessed

[2] Aleatory uncertainty describes natural or random uncertainty

[3] Epistemic uncertainty describes uncertainty rooted in (the absence of) knowledge or the ignorance of people

based on objective data and as well as subjective (value-based) expert judgement or best estimates.

Experts are subjected to judgement biases when their opinion is required on topics out of their primary field of expertise. Skjong & Wentworth (2001, p. 7) conclude that "when experts are forced to go beyond the limits of their observable expertise or to convert incomplete knowledge into judgement to be utilized in risk assessment, the experts may fall back on intuitive processes, just like lay people". Expert judgement regarding social and environmental risks and thereby sustainability-related risks can be considered irrational and judgement may be referred to as inconsistent due to the lack of data. It is thus relevant to clarify what lies at the root of the subjectivity and perception of lay people to be able to account for this bias throughout the sustainability assessment process.

Three ingredients influence the risk perception of individuals: (1) the characteristics of worldviews (Pidgeon, Hood, Jones, Turner, & Gibson, 1992), (2) heuristics (Plous, 1993) and (3) risk characteristics (Green, Short, & Levy, 1998; Litai, 1980; Skjong & Wentworth, 2001). Appendix K discusses these influences in more detail. The illustration in Figure 17 visualizes the dependency of expert perception on expert interests and the perception of reality of that person. It can be concluded that expert judgement is rarely entirely rational and objective. Appendix K also introduces four worldviews, five types of heuristics, and the thirteen principle of risk characteristics that should be considered when expert judgements are used in decision-making to understand their perception of reality.

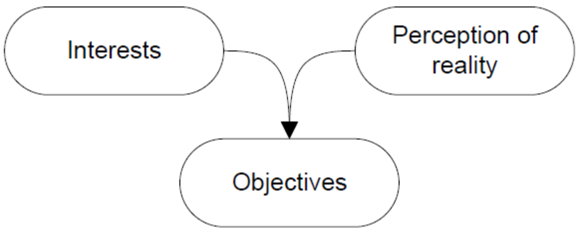


Figure 17 Relations between expert interests, perception of reality and objectives (adapted from Van de Riet, 2003, p. 23)

To be able to utilize expert judgement throughout risk and sustainability assessment, systematic approaches based on rationality and transparency are crucial to deal with the shortcomings of human value judgement. Majone (1989, p. 12) states that "choices are considered rational if they can be explained as the best means to achieve the objectives stated" in which criteria for rationality are: goal-orientation, effectiveness and efficiency (Van de Riet, 2003).

The statement of Majone introduces the last important remark on expert judgement and risk perception: Different actors will have different expert judgements as actors have different perceptions of best and different objectives. Subject matter experts should therefore be selected carefully, with unanimous support and their judgement should be trusted to prevent contradictory or unsupported judgements. In addition, the roles that different actors have with respect to risk assessment as well as their different interpretations of the risk assessment results need to be discussed prior to a risk assessment. The complex socio-technical system involved in risk management, ranging from governmental politicians to the technicians working directly within hazardous environments, stresses this need as discussed by (Rasmussen, 1997). Faber & Stewart (2003, p. 182) present three examples of risk analysis (risk assessment) roles that depend on the actor's background and are illustrative for the large variety of roles:

“Risk analysts:	*provide for better consistency in terms of methods, models and data so as to increase the credibility of risk analysis.*
Engineers:	*be capable of providing pertinent information to the risk analyst and critically review the outcomes of a risk analysis.*
Decision-makers:	*be informed about the rationality of their decisions and their impact on the interested parties.”*

It is thus important to carefully select experts and to discuss the roles of all actors involved to make each actor aware and act in accordance with his own role. Hereby, a productive decision process is secured and viscous and time-consuming value-judgement-based discussions can be prevented.

To conclude: introducing value-based and/or uncertain factors into risk and sustainability assessment calls for actor collaboration to be able to make decisions. Thorough understanding of decision-making in groups hereby becomes evident to be able to develop an effective sustainable procurement policy. Chapter 4 elaborates on this, often difficult, interaction between multiple actors in decision-making as well as the interdependencies among those actors.

3.6 The legal and regulatory framework of Dutch DSO asset management

To understand the environment in which asset management activities are executed, the legal, regulatory and standards framework is the basic point of departure: Compliance with these guidelines is undisputable. The goal of such documents is to guarantee a safe, reliable, sustainable and well-organized operation of assets. For Dutch DSOs the relevant (regulatory) boundaries in which the operation is optimized consists of:

- NTA 8120
- ISO 55001
- Procurement law (*in Dutch: Aanbestedingswet*)
- Guide on proportionality, according to the Procurement law
- Independent network operation law (*in Dutch: Wet Onafhankelijk Netbeheer (WON)*)
- Regulation of quality aspects of electricity and gas network operation (*in Dutch: Regeling kwaliteitsaspecten netbeheer elektriciteit en gas*)

Other relevant standards for this research are the sustainability-focused ISO 14001 (environmental management system), ISO 20400 (sustainable procurement) and ISO 26000 (guidance on social responsibility). While these standards are not directly related to the core business of the infrastructure operator, their relevance to this research is clear: these standards set out to include environmental and social aspects in the operation of organisations.

An introduction to the above mentioned pillars of the asset management framework is given in Appendix L to become aware of the existing regulatory structures and boundaries of a Dutch DSO.

3.7 Implications of the capital asset market

Dutch DSOs engage in a regulated market: a governmental supervisory body, Authority on Consumer and Markets (ACM), sets out the financial yield DSOs are entitled to as well as the service price benchmark of DSOs. The goal of this benchmark is to create a relative costing system among all DSOs to guarantee an equal consumer price and thereby stimulating competitive.

As DSOs generally do not manufacture their own assets, they rely on the (inter)national markets to acquire their assets. Two variables describing these markets are directly affecting the procurement strategies and asset life cycle management decisions: (1) The individual firm size of the suppliers and (2) the orientation of the market.

(1) The **size of the supplier** and the market share that supplier owns, has major implications on the procuring organizations dependability on suppliers. The rhetoric of this assumption is the assumed positive relation of the uniqueness of supplier’s product (the resource) and power distribution. The dependability of the purchaser on the market can be expressed in resource dependency quadrants. Table 4 shows that, the more important and rarer the asset is, the more the DSO depends on the market. And the higher the procurers dependability, the lower the power of the DSO to introduce unusual demands in the procurement process, including sustainability-related requirements.

Table 4 Resource dependency generalization of procurer on supplier

	Limited importance of resource	Great importance of resource
Limited options to replace supplier	*medium*	*high*
Can easily replace supplier	*limited*	*medium*

Small suppliers that own a small size of an asset market are dependent on the procuring organization, making the procurer the powerful party. While the opposite is true in case of large suppliers that own the majority of a market: the procuring organization often is only a minor client which makes the procurer less powerful and more dependent on the supplier.

Table 5 Dependency-power relation of supplier and procurer

			Procurer is …	
Supplier is …	… a small firm	and owns small market share	Independent	and powerful
		and owns large market share	Dependent	and powerful
	… a large firm	and owns small market share	Independent	and not powerful
		and owns large market share	Dependent	and not powerful

Table 5 illustrates the relation between the size of the supplier and the procuring organization as well as the level of dependency and power. The more powerful independent and powerful the supplier is, the more ambitious and demanding the procurement demands can be.

(2) The **orientation of the market**, either horizontal or vertical, also affects the procurement process:

- In a *vertical market*, the suppliers offer their assets to specific industries and clients, making their clients relatively more powerful as clients have a greater bargaining position when acting collectively (Hoejmose & Adrien-Kirby, 2012). While collaboration between clients is strictly regulated and monitored, the demand for more sustainable procurement can be expressed collectively. Difficulties arise however: sustainability has many faces, making a uniform transition to sustainable asset procurement very difficult due to the diversity of actors and their priorities.

- Suppliers offering their goods and services on a *horizontal market* have a wide range of clients in multiple industries. As such, suppliers are less prone to collective demands regarding sustainable procurement from a single industry as the supplier is not dependent on that single industry.

In terms of general economic theory, market supply and demand relations differ for the horizontal and vertical market: The horizontal market has a higher demand, while the vertical market has a higher supply. Competition can thus be stimulated in the vertical market as suppliers depend on DSO demand, while in horizontal markets, DSOs depend on the resources offered by the supplier.

Transparent dialogue with suppliers is an integral and fundamental activity in sustainable procurement as the procurer demands and the supplier's capability to fulfil those demands need to align in order to have a successful procurement process and end result. It is only through transparent communication and effective collaboration that the supplier is able to design and manufacture an asset that fits the needs of the procurer. It can thus be concluded that realistic yet ambitious demands require extensive market consultation as the dependency and power distribution between supplier and demand is procurement project dependent.

3.8 Conclusion and policy input

The asset characteristics and their function differs considerably form the consumer products with short (<5 year) useful lifetimes. Understanding the drivers in decision-making related to DSO assets is therefore an important input to the policy. The long useful lifetime of 20-80 years, the emphasis on risk mitigation and technical and economic performance, and the dependability on the asset market are three factors that results in a strong focus on strategic decision-making. These strategies mainly tend to optimize the use phase of an asset and, more recently, the asset life cycle from production to decommissioning. However, with an increased recognition of multidimensional life cycle impact factors, the scope of the asset life cycle needs to expand to the life cycle of asset materials. By doing so, decisions that relate to the asset design, raw material, and end of use also become relevant. This implies that the procurement process of an asset needs to expand its scope of demands as well and thereby needs to cope with the increased importance of expert judgement rather than eliminating topics of (high) uncertainty, as is often the case with unfamiliar topics such as environmental and social demands. Interdisciplinary collaboration to grasp the performance of assets from a systems perspective becomes inevitable. Therefore, insights and subsequent policy inputs related to actor collaboration and effective decision-making with multiple actors is of great importance. The following chapter discusses collaborative decision-making.

From the literature review on strategic DSO infrastructure asset management, the conclusive six goals, nine constraints and seven criteria used in the policy development process the are included in appendix G.

Chapter 4: Decision-making in multi-actor networks

Collaborative decision-making discusses the difficulties faced when decisions are to be made by multiple actors together. Fundamental principles of multi-actor decision-making need to be incorporated in the sustainable procurement policy to successfully facilitate the collaboration and decision-making of the different actors involved in the procurement process. To understand the complexities of this type of decision-making process, the *characteristics of actor networks and actor hierarchies* (§4.1) and difference between *single-actor complexity and multi-actor complexity in decision-making* is discussed (§4.2) in this chapter (See Figure 18). These two topics are then discussed jointly to understand and enable *decision-making in multi-actor networks* (§4.3) as shown in Figure 18.

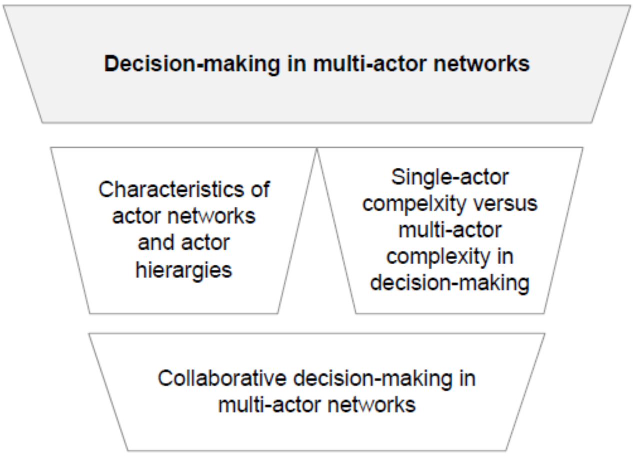


Figure 18 Content structure chapter 4

4.1 Characteristics of actor networks and actor hierarchies

In the bigger picture of DSO infrastructure asset management, the parties involved in making decisions can be addressed as a collaborating group of multiple actors. Besides the DSO, other external actors are for example: suppliers, regulating authorities, other DSOs and shareholders. Having a closer look at the DSO as an independent single actor shows that the DSO as an organization can also be described as a group of individuals and departments that collaborate. A multitude of actors who work together to achieve certain goals is referred to as a multi-actor network. In this multi-actor network, actors are the *nodes* and their mutual relations are the *links* connecting these nodes. What distinguishes a multi-actor network organization from a hierarchical organization is the essence of collective action to achieve certain mutually beneficial goals. Where collective action is valuable and complex as is discussed by Van Bueren et al. (2003). The characteristic differences between the network and hierarchy are discussed by De Bruijn & Ten Heuvelhof (2008, p.10). General differences in characteristics are:

- *Variety* of actors, interests and means of power in a network versus *uniformity* in a hierarchy
- *Mutual dependencies* between actors in a network versus *unilateral dependencies* among hierarchically organized actors. Dependability's can be simple or highly complex. De Bruijn & Ten Heuvelhof (2008, p.10) present five types of interdependencies:
    - I. Single-value – multi-value (e.g. information or money)
    - II. Bi-lateral – multilateral (e.g. A on B or A on C, C on B+D, D on A)
    - III. Synchronous – asynchronous (e.g. at the same time or with large time gaps)
    - IV. Sequential – simultaneous (e.g. activities in series or in parallel)
    - V. Static – dynamic (e.g. predictable and constant or changing and unclear interdependencies)
- *Closedness* and resistance to hierarchical signals in a multi-actor network versus *receptiveness* and sensitive to hierarchical signals in a hierarchy
- *Dynamic* (network) versus *stability* (hierarchy) of power distribution, knowledge levels, opinions and actors involved.

Thinking in terms of hierarchies and networks sheds light on decision-making processes when multiple actors are involved. Acknowledging and understanding the different roles, drivers and potential contributions of actors is considered a prerequisite to be able to anticipate on these actors and thereby act strategically in throughout the decision-making process. Actor analysis are frequently performed to gain a better understanding of other actors. The perspectives of actors acquired via stakeholder analysis should be considered stereotypes purely representing a limited and selective perspective, while in reality a more divided perspective is common. §5.5 elaborates on stakeholder perspectives in sustainable procurement of DSO assets.

A more abstract and diverse approach to multiple perspectives of actors is the *critical multiplism* perspective used in the field of policy analysis. Critical multiplism acknowledges that there are multiple perspectives on policy issues, methods, theories and perspectives, all of which have some validity and need to be taken into account. Policy analysts are less likely to commit preventable errors that stem from the analyst's own limited perspectives of a problem. Errors may be due to erroneous analysis (Dunn, 1994) or due to the limitations of specific knowledge (Van de Riet, 2003).

The alignment and aggregation of multiple individual perspectives into a fully representative multi actor perspective is a complicated and near-to-impossible endeavour due to the dynamic characteristics of multi-actor networks. In decision-making processes, both the individual actors perspective as well as the multi-actor perspective of the 'actor group as a whole' need to be taken into account. The differences between single and multi-actor decision-making and the complexity of satisfying multiple actors simultaneously is discussed below.

4.2 Single-actor complexity versus multi-actor complexity in decision-making

Policy study (or procurement alternative evaluation) requirements of individual actors differ from multi-actor policy study requirements. From a single actor perspective, a policy study focusses on analytical complexity: objective and facts-based decision-making in which the quality of information is crucial to the analysis performed and decision outcome decided upon (Broekhans, 2017). While from a multi-actor perspective, Broekhans (2017) argues that the policy study is dealing with political complexity: decisions are made based on negotiated knowledge[4] and information is not considered a necessary support in the policy analysis, but instead information is used strategically to influence the decision-making process. In multi-actor decision-making, information is thus often value-laden instead of neutral. The policy study requirement overview of Van de Riet (2003) in Table 6 summarizes the different types of complexity clearly.

Table 6 Policy requirements from single actor and multi-actor perspective (adapted from Van de Riet (2003, p. 35))

Single actor complexity	Multi actor complexity
S0 – scientifically valid, sound analysis ▪ Valid data, methods, technique, data	**M0 – trustworthy analysis** ▪ Involving trusted analysists ▪ Giving stakeholders a voice ▪ Making analysis accessible for all stakeholders
S1 – structured search for policy options ▪ Structured objectives ▪ Systematic/creative search for sound policy options	**M1 – bridging interests** ▪ Broad scope and multi-actor point of view in exploring policy options ▪ Maximize benefits, minimize losses ▪ Identify possible conflicts between stakeholders
S2 – Broad research focus ▪ Take into account all relevant parameters and insights ▪ Dealing explicitly with uncertainties ▪ Assessing all possible effects	**M2 – multi-perspective research focus** ▪ Covering all relevant features of all stakeholders ▪ Multiplism on views and assumptions ▪ Gain insight in gains/losses distribution among stakeholders

Concluding from the single and multi-actor policy requirements, single actor complexity aims to rationally decide which alternative is optimal, while multi-actor complexity sets out to decide which alternative is most acceptable for each actor involved. A closer look into the complications of a decision-making process in multi-actor networks offers decision-making guidelines.

4.3 Collaborative decision-making in multi-actor networks

When decisions are made by a group of actors, chances are the group is unable to come to an agreement when only one or two options are considered. Actors may favour (the absence of) one

[4] Negotiated knowledge is knowledge that is accepted by the actors who have an interest in the issue in hand and can withstand the test of scientific validity (De Bruijn & Ten Heuvelhof, 1999, p. 183)

option over the other and thereby refuse to agree to change their support. To successfully make a decision with multiple actors, enlarging the scope of the decision options to a multi-issue situation can prevent this decision deadlock. De Bruijn & Ten Heuvelhof (2008) presents multiple advantages of this so-called multi-issue decision-making, namely: a situation is created with room for giving and taking by actors, cooperative behaviour is stimulated, the decision process may yield unexpected outcomes, and each actor becomes involved in trade-offs and package deals which requires them to be willing to abandon (some of) their goals, making the decision process more flexible.

Successful decision-making in groups implies that all actors are satisfied with the end result and the process that lead to this result. Making a successful decision requires a careful approach and the consideration of the opportunties and threats of such a process.

To understand the implications of a hierarchy and a network on decision-making, both situations are briefly discussed.

- **Hierarchical decision-making** is described by De Bruijn & Heuvelhof (2008, p. 8) as "a top-down structure in which a focal actor has (access to) the information and power needed to make a decision". The focal actor instructs the actors on lower levels of the hierarchy.
- A **decision-making process in a network** differs from the hierarchical process on multiple levels. A successful decision in a network satisfies each actor involved after an initiating actor mobilized supportive actors to collectively achieve a goal. Networks of actors are long-term situations of interdependencies. This implies that actors meet eachother in the future. The repetition of collaboration asks for strategic decision-making as purely rational problem-solving may be impossible, or even undesirable, due to permanent harm of mutual trust amongst actors.

In the asset procurement process, both the characteristics of a hierarchy and a network can be identified. The procurement process can be considered a structured and orderly step-by-step process, while simultaneously facilitating a complex and chaotic dialogue. The process has a four characteristics. The process has (1) a variety of actors, interests and degrees of power; (2) involves many mutual dependencies amongst actors; (3) can partly be described as a process open to hierarchical signals; (4) fairly stable relations between and organization of actors. An insightfull illustration of the hierarchy-network hybrid situation is the hierarchy wheel (Figure 19). The wheel represents a changing power distribution (or more generally speaking: actor interaction dynamics) through time. The power and level of participation of actors depend on the interests, objectives of decisions, and the knowledge distribution among actors on a specific moment in time. For example: Technical specialists are the leading actors when technical details are discussed, while in the follow-up stage where long term collaboration is discussed, the procurement department or corporate management team may be in the lead. To be able to make a successful decision it is important that the attitude, power and interest of each actor involved or affected by a decision is clear and understood.

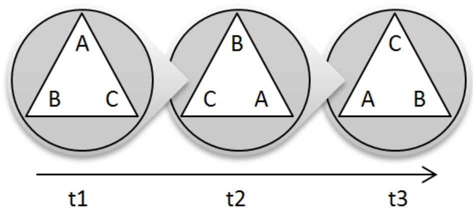


Figure 19 The hierarchy wheel in multi-actor decision-making (adapted from De Bruijn & Heuvelhof (2008, p. 14)

The interdependencies and different interests that characterise the network structure require a change from hierarchical *project*-based decision processes (Decide, Announce, Defend) to *process*-based processes (Dialogue, Decide, Deliver). Appendix M elaborates on the differences between these two types of decision processes in more detail. The dialogue between different actors aims to overcome obstructing conflict of interests and objectives which thereby allows the group of decision-makers to successfully decide on, and deliver, a mutually beneficial solution to a complex problem with compliance to a diverse set of requirements.

A different problem formulation is required for process-based change in comparison to project-based change. Three major differences directly relate to sustainable procurement: a broader formulation of the problem and goal, increased level of complexity and priming, goal framing and multi-targetting (De Bruijn & Heuvelhof, 2008).

- A **broad problem formulation** is necessary to enlarge the solution space to the problem. A detailed description of a problem requires a specific solution and is thereby destrictive for potentially relevant alternatives. A broad formulation of the problem invites more alternatives and actors to the solution-focussed dialogue. The goal should appeal to all stakeholders involved. Enlarging the formulation of the goal to fit both the problem formulated and its stakeholders.
- **Inceasing level of complexity** enlarges the solution space by increasing the problems and solutions within the scope of the decision-making process and thereby increase the likelihood of a 'window of opportunity' opening . A high level of complexity also offers a larger diversity of potential gains for stakeholders involved which stimulates their willingness to collaborate.
- **Priming and framing** aims to influence the perception of the problem or goal. Priming refers to the creation or formulation of a context in which parties are sensitive to a particular problem perception: priming shift priorities to specific matters. Framing is the creation of a mental construct via communication. Priming and framing both aim to maximize the chance of actor support.

These three means to facilitate process-based changes can all stimulate the strategy of multi-targetting, as the coupling of multiple goals to the same action or decision to increase the likelihood of collaboration between actors. Appendix M lays out additional problem formulation differences and goal formulation differences of problem-based and process-based changes.

Decision-making in networks is far more complex than the linear and structured decision-making in hierarchies. It can be best described as an unstructuered and unsteady process that requires actors to consider different types of negotiation strategies. Actors act strategically to achieve their individual goals while simultaneously prevenging any harm to their relationship with other actors. The combination of acting maintaining trust of actors while acting strategically can be considered a paradox. As De Bruijn & Heuvelhof (2008, p. 6) highlight: "Those who derive their strategies from the linear '[decision-making] model talk' stand little chance of success". Characteristics of networks are required to successfully make collaborative decisions.

Merging sustainable development and asset procurement (§2.2.7) may require actors to change from existing business models to sustainable business models (§2.2.5), share sensitive product and process information to collaborate with supply chain stakeholders (§2.2.6) to create innovative and sustainable solutions to the problems of today. From a suppliers perspective, collaboration and transparency can be considered an exampel of the well-known prisoners dilemma:

If all suppliers tendering put effort in more sustainable products (with potentially higher product prices) and invest resources in a assessing the environmental and social supply chain impact, the entire industry becomes more sustainable while relativele prices of products remain equal. However, abandoning sustainability-related ambitions may result in lower product prices or protecting intellectual capital. The three crucial ingredients of a successful sustainable procurement process, from a multi-actor network perspective, are therefore **trust**, **empathy** and **logic**. Mutual *trust* among actors to shift the business-as-usual practises to more sustainability-oriented practises accepting all potentially harmful consequences collectively, *empathy* to value sustainable development over individual gains and *logic* to structure the decision-making processes fairly, based on clear procedures and objective assessment of tendering suppliers.

The level of success of a multi-actor decision dilemma is difficult to measure. Literature often refers to the need for a win-win end result for all actors involved, meaning there should be more gains than losses for each actor (Mandell, 1988). The challenge in defining 'gains' and 'losses' is their situation and perception dependency (De Bruijn & Ten Heuvelhof, 2008).

It can therefore be concluded that a successful multi-actor decision process yields the *perception* of a positive gain and loss account for each individual actor involved in the process. Evaluating the outcome and the process towards this outcome is required to conclude on the level of success and thereby the level of satisfaction for each actor individually.

4.4 Conclusion and policy requirements

Decision-making by single-actors (or monodisciplinary groups of actors) differs significantly from decision-making by multi-actor groups (or multidisciplinary groups of actors. Where rational and systematic decision-making with single optimal outcomes is at the core of single-actor processes, a multitude of actors requires a different approach as different perspectives and views are to be considered simultaneously. Actor collaboration and establishing consensus among actors in the decision-making process requires mutual trust, the stimulation of empathy and logic-based measures. The interdependency of multiple actors stresses the need to find decision outcomes that are acceptable to all actors rather than optimal for one actor while unacceptable to the other. Making decisions with a group therefore needs to focus on finding the optimal decision from each relevant perspective, maintaining mutual trust among actors and minimize strategic behaviour for personal gains. A change from hierarchical *project*-based decision processes (Decide, Announce, Defend) to *process*-based processes (Dialogue, Decide, Deliver) is therefore required to enable collaborative decision-making.
The procurement context of decision-making provides the multi-actor group with a set of collective (organizational) objectives that can serve as the direction in which each individual should aim. Each actor contributes to these organizational objectives in their own way and from their individual point of view. In order to effectively achieve sustainability goals through procurement, the relation between the actor-specific goals and the sustainability goals of the organization need to be clear and fully understood. Only then can an effective sustainable procurement policy be developed and can potentially conflicting goals and interests be dealt with effectively. The organizational goals, as well as the current procurement policy, are discussed in the next chapter.

From the literature review on decision-making in multi-actor groups, the conclusive goal, four constraints and nine criteria used in the policy development process the are included in Appendix G.

Chapter 5: The current corporate context of Alliander

Figure 20 Content structure chapter 5

The successful implementation of the proposed sustainable procurement policy depends on its fitness with the policy context at Alliander. This chapter discusses this context (see Figure 20). The first paragraph elaborates on the empirical research methodology applied (§5.1) . Topics that are discussed are: *the place of Alliander within the Dutch energy distribution sector* and Alliander's *mission* (§5.2) and perspective on *sustainable development* (§5.3). Subsequently, four topics that are of direct importance to the policy are discussed: the variety and complementary *activities, interests and influences of external and internal actors* (§5.5) that are involved in the decision-making process. The current *procurement policy methodology* followed within the organizations (§5.5) with, more specifically, the role of *sustainability within the procurement process* (§5.6) and the *implications of supplier markets* on sustainable procurement (§5.7) conclude this chapter.

5.1 Empirical research methodology

Insights in the daily operation of Alliander, the practical complexity of sustainable procurement in the corporate context and inputs for the performed actor analysis are gathered through informal interviews with experts and participation in daily activities and meetings of relevant departments at Alliander:

- An **actor analysis** is performed to understand which actors are involved in the procurement process of Alliander and to discuss the differences in point of views. Based on this analysis the diversity of perspectives that the policy may need to accommodate can be considered in the policy development. Many different actor analysis methods are available (Hermans & Thissen, 2009). The fairly abstract and simple logic of a stakeholder analysis is considered of sufficient depth to gain an initial understanding of the primal (conflict of) interests and actor influences. Methods used to acquire information and be able to perform the actor analysis are informal interviews and the participation in the daily operation of Alliander.
- **Informal interviews** with 23 internal experts of Alliander, Alliander and Liandon as well as interviews with external experts of research groups and other Dutch infrastructure operators contribute to the understanding of the industrial context. Appendix N lists the experts consulted throughout this research.
- Participating with Alliander's **daily business** results in unwittingly and naturally evolving knowledge and understanding of the operation of the DSO. Weekly meetings with the Circular Economy group and four meetings with the Electricity Distribution Policy group give insights in the current activities and developments worked on at Alliander.

The above mentioned methods provide information not (easily) accessible through literature. Expert consultation throughout the policy development process is utilized to compare and validate information and assumptions with a scientific basis, which then leads to additional insights that are explored using academic literature (iteration loop in Figure 4).

5.2 Alliander's place in the Dutch energy distribution sector

The supply of electricity and gas to consumers in the Netherlands requires an energy supply chain that consists of four key shackles: upstream electricity generation and gas production, high voltage and high pressure transportation, mid-low voltage and mid-low pressure distribution, and downstream consumption of low voltage electricity and low pressure gas. In the Netherlands, high voltage electricity transportation is done by TenneT and high pressure gas transportation by N.V. Nederlandse Gasunie. Distribution system operators (DSOs) are responsible for the mid-low voltage and pressure distribution to the downstream consumers.

Downstream clients of DSOs are able to select an upstream electricity generating or gas producing organization. However, clients are unable to choose their DSO as of 2007. It is since the Independent Network Operation Law (Wet Onafhankelijk Netbeheer) in 2007 that upstream utility generation and downstream utility distribution are separated and isolated businesses. This law split multiple Dutch energy suppliers, among which N.V. Nuon who split into Alliander N.V. and Nuon Energy. Other large Dutch DSO organizations are Stedin Group and ENEXIS Holding N.V.

Alliander N.V. is the holding organization of Liander (the executive distribution system operator) and multiple smaller organizations, including but not limited to Liandon (construction and maintenance of energy infrastructure) and Kenter (utility consumption measurement services) (see Figure 21 below).

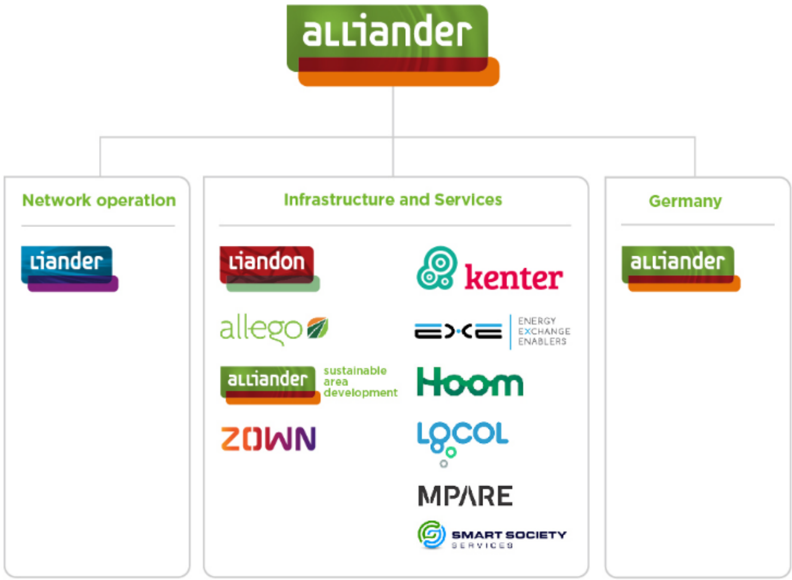


Figure 21 Corporate organizational structure Alliander holding (Adapted from Alliander (2017, p. 1)

The dependability of Dutch electricity and gas by the public puts a high emphasis on highly reliable and affordable service provision by each Dutch DSO.

The corporate mission of Alliander and describes the driving motives and objectives of both organizations: “Alliander stands for an energy supply that gives everyone equal access to reliable, affordable and sustainable energy” (Alliander, 2017b). Alliander is responsible for the distribution of mid-low voltage electricity and mid-low pressure gas and offers its utility distribution services in four Dutch provinces: Gelderland, Friesland, Flevoland and Noord-Holland, with 5,6 million customer affiliations. These customers are dependent on Alliander’s electricity and gas distribution services.

The Dutch DSOs are organized in such a way that provinces and a municipalities are shareholders of the DSOs. The capital of Alliander is divided in 350 million shares with a nominal value of €5. Major shareholders of Alliander are the province of Gelderland (44,68%), Friesland (12,65%), Northern Holland (9,16%) and the municipality of Amsterdam (9,16%). 50 other shareholders hold less than 3% of shares (Alliander, 2017, p. 3). The large amount of (financial and capital) assets and liabilities of Alliander enables the organization to have large impacts when supported by their shareholders.

5.3 Sustainable development within Alliander

DSOs finance their operation with revenue from the services provided. The price of their services for household clients and industrial clients is regulated by the ACM by means of a benchmark structure: prices of DSOs thereby remain comparable due to the mutual incentive for operational excellence at minimal cost. In order to create more financial space for specific investments in their operation, DSOs need to cut costs of other activities. The benchmark structure has direct implications to the sustainability goals of Dutch DSOs: Each DSO has its own perception of sustainability in their operation and the willingness to pay for sustainability also differs among DSOs and their shareholders.

5.3.1 Sustainable Development Goals and impact thinking at Alliander

Alliander has connected their business strategy and operation to three SDGs. Based on the definitions of the SDGs as presented by the United Nations (2015), three goals directly relate to DSO core business activities: Goal 7, 11 and 12 (Alliander NV, 2016):

- **Goal 7:** Sub-goals 7.1-7.a describe the goals for a more sustainable and efficient energy supply, including the facilitation of the energy transition. The core business of a DSO.
- **Goal 11:** Making Dutch urban areas more inclusive, safe, resilient and sustainable, as Goal 11 is set out to achieve, is the daily business objective of DSOs: constantly improving the service delivered while also innovating and preparing for future (sustainable) developments. Two examples indicate the need for flexible DSO strategies and activities: In the Netherlands, the integration of solar and wind energy in the electricity net is rapidly growing, and the dependability on natural gas is currently questioned, with the phasing out of natural gas of domestic environments.
- **Goal 12:** By directly relating to Circular Economy principles of recycling and waste reduction as well as achieving sustainable management of (toxic) materials throughout their life cycle, Goal 12 links to the sustainable asset life cycle management activities of the DSO.

While also goal 3, 8, 9 and 13 are relevant, the most direct impact does not lie within those goals, as is shown in Appendix O. Appendix C discusses SDG 3, 8, 9 and 13 into more detail.

Gaining insight in sustainable impact in a large organization such as Alliander and see actual results is complex and difficult due to the wide variety of (small) activities that lead to outputs and thereby (often) small steps forward. *Impact thinking* is a straightforward method to map the impact Alliander has on its environment. Six capital impact categories are adopted to gain insight in its positive and negative impacts: Financial capital, Manufactured capital, Intellectual capital, Natural capital, Social capital and Human capital. By reducing the negative impact and increasing the positive impact of Alliander, a more sustainable operation of the organization is aimed for. The impact hotspot analysis by Ecofys and True Price stresses Alliander's ability to have sustainable impacts simultaneously with their core business impacts (Alliander, 2016).

5.3.2 Translating SDGs to Alliander and Alliander specific sustainability goals

The selection of sustainability goals and quantitative targets are aligned with the core business activities of the organizations to guarantee the long term impact generated. The goals and targets are such, that the organizations and its employees are able to identify themselves with them and their mark on the horizon. The three focal areas of sustainable development Alliander are *circular economy, climate change* and *social labour participation.* Table 7 briefly describes the goal and measures of the areas.

Progress towards the sustainability goals, and the performance of departments in general, is monitored and stimulated using Key Performance Indicators (KPIs). These KPIs measure the progress of departments towards the KPI. On average, progress towards the specified KPI is measured four times a year. Individual employees are responsible for one (or multiple) KPIs, implying that those employees, together with their colleagues, work towards the performance-driven objectives represented by the KPI.

Besides sustainability-related goals, Alliander has many other goals and ambitions. These goals and ambitions are divided over more than 25 different department, making each department an actor with a different set of interests, goals, strategies and activities in addition to the general organizational mission and strategy. In order to effectively achieve sustainability goals through procurement, the relation between the actor-specific goals and the sustainability goals of the organization need to be clear and fully understood. Only then can an effective sustainable procurement policy be developed and can potentially conflicting goals and interests be dealt with.

Table 7 Alliander's focal areas of sustainable development (adapted from Alliander NV, 2016)

Topic	Goal	Date	Measures
Circular economy	40% circularity in procured assets (in kilograms)	2020	Integration of circular economy principles in at least five focal points: The Fair Meter initiative, circular safety clothing, reuse of assets, waste prevention and the circular electricity cable.
Climate change	CO2 neutral operation of Alliander N.V.	2023	The three focal points to achieve a CO_2 footprint reduction are: reduction of electricity distribution losses, reduction of emissions due to transportation and housing and reduction of emissions of suppliers.
Social labour participation	At least 180 participants have a job	2023	The Dutch participation law on social labour opportunities is integrated in procurement requirements to stimulate job positions for participants in the supply chain.

5.4 Actor analysis of the internal and external multi-actor networks

Understanding the drivers of actors that are part of the procurement process, or are affected by its consequences, is of vital importance to make the best decision as a group (see §4.2). Acknowledging different perspectives and aiming for consensus among actors helps to minimize the threat of obstruction by actors and maximizes the cooperative potential in general (Hermans & Thissen, 2009).

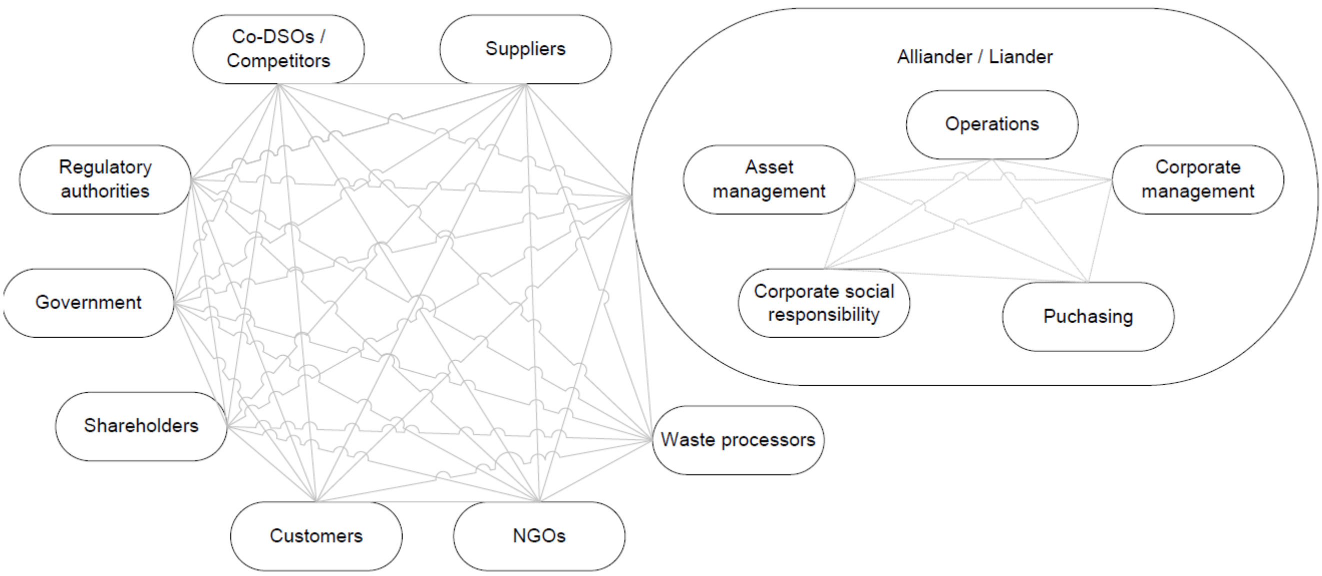


Figure 22 Internal and external actor network visualization

Two networks of actors can be identified: the internal multi-actor network of Alliander as an organization, and the external multi-actor network of the supply-chain of the asset. Figure 22 visualizes both networks and their relation. The paragraphs below discuss both multi-actor networks into more detail.

5.4.1 Activities, interests and influence of the internal multi-actor network

Based on the scope of this research, five departments are of specific interest: the corporate management board (raad van bestuur), corporate social responsibility (maatschappelijk verantwoord ondernemen, MVO), asset management, operation (operatie, BBU) and purchasing (inkoop). The (simplified) interdependencies are illustrated using a typical asset purchasing example:

> *Illustrative example of Alliander department interdependencies: The asset management department is in need of a new product and collaborates with the purchasing department to purchase the product. In the procurement process, CSR participates to assure the compliance with Alliander CSR objectives and targets of the product purchased (and the production process of that product). Throughout the procurement process, the corporate management board is obliged to approve the course of the procurement process and the decisions made by the stakeholders involved.*

The role of different actors within Alliander can be linked to the actor's interest and power regarding the integration of sustainability in asset procurement. The five following internal actors are considered most relevant: the asset management department, CSR department, purchasing department, the corporate management team and the operational department. Each actor is placed in the power-interest grid in Figure 23 to understand their role in sustainable procurement. The actor specific activities, interests and influences are discussed into more detail in Appendix Q.

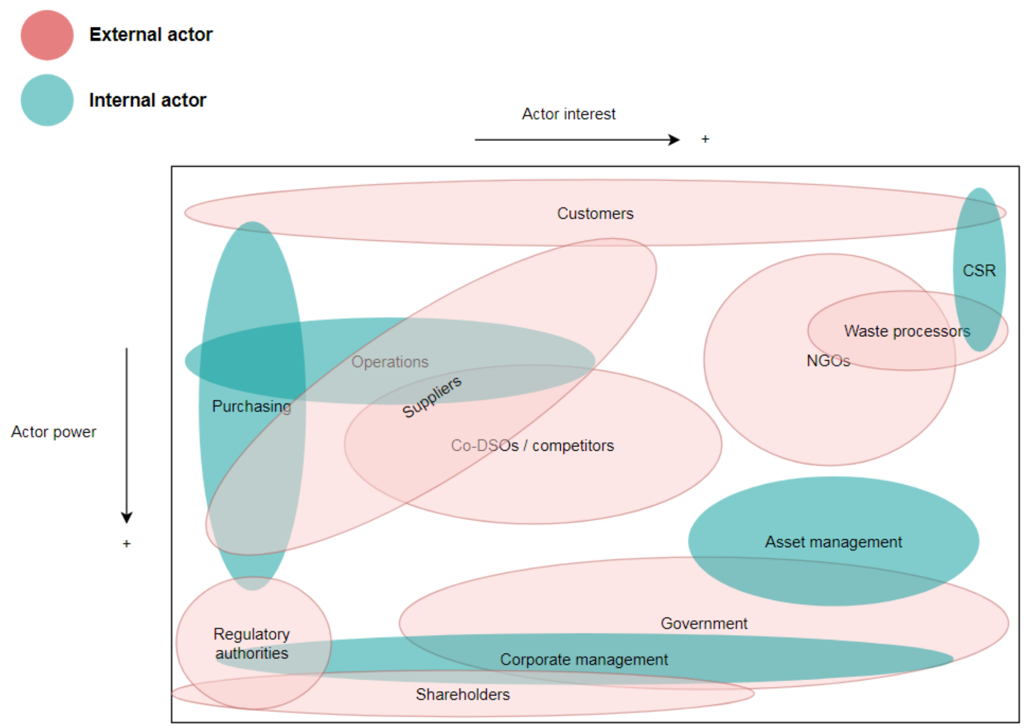


Figure 23 Power-interest grid of internal and external actors

Key players among internal actors are corporate management and asset management. CSR fulfils an important stimulating role, however the department remains subjected to the course of others. Purchasing dep. has no direct incentive to act, but can significantly contribute if the conditions to do so are set.

Internal actors become highly interdependent on each other to successfully accomplish sustainability goals throughout the purchasing processes as each actor contributes a different piece of the puzzle (e.g.: corporate management steers in a strategic and organizational direction, AM, operations and CSR bring specific knowledge and purchasing translates the diversity of demands to market-compliant requests for tenders).

5.4.2 Activities, interests and influence of external multi-actor network

Many external actors are considered relevant to Alliander's operation as the organization provides public services to Dutch customers, needs to comply with regulations and needs to collaborate with fellow DSOs/TSO to do so, ánd makes use of capital assets that need to be supplied. The external actors considered are the Dutch government, regulatory authorities, NGOs, co-DSOs and shareholders and the supply chain of Alliander assets (suppliers, customers and waste processors).

Differences in actor priorities make for a diverse set of influences. Simultaneously, actors are dependent on each other to be able to maintain their businesses and also influence each other directly, creating a network structure of actors. The power of external actors regarding, and their interest in the integration of sustainability in the procurement process is mapped in the power-interest grid in Figure 23.

Key players for sustainable procurement success are the regulatory authorities, Alliander's shareholders, the focus of the government on sustainable development and committed suppliers. A similar commitment of co-DSOs reduces the differences in DSO priorities, making collaborative procurement projects more successful and increasing the shared commitment which is a necessary stimulus to the supplier market to focus more on sustainability-related business models. NGOs, as with the internal CSR department, are crucial as their effort to change actor mind-sets to thinking in terms of 'the greater good' is needed to stimulate the intrinsic motivation throughout the external multi-actor network. Low power suppliers and customers may not have direct influences or interests, however these groups of actors are inseparable from the asset and energy supply chain which makes their support of sustainable procurement indispensable.

The external actor activities, interests and power which describes the roles and influences of actors regarding sustainable procurement is discussed in more detail in Appendix Q.

5.5 Alliander procurement methodology

The extensive financial means of Alliander enables the organization to make significant investments when needed due to planned and unplanned replacements of assets and expansion of the network. The long life cycles of assets require a set of assumptions and estimations regarding the exogenous and internal factors that may influence the useful lifetime of the asset as discussed in §3.2. Large contributions can potentially be made to a more sustainable operation of the DSO Through purchasing (Capital Expenditures, CAPEX) investments. Long term collaborations with supply chain stakeholders offer the opportunity to award contracts to suppliers based on both the product, the production process and the ambition to increase the level of sustainability in both.

In capital asset procurement, two standard procurement procedures are distinguished: the non-public procurement and the public procurement procedure. The non-public procedure has two phases and the public procedure has one phase. Figure 24 illustrates the general funnel-like process of both procurement procedures. Other, more specific, procedures are prescribed in the procurement law (PIANOo, 2017).

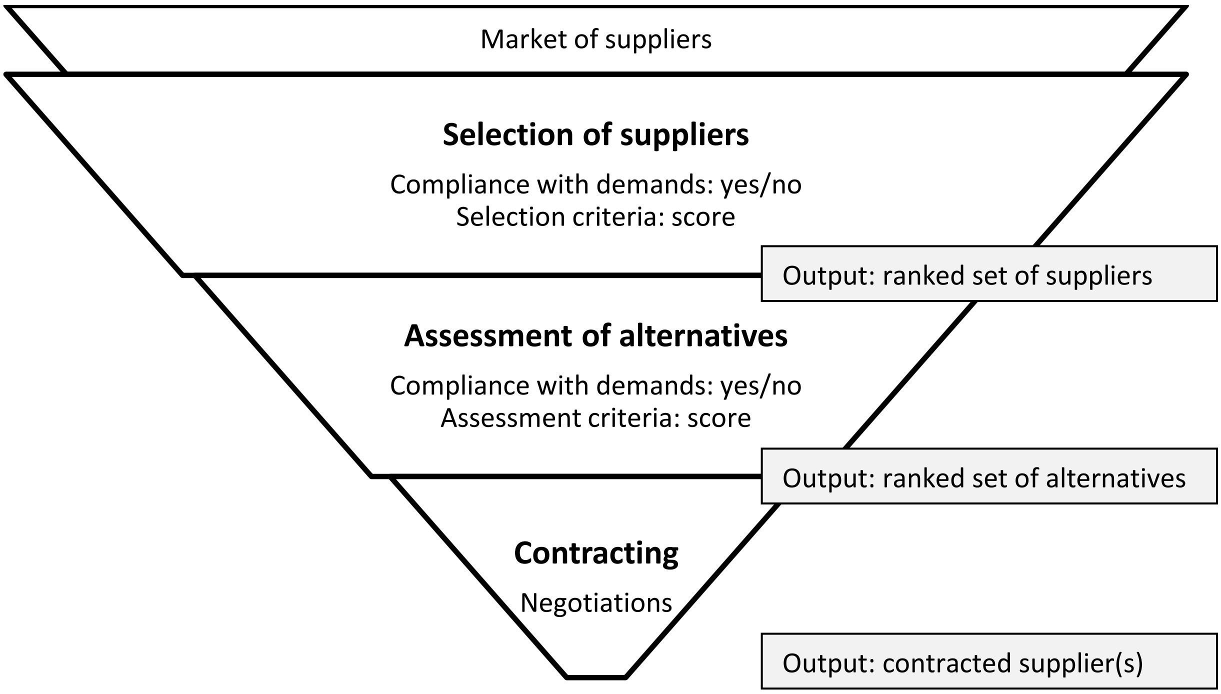


Figure 24 General funnel illustration of procurement process

The general course of non-public and public procurement procedures can be described as follows:

- **Non-public procurement**
  Firstly, a pre-selection of suppliers is made based on compliancy with supplier demands and/or supplier criteria scores. Secondly, the alternatives offered by the selected suppliers are assessed using alternative demands and alternative criteria. Lastly, from the ranked assessment results, a (combination of) final alternative(s) is chosen and contractual dialogue is started. In case of multiple suitable alternatives, negotiations between the highest ranked alternatives are started to determine the supplier(s) of choice.

- **Public procedure**
  A pre-selection of suppliers is made based on compliancy with supplier demands only. Secondly, the alternatives offered by the selected suppliers are assessed using alternative demands only. The suppliers with corresponding alternatives that both comply with supplier and alternative demands are assessed using alternative criteria. Lastly, from the ranked assessment results, a (combination of) final alternative(s) is chosen and contractual dialogue is started. In case of multiple suitable alternatives, negotiations between the highest ranked alternatives are started to determine the supplier(s) of choice.

At Alliander, one standardized purchasing methodology is used as a guideline for all purchasing processes. This methodology is developed by tier 1 professional service company Accenture and is applicable to a large range of organizations in different industries. The essence of this procurement process in asset management is a simple three phase process, divided in seven steps (Alliander, 2016a). Figure 25 describes the core activities of these seven steps. The detailed procurement methodology of Alliander (see Appendix R) lists each formal activity of the methodology.

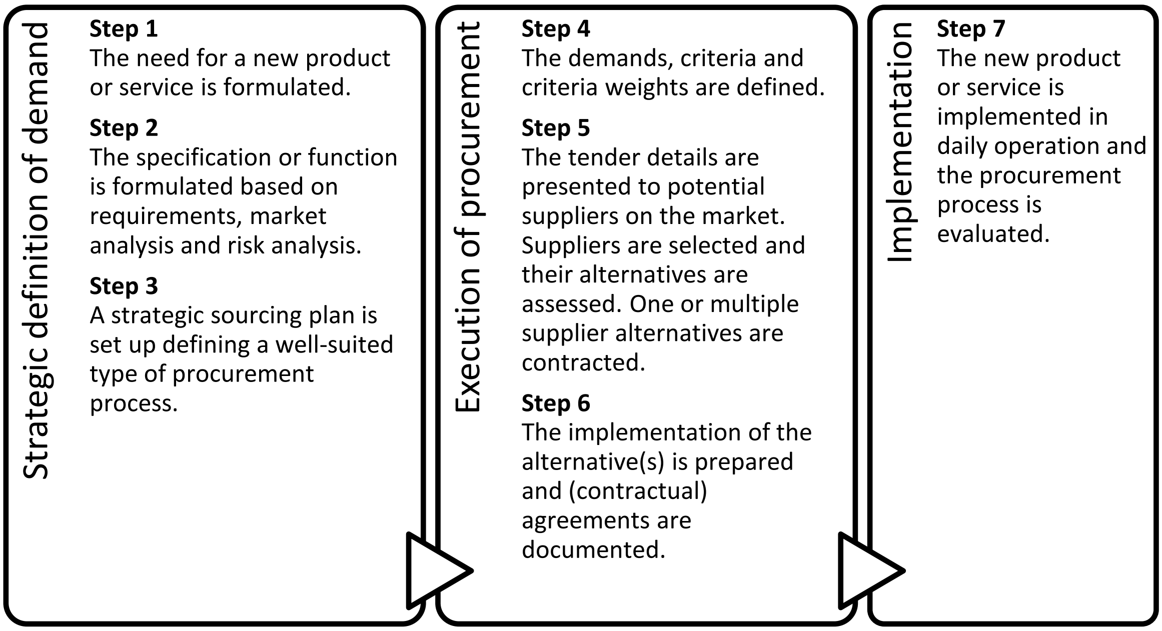


Figure 25 General outline of the Alliander procurement methodology

Three specific activities in the methodology are discussed that are explicitly related to decision-making: criteria definition and criteria weighting (activity 4.3), alternatives selection (activity 5.2.1) and alternatives awarding (activity 5.2.2).

- **Criteria definition and criteria weighting (activity 4.3)**
  In the procurement methodology, supplier selection demands (requirements and criteria), and alternative assessment demands (requirements and criteria) are defined by the Multi-Functional Team (MFT). The MFT consists of Alliander experts with backgrounds in multiple disciplines (Step 4). Requirements are compliance-based: no compliance is a basis for supplier or alternative elimination. For criteria scoring, each main category is given a weight, with a total sum of 100%. Demands and criteria are then categorized to structure the large amount of criteria. Four main categories are generally used: Price, product quality, production process quality and sustainability.
  The weighting process is an expert judgement based collaborative decision of the MFT. Subcategories are defined to define the procurement criteria into more detail. Subcategories depend on the product or service of interest. Sub criteria then divide the weight of the main category, e.g. sustainability has four subcategories with their own share of weights (i.e. climate change [CO_2 eq. emission], circular economy [input and output of recycled kilograms of material], transparency [quality of bill of materials] and social labour participation [number of participants]).

- **Alternatives selection (activity 5.2.1) and assessment of alternatives (activity 5.2.2)**
  The selection of suppliers and assessment of alternatives is done in accordance with European regulations on (public) procurement, procurement law and the guide on proportionality. The performances and specifications of each alternative is assessed and scored using the weight distribution of the assessment criteria. Each alternative then receives a single or a set of aggregated score(s) that represent its level of compliance with the asset demands. The alternative with the highest score typically wins the assessment and is thereby sourced.

This procurement methodology and environment characterises itself by having both hierarchical and network-like decision characteristics, as discussed in Chapter 4. The relevant characteristics are summarized in Table 8. It is important to consider these characteristics in the development of a sustainable procurement policy as the combination of the hierarchy and network structure leads to a hybrid process that does not follow familiar patterns as would be the case with the hierarchy or network separately.

Table 8 Applicable decision characteristics for DSO procurement (Adapted from De Bruijn & Heuvelhof (2008, p. 26)

Decisions in a hierarchy structure	Decisions in a network structure
Regular and sequential	Irregular and no clear sequence of activities
Phases	**Rounds**
Actors are stable	**Actors join and withdraw and behave strategically**
One arena, process has a clear starting point and end point	**Several arenas, no isolated starting point and end point**
Content of the problem is stable	Content of the problem shifts
Incentive to regard problems as structured	Incentive to regard problems as unstructured
Consistency and predictability	**Flexibility and unpredictability**

The procurement methodology in this form has matured over time, making it a robust process that is fully embedded in the organization and culture of Alliander. In this matured methodology the integration of sustainability goals, ambitions and 'thinking' is introduced which leads to multiple difficulties. The following paragraph discusses sustainability in Alliander's procurement methodology.

5.6 Sustainability within the procurement processes

Liander has serious sustainable ambitions and is exploring corresponding business strategies (Den Hartog, 2016) that ask for a new procurement approach. As Alliander does not manufacture its own assets, purchasing their assets offers the opportunity to invite their suppliers to offer 'more sustainable' assets and thereby become a more sustainable DSO.

Due to the regulated public procurement process, Alliander needs to specify what is meant with 'sustainable' characteristics. And it is this specification of sustainability that is challenging. As Alliander only installs, uses and decommissions their assets, knowledge on product criteria that relate to other phases of the product is limited. Setting realistic and transparent criteria on the sustainability of products (i.e. the fair source of virgin materials, preventing water pollution in the production process or material reduction in the product design) is very difficult.

Procurement regulations state it is required to explicitly define selection criteria. The lack of experience and procedural difficulties Alliander encounters in the integration of sustainability as a driver in their decision-making process results in troublesome integration. And thereby Alliander's disability to significantly increase their contribution to the sustainable development of the Dutch energy system.

A complementary problem that emerges in the decision process when sustainable criteria are introduced, is the need to objectively assess and select a tender offer. The diversity of values, interests and requirements of the individual decision-makers and experts in MFTs needs to be expressed in measurable criteria and indicators. The criteria are then prioritized based on expert judgement and dialogues.

Sustainable requirements of capital DSO assets are focussing on three general types of sustainable business models, namely *dematerialization*, *optimize functionality* and *circularity & material loops* (see Table 1 for more details on generalized sustainable business models). The *prolong lifetime* business model, and also the *optimize functionality* to some extent, are already considered daily practise in infrastructure asset management. These sustainable business models require systems thinking and the consideration of the complete asset material life cycle to explore their feasibility and multidimensional added values.

The asset management body of knowledge has adopted asset life cycle thinking through the past decades. Alliander has also adopted the consideration of entire life cycles in their asset management plans and cost estimations by using life cycle costing approaches and, more recently, life cycle assessment approaches. Asset life cycle thinking is a strong framework that requires and affects many departments of the DSO when applied. Alliander's current approach towards sustainable procurement is based on gaining experience through pilot projects and sustainability-related topics (e.g. the adoption of bills of materials, CO_2 performance and circular material content in procurement decision-making and asset life cycle management, TECCO perspectives and life cycle costing in asset management decisions).

Setting successful examples of more sustainability-focussed procurement are an important source of inspiration for Alliander employees to stimulate a change in the organizations culture. These examples also send out signals to external stakeholders, with suppliers in particular, stressing that Alliander is actively 'practising what it preaches' regarding the incorporation of *circularity* in recent, current and future tenders. The most recent tender to market publication of a 2-5 million/year contract for circular personal safety clothing is a next maturing step in sustainable procurement of large investments and a follow-up on the Fair Meter project in 2013. Appendix P describes the circular ambition in the clothing tender. Other recent innovative collaborations with suppliers also aims to materialize Alliander's sustainable development goals and execute pilot procurement projects on more sustainable procurement. Three examples of such projects are the Fair Meter project (see §8.1), the circular electricity cable project (see §8.2) and a pilot project in which a the bill of materials (Dutch: Grondstofpaspoort) model is developed during a gas pipe surface box (Dutch: gasbuis straatpot) procurement process.

5.7 Conclusion and policy input

The policy is developed for Alliander. The sustainability goals of the organization need to be discussed and considered in the policy development process to align the policy with these goals. In addition, as the procurement decision is a multi-actor decision, the power and interest of external (supply chain) and internal (Alliander) actors involved are to be considered. To successfully implement a new policy, the current way of procurement at Alliander provides valuable insights and regulatory guidelines that are important policy input.

Alliander translated three United Nations Sustainable Development Goals into three focal areas of sustainability within the organization that align with its core business: Circular Economy, Climate change and Social labour participation. The external actors able to stimulate sustainable development, and thereby the progress within these three focal areas, are Alliander's shareholders, regulatory authorities and the Dutch government. Internally, Alliander's corporate management team and the asset management department are the most powerful and interested actors.

The general course of procurement procedures at Alliander is described by seven general and sequential steps in which the procurement activities are described in detail. This procurement methodology is developed for general applications within industries, making it a methodology representative for DSO asset procurement as well as (public) procurement in general. The procurement process need to be considered both a hierarchical (i.e. top-down) and network-like (i.e. collaborative) decision process. The relevant characteristics of both need to be considered in the development of a sustainable procurement policy.

From the literature review and empirical research on the current Alliander context of the sustainable procurement policy, the conclusive goal, four constraints and five criteria used in the policy development process the are included in Appendix G.

Part II: Policy development & case study validation

Chapter 6: Policy development methodology

To develop the sustainable procurement policy, a *policy development methodology* is set up, case studies validate the policy and the policy evaluation discusses its use (see Figure 26). This chapter describes the methodology (§6.1) which combines five major sources of inputs: (1,2) Two theoretical sustainability-focused decision-making frameworks; (3) The current Alliander procurement methodology; (4) The multi-criteria decision analysis method *Analytic Hierarchy Process* (§6.1); and (5) Policy inputs (goals, constraints and criteria) taken from both theoretical literature review (Chapter 2-4) and industrial practices (Chapter 5). Validating the added value of the developed policy compared to the current process is done by conducting two expert consultation-based case studies. The first case study is the completed Fair Meter project, the second case study is the ongoing procurement of the Circular Cable. The set-up of these case studies is discussed (§6.2). The evaluation of the policy (§6.2) concludes the methodology chapter.

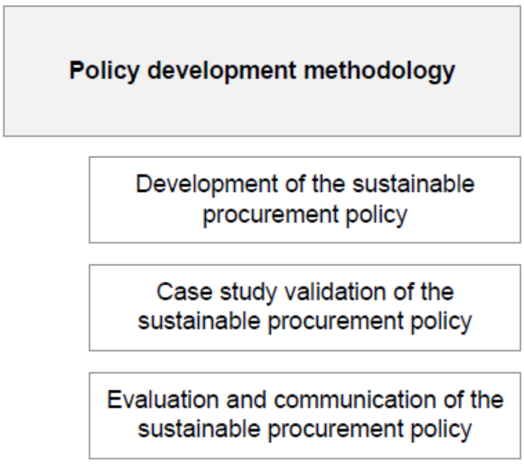


Figure 26 Content structure Chapter 6

6.1 Development of the sustainable procurement policy

After the initial problem structuring phase through literature reviews, the policy inputs gathered and organised need to be combined into a policy proposal, consisting of a procurement methodology and a decision support tool.

As discussed in Chapter 1, Figure 3 shows the general policy development procedures. The second procedure, the policy development, is discussed in more detail in §6.1.1. An additional decision-making framework is introduced to provide decision support: the Analytic Hierarchy Process, discussed in more detail in §6.1.2. This multi-criteria decision analysis method forms the basis for the decision support tool, the practical support tool in addition to the procurement methodology that is developed.

6.1.1 Sustainable procurement policy: methodology

The policy development procedure is arranged as depicted in Figure 27 below. Five information sources are combined into one policy proposal. These five sources of input are:

Two theoretical sustainability-focused decision-making frameworks that provide new insights in procurement decision-making:

- The ProBiz4CE framework by Witjes & Lozano (2016)(see §2.2.8.1)
- The Solution-focused sustainability assessment framework of Zijp et al. (2016) (see §2.2.8.2)
- The Alliander procurement methodology, based on EU regulations, as the current procurement guideline in which sustainability needs to be integrated.
- The multi-criteria decision analysis method *Analytic Hierarchy Process (AHP)*, providing a practical, matured and easy-to-use decision framework based on objective (mathematical) logic.
- The policy inputs: goals, constraints and criteria taken from Part I of the report that describe the requirements of the policy in order to become of added value from a theoretical (literature review) point of view.

The four existing frameworks and the goals, constraints and criteria are then rearranged and aligned into one policy. The policy constraints and criteria are used to evaluate the developed policy on its ability to comply with constraints and score well on criteria. Additional methodological steps are added, or merged, to fulfil all policy goals simultaneously. Subsequently, this policy is applied in a practical setting twice to validate its usefulness. The first application is the Fair Meter case study and the second application is the Circular Cable case study. The policy is then improved upon by making two iteration steps after practical insights regarding the application of the policy are gained.

6.1.2 Sustainable procurement policy: Analytic Hierarchy Process decision support tool

The sustainable procurement methodology is mainly describing processes, actions and decisions based on theory. To enable the implementation of the policy and thereby explore its feasibility, a more practical *decision support tool* is desirable. The tool needs to offer easy-to-use aids throughout the procurement process and effectively guide the structuring of diverse and relevant information as well as objectively document the comparison of alternatives. This sub paragraph discusses the selection of the basic framework for the tool: the AHP. The next chapter introduces the tool in more detail.

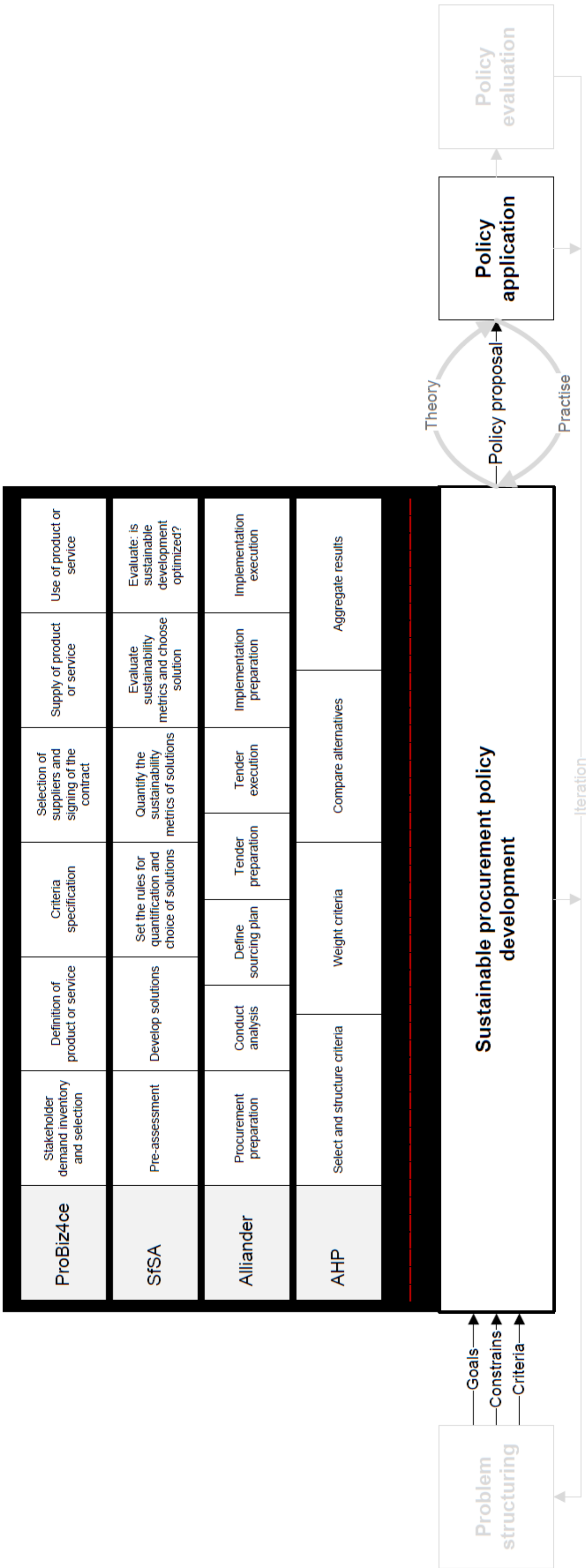


Figure 27 Policy development procedure methodology

Methodologies that evaluate alternatives using a set of (weighted) criteria to rank and select a desirable solution from alternatives are addressed as multi-criteria decision analysis (MCDA) methods. Major advantages of methods are their capabilities to address multiple interests and perspectives in decision-making and are able to deal with quantitative and qualitative criteria as well as uncertainties. MCDA therefore aligns very well with sustainability assessment. Disadvantages of MCDA are the need for useful data, consensus on criteria and weighting due to different stakeholder perspectives, interdependency between criteria and the required willingness to implement the method in the existing decision-making process.

There is a wide variety of MCDM available (see for example the comparative analysis by Cinelli et al. (2014) and Wang et al. (2009). Each method has its own strengths and weaknesses which make them applicable to different types of decision-making situations. Wang et al. (2009) identified four general steps of the MCDA process, visualized in Figure 28.

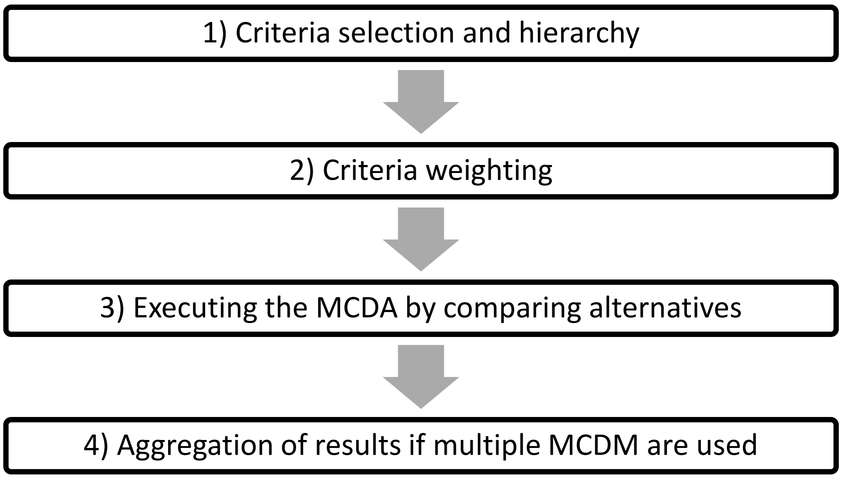


Figure 28 General steps of a multi-criteria decision analysis process (adapted from Wang et al. (2009)

Steps 1-3 align with the procurement methodologies: a desirable solution to a problem is defined in terms of criteria and by means of weighting, these criteria are prioritized. Tender offers are then evaluated objectively using the weighted criteria, leading to a transparent selection from the alternatives offered. The design of the decision support tool is therefore built upon the MCDA body of knowledge. The choice for a well-tailored MCDA method for this research is based on four factors:

1. Suitability and reliability
2. Proven method both in academics and practice
3. Experience and skills needed
4. Affordability, both financially and time span wise

Based on the MCDA comparison of Cinelli et al. (2014) (see Appendix S) and considering these four factors, the Analytic Hierarchy Process (AHP) is chosen as a method for this research application.

AHP is originally developed by Professor Thomas Saaty in 1980. The ability of AHP to combine quantitative and qualitative (value based) input, combine multiple perspectives of stakeholders in the MCDA and the availability of simple software support makes AHP a very suitable method for the decision support tool. One of the major strengths of the hierarchical characteristics is its ability to structure demands such, that different alternatives can contribute to differing demands, while still assessing these demands on their overall contribution to the desired, diverse and overall performance (Saaty & Vargas, 2013). It is this property that will enable the comparison between different types of alternatives in the procurement process while acknowledging their common overall functional demand.

AHP has the mathematical basis of an Eigen value problem and a consistency index is used to guarantee the consistency of the AHP results. Is a well-established method used in almost all decision-making applications and frequently used in reputable journals (Vaidya & Kumar, 2006). Its application in, for example, purchasing decisions, evaluating company performance and selection processes of job candidates makes AHP a method used in practice.

The principles of the AHP are fairly simple and easy to grasp. The pairwise comparison method however requires a sufficient level of knowledge and information on the subject matter to successfully execute a reliable AHP. Under the assumption that subject matter experts are involved in the utilization of the decision support tool, the required experience and skills on AHP application and subject matter input are available. Free software and spreadsheet templates are available (e.g. Goepel, 2017; Ramík, 2014) and the time required to perform an AHP largely depends on the amount of criteria used, the level of detail of indicator data and (mis)alignment of interests of the decision makers involved.

AHP is a method based on hierarchies which has its limitations regarding causal interdependencies. A directly related MCDA method capable of dealing with network-like criteria and alternative structures is the Analytic Network Process (ANP). ANP allows the consideration of interdependencies in the MCDA which is highly relevant to multidimensional (sustainability) assessments. However, the ANP method requires significantly more expertise, knowledge and information and sophisticated software, and is therefore less suitable for the current research project. AHP is concluded to be a MCDA method well fitted for this research and in the decision support tool. Supportive mathematical background is found in many publications, for example Saaty (1977) and Saaty & Vargas (2013) .

6.2 Case study validation of the sustainable procurement policy

The application and validation of the conceptual sustainable procurement policy and the supportive tool is tested using two case studies. Small-scale (two-three person) and short (two hour) workshops are organized to test the policy and facilitate group in a focussed and goal-oriented situation. Testing the policy with experts from different disciplines contributes to the understanding of its added value and of required iterations to mitigate malfunctioning or incompleteness. The following cases are studied:

1. The Fair Meter project:
   In collaboration with Stedin, another Dutch DSO, a smart electricity and gas meter for domestic use (hereafter the *Fair Meter*) is developed with specific product social and environmental sustainability requirements. Extensive information on the product life cycle sustainability demands is available at Alliander. This recent procurement process offers insights in this pilot procurement process as well as the ability of the proposed policy to select a desirable end product.
2. The Circular Cable: Alliander is currently in the procurement process of an electricity cable. For this cable, a level of sustainability / circularity is demanded in the specifications of the cable and its production process. As Alliander will develop the sourcing details that will determine which supplier wins the tender procedure, a (transparent) decision on sustainable characteristics need to be made. As the sourcing details are not yet defined, this case study

can serve as a test case for the policy developed due to the ongoing process and the consultation of experts currently involved in this process.

In both cases, content experts within Alliander will be consulted to discuss the applicability and usefulness of the policy and tool. A workshop environment is created that stimulates a transparent dialogue and constructive feedback on the policy and tool proposed. At least two content experts with different backgrounds (preferably a technical expert and a purchasing expert) are invited to collectively discuss the case. Experts participating in the case studies are listed in Appendix V (Fair Meter project) and Appendix W (Circular Cable). The organization of the workshop entails three steps:

Step 1: Preparation: The internal documents regarding the case study are requested from Alliander and briefly reviewed on content. The decision-making process is sketched. The level of detail of the sketch needs to correspond with the level of detail of the policy proposal in this research. Specific details on the integration of social and environmental criteria are summarized and the lessons learned from the case study with respect to sustainable procurement are also summarized. The preparation document as well as the general introduction of the sustainable procurement policy is sent to the Alliander experts in due time before the consultation step.

Step 2: Consultation: In a 2 hour workshop, Alliander experts are invited to do a walk-through of the procurement case using the sustainable procurement policy as a guideline. Detailed discussions on pros and cons are to be prevented, however the identification of misalignments of the theoretical policy with the practical reality are valuable inputs to the iteration loop of the policy. The evaluation of alternatives using the decision support tool proposed is tested to explore its suitability in the evaluation process.

Step 3: Generalization: After the workshop, lessons learned from the consultation of experts and based on the case study are then generalized to identify the iteration steps required in the policy development process.

The insights gained from the case studies on the feasibility of the developed policy and tool enables the possible integration of improvements until the final policy is presented.

6.3 Evaluation and communication of the sustainable procurement policy

The final sustainable procurement policy methodology and decision support tool are evaluated by discussing their application in the case studies and their compliance with the design constraints and criteria set throughout the literature review. The project results are communicated to relevant stakeholders after the policy evaluation.

6.4 Conclusion

The development methodology chosen merges four decision frameworks from both literature and practise into one decision policy. The policy inputs, gathered throughout the four previous literature review chapters provide important guidance in this development process.
An important remark is made by Faber & Stewart (2003, p. 181) regarding the development of a decision-making framework that has the objective of facilitating a multi-actor, multi-attribute and multi-objective decision: “it is of importance that decision theory is more than just a ‘one-off’

numerical analysis, but should be a dynamic and transparent process involving on-going consultation with interested parties that may result in changes in preferences, trade-offs, new insights and hopefully at the end of such a process a decision that most interested parties can live with". The development methodology therefore aims to deliver a policy capable of accommodating the challenging dialogue that enables the decision-makers involved to come to mutually beneficial decisions.

The policy, presented in the following chapter, consists of a procurement methodology describing the activities required to successfully procure more sustainably, and a decision support tool that operationalises this methodology.

Chapter 7: The sustainable procurement policy: methodology and decision support tool

The sustainable procurement policy proposal consists of two complementary parts, as shown in Figure 29: The *sustainable procurement methodology* (§7.1) and the *decision support tool* (§7.2). The methodology consists of three stages, the Initiation stage, the Sourcing stage and the Completion stage. Each stage is divided into multiple procurement phases, with a total of eight procurement process phases. In addition to the activities within the eight phases, multiple continuous quality management activities are presented to monitor the decision-making process. The decision support tool operationalizes the methodology, offering support in critical procurement activities with the demand matrix and AHP method application.

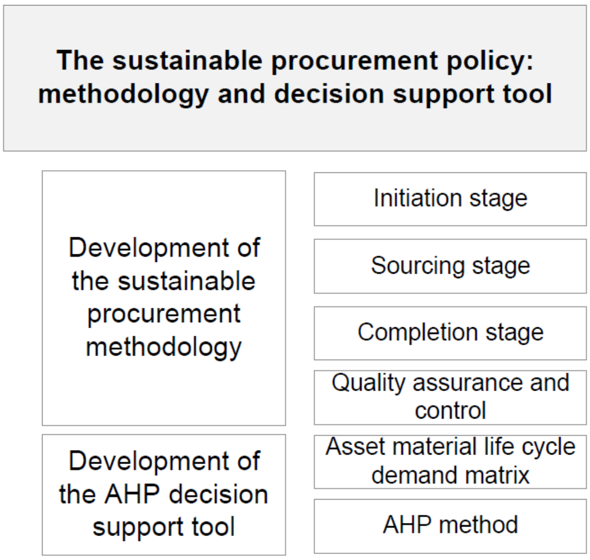


Figure 29 Content structure Chapter 7

7.1 Development of the sustainable procurement methodology

To successfully arrive from the positive business case to the implementation of the asset in daily activities, the procurement process needs to translate strategies into functional needs and objectively evaluate the market offers on their capabilities to provide those needs. The procurement process should be able to translate needs into (a) solution(s) as efficient as possible out of the alternatives offered by suppliers. The procurement policy goals in Appendix G summarize the objectives the policy aims to meet, which ultimately lead to overcoming the challenges currently experienced in sustainable procurement. The policy thereby leads to more efficient procurement processes. After the policy is developed and validated, the constraints and criteria of in Appendix G are used to evaluate the policy performance regarding the goals set.

The procurement policy proposal does not explicitly incorporate the definition of commodity strategies[5] and the explorative business case phase. However, the policy does acknowledge the drivers of the organizations commodity strategy and allows them to be part of the decision-making process. For sustainability and circular economy principles within the business case evaluation, the work of Korse, Ruitenburg, Toxepeus, & Braaksma (2016) discusses the need for an asset life cycle criteria in order to successfully evaluate the business case. Those criteria can be an input to the procurement activities. The policy hereby aligns well with the existing organizational steps prior to asset procurement.

The sustainable procurement methodology, depicted in Figure 30 below, facilitates the entire procurement process, starting after the positive business case evaluation and finishing with the implementation of the acquired product or service. §7.1.1. describes the general methodology overview and subsequent paragraphs describe the activities required in the initiation stage (§7.1.2), sourcing stage (§7.1.3) and completion stage (§7.1.4) in detail.

7.1.1 The three stages of the sustainable procurement process

The procurement process is organized in three stages and eight phases:

1. *The initiation stage*, in which the need for a solution is defined, the demands the solution has to fulfil are set and the alternatives are identified.
2. *The sourcing stage,* in which the selection of supplier(s) is undertaken. Facilitating the selection process by means of requirements, criteria, indicators and alternative comparison enables the decision-makers to select the desired alternative.
3. *The completion stage* includes the transfer of the procured product or service to the operational department and the evaluation of the procurement process.

In each phase, a multitude of leading and supportive activities and decisions are made that serve specific objectives. Table 9 illustrates the activities for each phase, structured by their stage and phase in the process.

[5] A commodity strategy is the long term and high level purchasing plan to acquire commodities (products or services) that enable the organization to continue their activities that involve the utilization of those commodities.

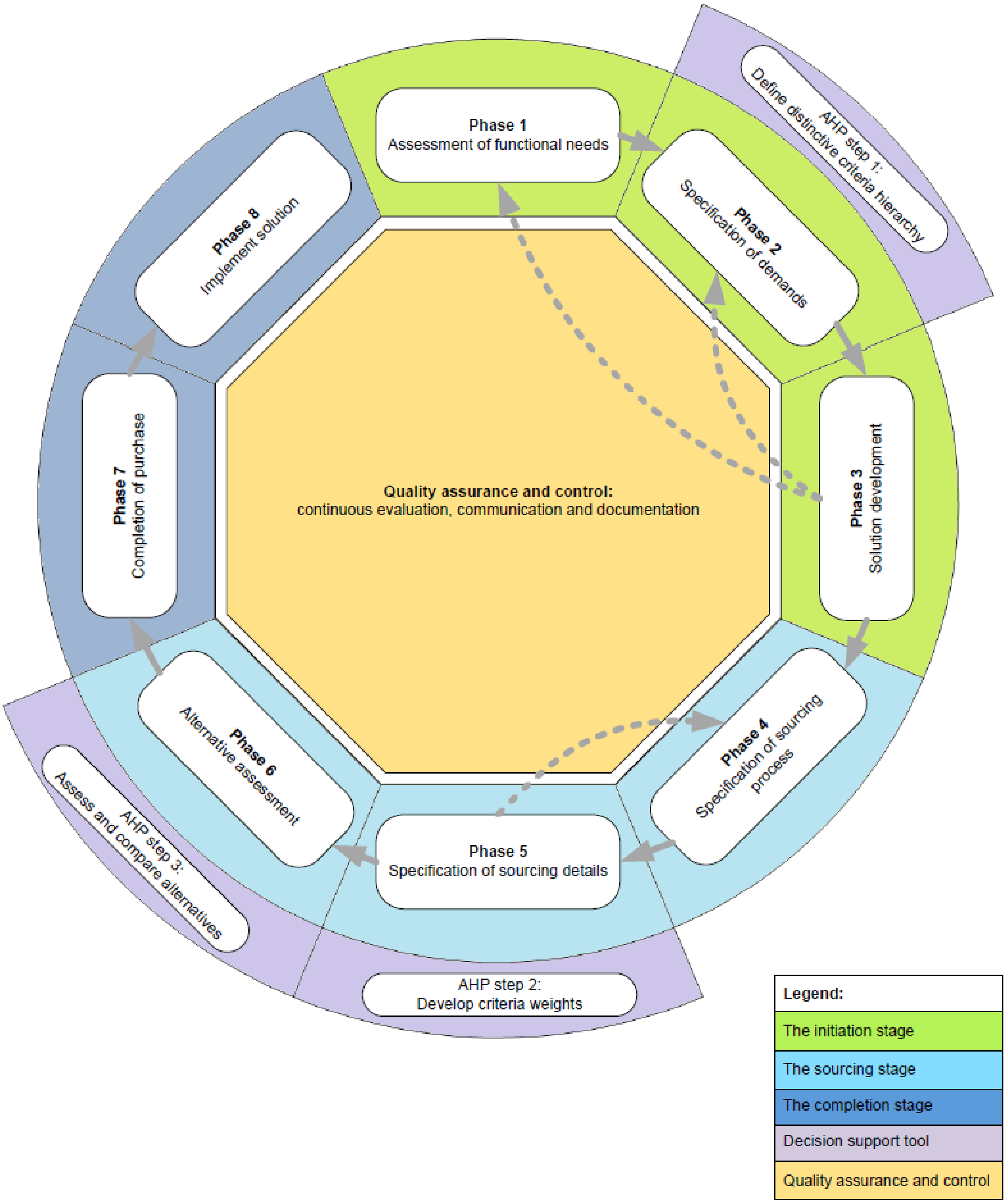


Figure 30 Sustainable procurement policy methodology

Table 9 Overview of the sustainable procurement stages, phases and activities

Phase 1	Assessment of functional needs
Activity 1.1	Set up multi-disciplinary team
Activity 1.2	Perform stakeholder analysis
Activity 1.3	Formulate views on sustainability
Activity 1.4	Define and motivate project goals on sustainability
Activity 1.5	Define and motivate functional demand of asset
Activity 1.6	Develop preliminary asset strategy

Phase 2	Specification of demands
Activity 2.1	Define and motivate procedural sourcing process demands
Activity 2.2	Define and motivate hard requirements
Activity 2.3	Define and motivate distinctive criteria
Activity 2.4	Define time-based demands

Phase 3	Solution development
Activity 3.1	Perform market analysis
Activity 3.2	Perform multi-dimensional risk assessment
Activity 3.3	Develop scope of feasible solutions
Activity 3.4	Explore business models & contracting types
Activity 3.5	Assess level of comfort feasible solutions and business models

Phase 4	Specification of sourcing process
Activity 4.1	Determine sourcing strategy
Activity 4.2	Determine sourcing procedure

Phase 5	Specification of sourcing details
Activity 5.1	Define supplier selection and alternative assessment requirements with a representative set of indicators
Activity 5.2	Reach consensus on weighting strategy
Activity 5.3	Develop criteria weights
Activity 5.4	Select information collection methods
Activity 5.5	Define consequences time-based demands
Activity 5.6	Request for proposals of alternatives

Phase 6	Alternative assessment
Activity 6.1	Select suppliers
Activity 6.2	Receive alternatives
Activity 6.3	Assess and compare alternatives
Activity 6.4	Discuss production and delivery details
Activity 6.5	Determine asset life cycle impacts
Activity 6.6	Determine asset strategies of alternatives

Phase 7	Completion of purchase
Activity 7.1	Select solution(s)
Activity 7.2	Reach consensus on contract details

Phase 8	Implement solution
Activity 8.1	Transfer to operational department for implementation
Activity 8.2	Evaluate procurement process with external and internal stakeholders

The initiation stage

The sourcing stage

The completion stage

Aligned with AHP decision support tool

7.1.2 The initiation stage

The initiation stage consists of three preparatory phases. The first phase, *assessment of functional needs*, explores the multitude of different perspectives of a perceived problem and sets the goals and scope of the problem. The second phase, *specification demands*, drafts a diverse set of different types of demands. The third phase, *solution development,* explores the range of alternatives that are potential solutions to the perceived problem.

Phase 1: Assessment of functional needs

Objective: Define the (functional) demand for which a solution is required. After identifying a general problem (e.g. an asset needs to be replaced, new assets are required), the solution to the problem needs to be formulated based on the function required. The following activities are required to formulate and motivate this function from multidimensional point of view.

Activity 1.1	Set up multi-disciplinary team
Description	A well-balanced team of experts (multi-disciplinary team, referred to as an MDT) is needed that represents the full range of expertise required to define the holistic functional demand and any follow-up activities in the process.
Means	Skjong & Wentworth (2001, p. 4) proposes four criteria to be used to select experts. Individuals should (i) have "experience in performing judgements and making decisions based on evidence on expertise, e.g. degrees, research, publications, positions and experience, awards, etc.", (ii) have a positive "reputation in community", (iii) be "available and willing to participate", and be "impartiality and [have] inherent qualities like self-confidence and adaptability".

Activity 1.2	Perform stakeholder analysis
Description	A stakeholder analysis is required to be able to establish a representative MDT. The interests and objectives of each stakeholder need to be identified as well as the interdependencies between these stakeholders and their power. Any stakeholder powerful enough to block decisions in the process should be represented to prevent delays in the subsequent process due to unexpected misinterpretation of stakeholder interests. Stakeholders can both be internal to the and external to the organization, and can be active (participating in decision-making processes) or passive (not participating while still influencing the course of the process (e.g. regulatory authorities)). The establishment of the MDT and the stakeholder analysis is an iterative and continuous process.
Means	Performing the stakeholder analysis using worldviews and heuristics (§3.1.5) as well as actor characteristics (§3.2.1) makes the relations between actors explicit.

Activity 1.3	Formulate views on sustainability
Description	Different interpretations of the phenomenon 'sustainability' need to be discussed to stimulate mutual understanding of stakeholders. Consensus on a definition of sustainability is not required and often not realistic. Transparency regarding the interpretation of what sustainability means is however crucial to counter dialogue stagnations further on in the procurement process. For the entire duration of the procurement process the MDT need to agree on a set of sustainability principles. As these principles will provide guidance in the formulation of criteria, the principles should not change throughout the procurement process.

Means	A complete picture of actors view on sustainability can be acquired using the four questions on sustainable development of NRC (1999, p. 1658): 'What is to be sustained? What is to be developed? What is the relation between what is to be sustained and what is to be developed? And over what scales in space and time are those relationships meant to hold?"

Activity 1.4	Define and motivate project goals on sustainability
Description	The multidimensional project goals regarding the end product and the procurement process need to be defined. Transparency regarding (conflicting) goals is required to enable fruitful decisions throughout the procurement process. The scope of the project as well as the scope of the asset supply chain stakeholders (tiers) to be considered also needs to be determined prior to the formulation of the function demanded.
Means	Project goals are to be based on the corporate strategy of the DSO organization and the roadmaps of relevant departments (e.g. asset management, CSR) and the strategic (long term) scenarios of the Dutch DSO industry. The Doughnut economics model and the SDGs offer holistic frameworks on which sustainable procurement goals can be based.

Activity 1.5	Define and motivate functional demand of asset
Description	Formulating the functional demand requires a time horizon as well as a clear scope of the function(s). As DSO assets operate in an environment of dynamic social, political and economic influences, a multidimensional view on the asset's function is required. In case of re-contracting of current supplier, the functional demand may be(come) clear before an MDT is compiled as the re-contracting is considered a formality. Re-assessing the existing formulation of the functional demand may still be desirable and can thereby lead to changing demands and changing collaboration conditions between the existing supplier and the DSO.
Means	Adopting an asset life cycle management vision and focussing on multidimensional performance-based functionalities may stimulate systems thinking and the formulation of strong functional demands.

Activity 1.6	Develop preliminary asset strategy
Description	Prior to the exploration of asset alternatives available on the market, a rough and preliminary asset strategy is to be developed to complement the functional demand with an initial ideas and strategic considerations regarding the total asset materials life cycle and potentially important decisions that affect the assets and asset material specifications.
Means	The preliminary asset strategy can be developed based on existing long term asset management roadmaps and the four asset strategy inputs: (1) Corporate values, vision, long-term objectives and strategy, (2) technology, (3) company and (4) markets.

Phase 2: Specification demands

Objective: Define and motivate supplier and product demands.

Four types of demands need to be defined: Procedural procurement process demands, binding requirements, distinctive criteria and time-based demands. Throughout the sustainable procurement policy, 'demands' refers to supplier and product demands only. Both requirements, criteria and time-based demands can have different perspectives (e.g. technical, economic, environmental, social, compliance, commercial, organizational). The more specific the formulation of demands, the smaller the solution space for the market.

Activity 2.1	Define and motivate procedural sourcing process demands
Description	Within legal public procurement boundaries, many different procurement processes are acceptable. The procurement process should be chosen as such that it enables all stakeholders involved to address the demand or problem and find a solution that fits this demand or problem.
Means	Available means to determine the sourcing process demands are expert judgement of the MDT, the outcome of the first phase and the sourcing procedures as discussed by PIANOo.nl.

Activity 2.2	Define and motivate hard requirements
Description	Requirements have a compulsory character: the tendering organization or the alternative offered has to comply with the what is required. Asset life cycle characteristics that need to be complied with are normative (certification and regulation) requirements and technical and/or dimensional restrains. Requirements aim to guarantee the functionality of the organization or alternative. The amount of requirements should be minimized to enlarge the solution space.
Means	Iteration between the demand phase and both the assessment of functional needs and solution development step is crucial to find the optimal formulation of demands and market capabilities. A continuous Plan-Do-Check-Act improvement cycle can offer guidance in the process to define a representative set of demands. Corporate strategies, SDGs and Impact Hotspot Analysis offer input to the demand specification phase. The causal relations between independent binding and distinctive demands need to be defined to understand the complexity of the set of demands. The demands need to be organized effectively. The demand matrix (paragraph X) structures demands based on their dimension and the relevant asset material life cycle phase.

Activity 2.3	Define and motivate distinctive criteria
Description	asset life cycle characteristics specified as distinctive criteria are describing the ideal characteristics that would fulfil the functional demand. It is often not possible to fully meet all distinctive criteria and optimal balances need to be found to comply with as many of the distinctive requirements as possible. Criteria hereby introduce the opportunity for suppliers to offer alternatives that can distinguish themselves from their competitors, leading to the 'better' tender offer.
Means	See activity 2.2

Activity 2.4	Time-based demands
Description	Binding and distinctive demands can both be defined as either status quo demands, or time-based demands. The latter hereby refers to required changes and/or (sustainable) developments that are to be achieved or complied with in a specified timeframe. Time-based demands allow the integration of future ambitions of the tendering organization into the procurement decision process.
Means	See activity 2.2

Phase 3: Solution development

Objective: The solution development phase aims to identify the initial benefits, opportunities, costs and risks of the different alternatives available to the organization to fulfil the functional demand. To do so, information regarding the capabilities of the market, risks, scope of feasible solutions and (sustainable) business models is required.

Activity 3.1	Perform market analysis
Description	The procurer-supplier(s) relation (e.g. dependency, power distribution) and the solution space (e.g. ongoing innovations) of potential feasible alternatives needs to be explored by analysing the supplier market. Also the physical and socio-cultural proximity of potential suppliers need to be determined.
Means	Unprejudiced analysis of the capabilities of the market. The market can be analysed using different techniques (e.g. market consultation, the five forces analysis of Porter, SWOT analysis, supply chain collaboration, collaboration for innovation). Such methods are beneficial to behave strategically during the procurement process. Market consultation and subject matter expert consultation both provide inputs to the definition of the scope of feasible solutions.

Activity 3.2	Perform multi-dimensional risk assessment
Description	Risks covering the complete supply chain and asset life cycle from each relevant dimension need to be assessed
Means	Conducting the multidisciplinary risk analysis requires the explicit integration of environmental, social and organizational risks in existing techno-economic risk analysis models. In the risk analysis activities, the risk perceptions of each stakeholder and each dimension need to be considered. Risk acceptance criteria can be connected to corporate sustainability goals. Based on the precautionary principle[6], undesirable environmental and social events can be considered as risks. Both aleatory (natural or random) uncertainty and epistemic (knowledge or ignorance) uncertainty needs to be included to address opportunities and risks related to environmental, social and organizational factors. Risk characteristics offer guidance in the assessment of (qualitative) sustainability-related risks.

[6] The precautionary principle states that one should act to reduce risks, even if scientific proof is lacking or consensus on values is not available (e.g. climate change mitigation)

Activity 3.3	Develop scope of feasible solutions
Description	The full scope of solutions available on the current market is to set realistic expectations and demands of potential alternative. Preliminary asset designs and asset material life cycle specifications aid the exploration of feasible solutions.
Means	Consult and explore possibilities with (leading) suppliers on the market. Internal and external expert consultation.

Activity 3.4	Explore business models & contracting types
Description	Different types of contracts and (sustainable) business models that prove to be feasible regarding the functional demand are to be explored.
Means	Exploring suitable contract types and (sustainable) business models can be done using the business model typology in §2.2.5.

Activity 3.5	Assess level of comfort feasible solutions and business models
Description	To guarantee a successful implementation of a solution to the functional demand, the extent to which feasible solutions and related business models are expected to be within the comfort zone of stakeholders needs to be assessed.
Means	Consultation of internal and external actors

The solution development phase feeds back to the assessment of functional needs phase and the demand phase iteratively to evaluate whether the functional need and/or the demands are in need of improvements. Only when consensus throughout the initiation stage is achieved, the procurement process continues with the sourcing stage.

7.1.3 The sourcing stage

In the sourcing stage, the preparations of the initiation stage are converted into practical results. The fourth phase, *specification sourcing process*, determines the required type of procurement procedure. In phase five, *specification sourcing details*, the set of demands with corresponding weights are made explicit as well as the information required to assess the suppliers and alternatives on their performances. In the sixth phase, *alternative assessment*, suppliers are selected and their proposed alternatives are assessed using the sourcing details of the previous phase.

Phase 4: Specification of sourcing process

Objective: A strategic consideration of the appropriate sourcing procedure is made and the most suitable procedure is selected.

Activity 4.1	Determine sourcing strategy
Description	Determining the sourcing strategy requires an understanding of the position of the procuring organization with respect to the supplying market, and the maturity of this market. Off-the-shelf products or services require a considerably different sourcing strategy than an innovative trial-run of a new technology.
Means	Inputs from the initiation stage regarding the product or service function, multidimensional demands and values, the capabilities of the market and the internal level of knowledge of the purchasing organization are of importance to set out an effective strategy. Sustainable business model typologies may offer unconventional models that can be exploited in the strategic sourcing process.

Activity 4.2	Determine sourcing procedure
Description	Formal specification of the procedure is then done to comply with EU procurement regulations.
Means	EU regulated procurement procedures offer a range of different procedures. The most common public and non-public procedures are introduced in paragraph X.

Phase 5: Specification of sourcing details

Objective: The supplier and alternative selection guidelines that will be used during the alternative assessment phase are defined. It is of importance that no misinterpretations can occur regarding the supplier and alternative demands, indicators and the corresponding weight distribution.

Activity 5.1	Define supplier selection and alternative assessment requirements with a representative set of indicators
Description	Specifications of requirements and criteria need to describe the definite functional demands with corresponding measurable indicators representing the scope and level of detail of those demands.
Means	Defining the criteria hierarchy using criteria dimension categories and sub-criteria. Defining requirements, criteria and their indicators needs to be done in direct and transparent collaboration of stakeholders to secure consensus and similar understanding of the definition of the demands. The MDT has a leading role in defining the demands and should be complemented with subject matter experts when topics are outside the knowledge scope of the MDT. Establishing the set of criteria and indicators is a dialogue-based process that may require multiple rounds of discussions.

Activity 5.2	Reach consensus on weighting strategy
Description	A weighting strategy needs to be determined that fits the specific procurement situation and that all actors involved with agree on.
Means	Different types of multi-criteria decision methods are available and thoughtful selection of the best suited method results in the (theoretically) optimal weighting process. This policy limits the methods considered to the AHP method as discussed in §6.1.2 and the conventional dialogue-based expert discussion to conclude on criteria weights.

Activity 5.3	Develop criteria weights
Description	A weight need to be assigned to each criterion. Requirements are compliance-based and do not require weights. Weighting is a group effort in which collective expert judgement enables the MDT to define a weight distribution representative for the procuring DSO. The knowledge level of actors is more important than the power or interest of actors. Establishing consensus on criteria weights can be either average-based or dialogue-based: - **Average-based consensus** on weights aggregates the individual weights assigned to criteria to single values without further discussion. - **Dialogue-based consensus** on weights considers the individual weights a starting point from which large spreads in priorities between criteria are discussed. The aim of the dialogue is to agree on a weight distribution representative for the corporate priorities and goals. Individual MDT actors will represent different goals and therefore collaboration among actors to achieve perceived wins for each actor is required. After the individual criteria weighting process, a decision is required for each criterion or indicator individually on whether the average-based or dialogue-based approach is used. Both approaches ultimately lead to a defined weight for each criterion with a cumulative total of 100%.
Means	The AHP decision support tool facilitates the criteria weighting activity. MCDA logic is required to eliminate subjectivity and heuristics in this weighting process. Deciding between average-based and dialogue-based consensus needs to be done systematically. Visual representation of MDT weight distribution spreads among actors through radar plots and box plots offer insights on which the decisions can be based. Establishing consensus through dialogue needs to recognize the individual expert knowledge of the MDT actors involved in the dialogue. Depending on the topic discussed, different actors may be interested and powerful. The Hierarchy wheel (paragraph X) is a useful analogy to consider for this situation. Each actor of the MDT should have a say in the prioritization of each criteria to prevent omitting actor opinions and to stress the different value judgements involved. Each value judgement should be backed-up with as much information as practical and desirable based on the procurement procedure and stakeholders involved.

Activity 5.4	Select information collection methods
Description	Methods to acquire requirement, criteria indicator information and the level of detail and scope of this information needs to be discussed with relevant stakeholders. Conclusions on information compilation is essential to increase the required information quality and quantity on which the supplier selection and alternative assessment can be based in a later stage.
Means	Indicator information collection methods can be selected using the Method Identification Key of Zijp et al. (2015b).

Activity 5.5	Define consequences time-based demands
Description	Consequences of compliance or failure to comply with time-based demands need to be drafted, preferably using range estimates of time and demand-specific performance. Range estimates, in comparison to point estimates, enable stakeholder dialogue based on a larger spectrum of ambition and consequences can be aligned with the degree of compliance.
Means	Consequences, both positive and negative, can be determined using scenario analysis and dialogue with the actors involved to determine the realistic range estimates of near and long term future performance and achievements of goals.

Activity 5.6	Request for proposals of alternatives
Description	Request for tender responses through publication of the tender details completes the activities in the initiation stage.
Means	Requests for tender responses can be made public and communicated to potential suppliers through the public procurement website commercehub.com.

Documentation of reasoning, limitations, assumptions and estimations throughout the activities in the specification sourcing details phase is essential to achieve objective, transparent, reproducible and logic-based results.

The specification sourcing details phase feeds back to the specification of sourcing process phase to evaluate whether the sourcing details align with the chosen process. The sourcing details should also be in line with the decisions made in the initiation stage. While iterations between the sourcing detail phase and the phases in the initiation stage are undesirable due to the consensus reached on the outcomes in the initiation stage, a set-back to an earlier stage may be required when sourcing details are unable to align with the initiation stage decisions. Only when consensus on the demands and weights is achieved and concluded to be in line with the organization's corporate strategy, procurement details are sent out to the supplier market in their final form.

Phase 6: Alternative assessment

Objective: Select suppliers using selection demands and assess alternatives using assessment demands to compare multiple alternatives and their capabilities to fulfil the functional demand needs. Objectivity and logic are core principles in supplier and alternative evaluation.

Activity 6.1	Select suppliers
Description	Suppliers are selected based on their compliance with requirements. Depending on the procurement procedure chosen, suppliers may also be selected based on their distinctive criteria scores.
Means	Demonstrable evidence of supplier performances and ambitions are valuable inputs to the supplier selection process. Compliance with requirements and criteria scoring needs to be evaluated by subject matter experts, where each expert can be responsible for the selection on his/her topics of expertise. Combining individual expert judgement evaluations then leads to a complete expert-based validation of demands. There should be no need to reach consensus due to differentiating value judgements as the performance and characteristics of suppliers is an objective snapshot or well-argued estimations of (future) supplier performance and impacts. Introducing an external supervisor governing the evaluation process may be desirable to guarantee an objective evaluation to suppliers.

Activity 6.2	Receive alternatives
Description	Alternatives are received from the potential suppliers selected in the previous activity.
Means	Asset material and supply chain information can be documented in a resources passport, bill of material, or comparable documentation forms.

Activity 6.3	Assess and compare alternatives
Description	Assessment of the alternatives received is done using the predefined binding requirements, distinctive criteria and time-based demands. The absolute and/or relative performance of the alternative is weighted and summed into a single score per alternative. Greenwashing in both supplier selection and alternative assessment need to be prevented and eliminated. Comparing the single cumulative scores enables the procuring organization to rank the alternatives available and decide on the solutions to be procured. Assessing alternatives with respect to a functional need should be done based on the functional lifetime of the alternative. The functional lifetime of an alternative, also defined as the *useful lifetime* of the alternative, is its function or performance delivered over a specified amount of time. Considering the functional lifetime throughout the procurement (evaluation) process enables decision-makers to determine the asset life cycle performance per unit of time instead of per unit of product. The latter enables different (sustainable and circular) business models to be assessed using the same set of demands (e.g. assessment and comparison of life cycle assessment results or life cycle costs of each alternative).
Means	Evaluating and comparing multidimensional indicators with different qualitative and quantitative units of measurement requires decision support methods to offer guidance throughout this phase. The decision support tool proposed in this research, discussed in §6.3, enables the comparison of different types of alternatives towards their common functional demand and their spectrum of performances. Transparent documentation is crucial for the evaluation of the alternatives under consideration as the alternative assessment activity requires reproducible and objective conclusions rather than subjective judgements. Quantitative performances (P) can be translated into final scores (S) via criteria weights (W). The formula below then translates criteria scores into a single alternative ranking score (RS), presenting the individual comparable performance of up to *n* alternatives. Qualitative criteria require a quantitative scale to be weighted into criteria scores. $P_{criterion} \times W_{criterion} = S_{criterion}$ $\sum S_{criteria} = RS_{alternative}$ $Alternative\ ranking: RS_1 >..> RS_n$ Alternative assessment using expert judgement follows the expert judgement approach as discussed at activity 6.1. Useful lifetime can be determined based on, for example, the TECCO perspectives on ALCM (Ruitenburg et al., 2017)

Activity 6.4	Discuss production and delivery details
Description	Discussing production and delivery details with suppliers of alternatives complement the product or service specific details and provide more insight in the potential future collaboration with that supplier.
Means	Supplier consultation and dialogue.

Activity 6.5	Determine and compare asset life cycle impacts of alternatives
Description	Determining the asset life cycle impacts provides insights in the life limiting factors and other life cycle impacts that affect the use phase of the alternative. Based on the asset material life cycle information available, the asset demands and future utilization scenarios, the multidimensional impacts for each alternative offered can be compared and asset strategies can be developed for each asset (see activity 6.6).
Means	Life cycle impact identification tools can be used to determine the impacts, including PESTLE categories, TECCO perspectives and asset lifetime impact factors

Activity 6.6	Determine and compare asset strategies of alternatives
Description	The asset (material) specifications, performance and life cycle impacts of each alternative enable the MDT to update the preliminary asset strategy (activity 1.6) of each alternative. Hereby, the long term consequences and strategic decisions that are related to each alternative become clear which provides valuable inputs to the selection and purchasing of one or multiple asset solutions.
Means	Asset strategy information inputs (paragraph X.X) and strategic asset material life cycle plan methods.

7.1.4 The completion stage

The completion stage finishes off the sourcing stage on a formal level. Phase seven, *complete sourcing*, confirms the collaboration between the procuring organization and the supplier(s) through a formal contract. Phase eight, *implement solution(s)*, complements the procurement process by transferring the procured product or service to the department of interest within the organization to be implemented in the business-as-usual activities.

Phase 7: Complete sourcing

Objective: The procurement completion stage concludes the decision-making and negotiation process by formally signing contracts with the supplier(s) with the most desirable alternative(s).

Activity 7.1	Select solution(s)
Description	One or multiple supplier(s) and corresponding alternative(s) are selected based on the alternative assessment.
Means	Select solution and award contract by following procurement procedures.

Activity 7.2	Reach consensus on contract details
Description	The complete sourcing phase ideally only entails the formal documentation, reaching consensus on detailed arrangements and signing the contract.
Means	Desirable different contract types have already been discussed in the solution development phase.

Phase 8: Implement solution(s)

Objective: To complete the procurement phases the procured product or service has to be implemented successfully in the organization and the procurement process needs to be evaluated.

Activity 8.1	Transfer to operational department for implementation
Description	The operational departments within the DSO organization needs to implement the product or service in the existing infrastructures and operational activities.
Means	Follow transfer procedures of the organization

Activity 8.2	Evaluate procurement process with external and internal stakeholders
Description	Evaluation with internal stakeholders and external stakeholders enables all parties involved to set up lessons learned for future procurement processes and potential repetitive collaboration.
Means	Dialogue with internal actor network and external actor network collectively and/or separately.

7.1.5 Quality assurance and control: Continuous evaluation, communication and documentation

Assuring and controlling the product (procurement end result) and process quality requires constant monitoring of the procurement situation. Three core values for successful procurement collaboration are presented and need to be maintained: Behavioural guidelines for actors, quality of the decision-making process and the use of knowledge and research.

Behavioural guidelines for actors

Social and organizational norms and (unwritten) rules are dependent on geographical and organizational cultures (Hofstede, Hofstede, & Minkov, 2010a). Awareness and active anticipation of these differences may help to overcome social difficulties. Another set of norms and values in decision-making is proposed by Bruijn & Heuvelhof (2008), who define seven behavioural ‘rules’ on the position and actions of decision-makers and other actors involved in the process, and four ‘rules’ related to the process itself (see Table 10 and 11 respectively). Following these 11 guidelines on social interaction in a strategic procurement context may contribute to a more fruitful and long-term collaboration of actors.

Table 10 Behavioural guidelines for actors (Adapted from De Bruijn & Heuvelhof (2008, p. 96))

Behavioural guidelines for actors
Do not 'dance on the dead body' - the loser deserves respect
Do not affect the core values of other actors
Explain the outcome of the process substantively to your rank and file – and give the other actors the opportunity to do so as well
Use your power in a reserved way – the more power you have, the more reserved you should be
Go the extra mile with the loser; consultation should not be refused
Respect the principle of reciprocity: decision-making is giving and taking
Act proportionately

Table 11 Behavioural guidelines for the process of decision-making (Adapted from De Bruijn & Heuvelhof (2008, p. 105))

Behavioural guidelines for the process
Show respect for the ritual
Do not play chess on two boards at the same time (unless you can be open about it)
Do not use the exit option (at least until after some time) and complete the process properly
Respect procedures: no change of procedural agreements midway

Quality of the procurement process

Measuring quality generally requires a description of an ideal state and the subsequent comparison of the actual state with that ideal state. The closer the actual state is to the ideal state, the higher its quality. Measuring the quality of a continuous process and from an unspecified end result may thus impose several difficulties to the principle of quality management. De Bruijn & Ten Heuvelhof (1999, p. 180) discuss the conditions and ingredients for a high quality decision made: "A necessary condition for quality is that a wide variety of options should be considered, that selection should be made in an authoritative way and based on that variety. If the variety/selection standard is complied with and the actors are satisfied, it may be assumed that the decision(s) taken are of the necessary quality." Translating this guideline on qualitative decision-making to sustainable procurement results in three process goals to be achieved De Bruijn & Ten Heuvelhof (1999).

- **Continuous adaption** to the changing environment of the procurement process is required (e.g. stakeholder interests, market capabilities, intrinsic motivation of stakeholder to collaborate). The multi-actor network and hierarchy characteristics, variety, mutual dependence, closeness and dynamics (§3.2.1), are insightful means that can help the awareness and understanding of the present relationships among actors.
- Decisions should be based on **authorative selection** and from multiple alternatives, implying a reliable and accurate outcome that can be trusted by stakeholders due to a transparent regulatory compliant process. A long-term prospect of a positive and large gains/loss ratio is recommended to maintain actor support after the decision for a solution is made.
- **Satisfaction of project goals and actors simultaneously**. An optimal end project end result is desirable to deliver the optimal function demanded. The multi-actor context and subsequent multi-criteria decision introduces inevitable trade-offs. Each actor should perceive more gains than losses and interests of actors not represented (e.g. high supply chain tiers) should be explicitly considered to prevent bad decisions that satisfy only the decision-makers. A high quality result is a prerequisite for the willingness to participate in subsequent collaborations. A good process with bad results enables the actors involved to repeat the process in order to

achieve better results, while a bad process does not necessarily stimulate the repetitive collaboration, even though the result was good. This goes especially for sustainability goals: they may not be achieved, but showing leadership, stimulating managerial incentives and creating awareness among actors are goals on their own which are difficult to measure.

Project results are typically evaluated at the end of the procurement process, where questions such as 'does the end result meet the pre-formulated goals?'. The process is evaluated continuously by answering questions that provide inputs that may directly lead to process improvements (De Bruijn & Heuvelhof, 2008, p. 87), e.g. "Are the parties satisfied? Have any problems been solved? Have the parties learnt anything? Have trustful relations for the future developed? Was[/is] the process fair?

The pyramid of responsibilities in Figure 31 offers an illustrative prioritization framework for the organization of responsibilities of actors (Carroll, 2016, p. 5). The pyramid has an economic and legal foundation that both are required by society, and ethical and philanthropic reasoning of a decision, which are expected and desired by society on top of that foundation. In situations of trade-off deadlocks or decision difficulties, the group of decision-makers can act in accordance with the CSR pyramid priorities.

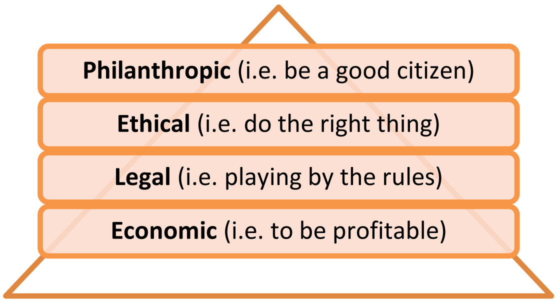


Figure 31 The pyramid of responsibilities, adapted from Carroll (2016, p. 5)

Utilize knowledge and scientific research

The role of knowledge and scientifically valid data is increasingly important in sustainable procurement. Reasons are, among others, the increased level of complexity due to a more diverse set of requirements, the introduction of sustainable and circular business models, the consideration of the total asset material life cycle and related long term estimations and assumptions, and the execution of a logical and objective assessment of different tenders. Scientific research may be a bouy of hope in the increasingly more value-based procurement process. Aligning science and procurement should however be done carefully to prevent an adverse effect of increased complexity rather than the clarifying role science may serve. Three considerations are of interest throughout the initiation, procurement and completion stage:

- **Mandated science** should be avoided. Mandated science describes scientific anwers to layman questions, with the aim to increase the credibility of the answer due to its scientific roots (Salter, n.d.). By introducing political incentives to science, the objective and undisputable logic and reliability of science may become questionable due to potential framing of scientific results or the delivery of results requested by political drivers. An example of mandated science is the blind trust in life cycle assessment (LCA) results to determine the environmental impact of an asset. Interpretation of LCAs is largely determined by underlying assumptions and qualitative data availability.

- Use of **negotiated knowledge** should be facilitated. Consensus on information collection methodologies, related assumptions and the level of detail is required to eliminate setbacks in the procurement process due to disagreements on knowledge or data.
- **Effective interaction** of scientific or industrial experts and decision-makers. Three advantages of interaction are (1) the expert value judgement regarding acceptability and rationality of decisions, (2) the distinction between soft and subjective statements and undisputable and incontrovertible statements and (3) input of insightful (causal) underlying relations between problems and solutions into the decision-making process.

7.2 Development of the AHP decision support tool

To operationalize the proposed procurement framework, a decision support tool that can facilitate the process from the first to the last phase is proposed. The decision support tool aims to operationalize the procurement policy by offering a structured and transparent instrument for group decision-making. The tool consists of two elements: the *demand matrix,* in which the asset material life cycle demands are organized based on their dimension, and the AHP method which leads to the best (ie. most desirable) outcome of the alternative assessment. Both parts of the decision support tool are introduced separately in the paragraph below.

7.2.1 Asset material life cycle demand matrix

In accordance with the need to consider the total life cycle of the asset (Liyanage, 2012) and the principles of the Circular Economy that transcend the borders of single life cycle phases, demands need to be organized based on their applicability and relevance from a life cycle perspective. Organizing criteria based on the life cycle of raw material instead of the life cycle of the product allows for transparent and more holistic view on the asset that is to be purchased. The possibilities to directly include the waste hierarchy R's (i.e. Refuse, Reduce, Reuse, Repair, Recycle, Re-think) into the formulation and organization of procurement criteria creates the opportunity to openly discuss circularity of assets. The structuring procurement criteria and thereby sustainability issues throughout different stages of the supply chain is also in line with the proposed continuation of research on sustainable procurement by Walker et al. (2012) to better frame the complex and multiple issues that arise during procurement. Table 12 illustrates the concept of the demand organization matrix, listing the asset material life cycle phases that offer guidance in the upcoming decision-making process.

Table 12 Asset material life cycle demand matrix

	Design	Raw material	Production	Transportation	Installation	Use	End of use
	Conceptual design, preliminary design, detail design	Virgin and recyclate	Development, production	Transport	Construction, commission	Utilisation and support: operate, maintain, performance and modify, upgrade	Retirement and disposal: decommission, waste management, integration in other chains
Technical							
Economic							
Environmental							
Social							

The procurement requirements and criteria can also be organized based on their sustainability dimension, following the Triple Bottom Line concept (Elkington, 2001): *economic, environmental* or *social*. As the majority of the solutions to functional demands of a DSO will be technical physical assets that need to comply with (normalized and regulated) technical specifications, *technical* is added as a fourth dimension. Based on both the asset material life cycle phases and the criteria dimensions it is now possible to organize procurement criteria based on their specific nature and moment in time. The overview enables the stakeholders involved to openly discuss causal relations as well as hierarchies of importance between criteria transparently. The electrical cable example below illustrates the independency of criteria and the insight that organization of criteria in the purposed matrix facilitates.

Example: Electrical cable (Table 13)
Among other criteria, the technical criteria "reliability" and "% purity of material" and the environmental criteria "recyclate IN" are selected for a specific asset. While non-virgin material in the asset may lead to less pure material and thereby a less reliable asset operation, there are also possible alternatives that may still assure the reliability of the asset while adding a certain percentage of recyclate in the asset material. The criteria may not be mutually exclusive, while from a technical point of view they may initially be. The asset specifications are however limited in their design: the cable needs to comply with, for example, the minimum and maximum diameter that installation equipment can process. By organizing the criteria as listed below, the performance during operation (use phase) that needs to be guaranteed requires innovations in the composition of materials (raw material phase). These innovations align with the circularity and material loops sustainable business model type generalization. One could add an economic criterion related to a maximum material price, implying that the innovation cannot lead to increased raw material costs.

Table 13 Asset material life cycle demand matrix: Electrical cable example

	Design	Raw material	Production	Transportation	Installation	Use	End of use
	Conceptual design, preliminary design, detail design	Virgin and recyclate	Development, production	Transport	Construction, commission	Utilisation and support: operate, maintain, performance and modify, upgrade	Retirement and disposal: decommission, waste management, integration in other chains
Technical		**% purity of material**			**X-Y mm diameter**	**Reliability**	
Economic							
Environmental		**% recycled in**					
Social							

Dematerialization	Circularity and material loops	Dematerialization			Dispossession	Circularity and material loops
Optimize functionality		Circularity and material loops			Prolong lifetime	
					Optimize functionality	

The advantage of organizing criteria, as seen in the electrical cable example, over an unstructured list of criteria is found in the transparency and possible dialogue: the demand matrix opens up the solution space when a stakeholder specialized in material innovations (supplier) is introduced to the dialogue with the product users (purchaser).

Actors involved in the operation of the asset are more inclined to accept a "% recyclate" criterion when their "reliability" criterion will not be negatively influenced. Acknowledging the values and needs of individual actors hereby results in widening the negotiation space.

Added value of transparent criteria structuring is also found in company specific targets (measured by corresponding KPIs). The circular DSO targets of Alliander include *40% circularity in purchased assets (functional unit: asset quantity in kilograms) in 2020,* while also the annual outage, which is the average number of failure minutes per customer per year, needs to be reduced simultaneously. Example A shows that by listing both criteria explicitly, the procurement of the asset can contribute to both targets.

7.2.2 Multi-criteria decision analysis utilizing the Analytic Hierarchy Process method

The Specification Sourcing Details activity of the procurement methodology can be considered a decision process with multiple criteria, objectives and participants. To assist this decision process, the web-based decision support tool *AHP Open System* (AHP-OS) is used to execute this multi-criteria decision analysis. The AHP-OS program is designed and maintained by Dr Klaus D. Goepel (2017) and can be accessed via www.bpmsg.com freely.

The software facilitates both the weighting of criteria by pairwise comparison logic and the evaluation of multiple alternatives based on these weighted criteria. Input of multiple participants in the decision-making process can be processed and the integrated AHP consensus indicator quantifies the level of consensus and differences in value judgement (i.e. among participants. The AHP application software instructions are discussed into detail by Goepel (2017). Figure 32 illustrates the sequence of AHP steps.

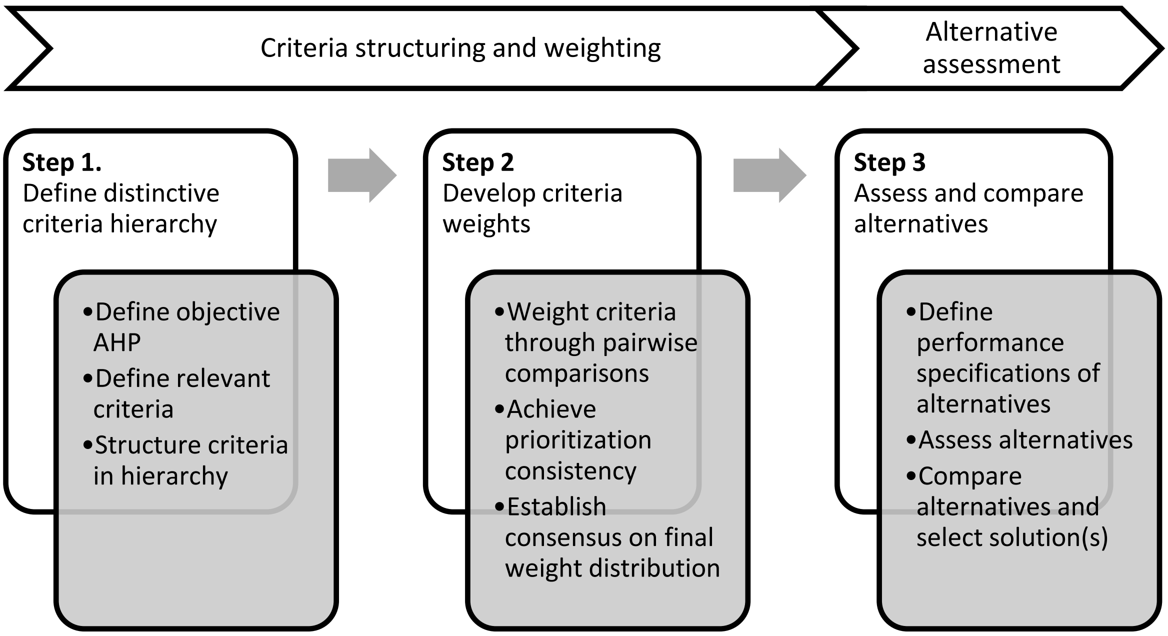


Figure 32 Sustainable procurement policy decision support tool

The AHP steps in the sustainable procurement process are discussed below and their application is presented in Chapter 8 through case studies.

Step 1: Define distinctive criteria hierarchy

Step 1 of the AHP decision support tool establishes a hierarchically structured set of criteria. The criteria hierarchy step aligns with **Step 2 Specification of demands** in the policy methodology.

- **Define objective AHP**
  The objective of the AHP decision support tool need to be formulated by the MDT prior to its execution. Objectives can range from an initial estimation of actor value priorities to an extensive utilization of AHP to determine average-based criteria weight distributions.
- **Define relevant criteria**
  See **Activity 2.3 Define and motivate distinctive criteria** in the sustainable procurement methodology.
- **Structure criteria in hierarchy**
  Structuring the criteria in a hierarchy follows a branching syntax Goepel (2017, p. 4): "Each branch in the hierarchy is defined by its node (the category) and the node's leafs (the sub-categories)". The category refers to the sustainability dimension of the demand matrix and the sub-categories refer to the criteria within that dimension. Multiple levels of categories are possible.

  Example of a criteria branch:

  Sustainability criteria: Technical, Economic, Environmental, Social;
  Technical: criterion 1, criterion 2, criterion 3;
  Economic: criterion 4, criterion 5;
  Environmental: criterion 6, criterion 7;
  Social: criterion 8;

  The AHP-OS software is able to process a theoretically unlimited amount of criteria and decision-makers (participants) and between 2 and 12 alternatives.

Step 2: Develop criteria weights

Step 2 of the AHP decision support tool systematically weights the set of criteria through pairwise comparison and supports **Activity 5.3 Develop criteria weights** in the methodology. Each actor involved in the procurement process (typically each member of the MDT) needs to participate in this weighting step.

Perform pairwise comparisons of criteria

Prioritization of criteria results in an order of importance by assigning each criterion a single weight, with a total cumulative value of 100%. Multi-criteria decision methods use weighting logic to establish criteria prioritization to prevent subjective value judgements and intuitive common sense. The weighting method in AHP is called pairwise comparison, a method to determine a scaling ratio using mathematical matrix (eigenvector) logic (Saaty, 1977). Each criterion is compared to a criterion from the same hierarchical branch (illustrated by Figure 33) and the level of domination of one criterion over the other is expressed on a scale from 1 (equally important) to 9 (absolute importance). Table 14 presents the weighting scale with corresponding descriptions of each value.

Each MDT actor that participates in the criteria weighting process has an individual and unique view on the priorities of criteria. Therefore, each of these actors is required to perform their own pairwise comparison without interacting with other MDT actors. The combination of the multiple pairwise comparison criteria weight distributions result in a total weight distribution through average-based consensus or dialogue-based consensus. Appendix T shows the activity flow of the process with multiple participants

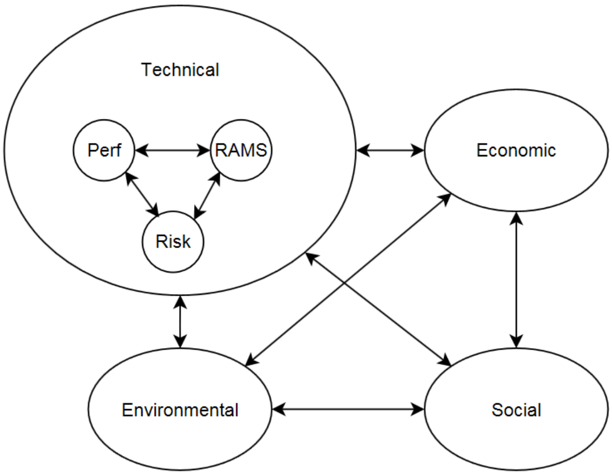


Figure 33 Visualisation of AHP pairwise comparison example between four level 1 and three technical level 2 criteria

Table 14 Weighting scale and scale description (Adapted from Saaty (1977, p. 246)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favors one activity over another
5	Essential or strong importance	Experience and judgement strongly favors one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgements	When compromise is needed

Achieve prioritization consistency

A prerequisite of pairwise comparison is a minimal level of consistency in the criteria prioritization. The consistency ratio (CR) represents the trustworthiness of the pairwise comparison value judgements. In essence, the CR compares the judgements with purely random judgements. If the CR increases, the value judgements are considered more random. If the CR exceeds a CR limitation, the pairwise comparison performed should be considered invalid and needs to be improved to become more trustworthy. The AHP software of Goepel (2017) requires a <10% consistency value, which is a common limitation in AHP literature and practise. The mathematical background of the CR is discussed by Saaty (1977).

Establish *average-based* consensus on final weight distribution

The individual pairwise comparisons now need to be merged into a single weight distribution. The AHP weighting process can do so and an example is presented below. Figure 34 illustrates a simple Excel spreadsheet example of the AHP pairwise comparison ratios, the corresponding consistency ration and subsequent weight distribution.

Pairwise comparisons

Item Number		1	2	3	4
	Item Description	Reliable	High Gas Mileage	Power	Color
1	Reliable	1,00	7,00	5,00	3,00
2	High Gas Mileage	0,14	1,00	0,33	0,20
3	Power	0,20	3,00	1,00	0,25
4	Color	0,33	5,00	4,00	1,00

Consistency ratio (CR) Value = 0,065 OK

Standardized matrix

Item Number		1	2	3	4	
	Item Description	Reliable	High Gas Mileage	Power	Color	Weight
1	Reliable	0,60	0,44	0,48	0,67	54,8%
2	High Gas Mileage	0,09	0,06	0,03	0,04	5,6%
3	Power	0,12	0,19	0,10	0,06	11,5%
4	Color	0,20	0,31	0,39	0,22	28,1%

Figure 34 AHP criteria weighting example: Car assessment criteria

The average-based consensus on criteria weight distribution requires the individual weighting to be consolidated into a single weight (see consolidated weight in Figure 35). Consensus among participants is expressed in overlap percentages from 0 to 100%. Low, moderate and high consensus correspond to <65%, 65-75% and >75% respectively. This consensus indicator measures the overlap of weights and thereby the shared value judgements of the participants involved. High levels of consensus are desirable to decrease the resistance of actors towards the concluding consolidated weight distribution.

Weight matrix

Item Number		Weight				
	Item Description	Participant 1	Participant 2	Participant 3	Participant 4	Consolidated weight
1	Reliable	60%	44%	48%	67%	54,8%
2	High Gas Mileage	9%	6%	3%	4%	5,6%
3	Power	12%	19%	10%	6%	11,5%
4	Color	20%	31%	39%	22%	28,1%

Figure 35 Car assessment example: consolidated weight

Establish dialogue-based consensus on final weight distribution

The average-based consensus approach to determine the criteria weight distribution has little use when large differences in values and preferences exist among the MDT actors. A wide spread in assigned weights should therefore not be aggregated into a single average value through applied mathematics. A more subjective approach is required in which actor dialogue is utilized to conclude on the final weight distribution. Dialogue creates the opportunity to have do trade-offs and have strategic negotiations between actors from different disciplines to end up with a weight distribution that each actor feels comfortable with (referred to in this policy as a perceived win for each actor).

The AHP-OS software presents a complete documentation of pairwise comparison matrices and consolidated results, both online and in spreadsheet format. The spreadsheet data can be processed to effectively use the AHP output in MDT dialogues. Appendix U shows the transformation of AHP-OS outputs to visualized dialogue input. Two types of visualizations are recommended in the criteria weighting step: the radar plot and the box plot. The radar plot creates an overview of the actor priorities which then provides the MDT with insights regarding the weighting differences and similarities. The box plots present a more detailed overview, which is particularly interesting when the radar plot is cluttered due to large amounts of actors participating.

Radar plot: The radar plot presents a quick overview of where individual priorities of participating experts lie. In addition to insights of varying weight distributions, the corporate vision and core values can be included in the radar plot to set out the (long term) goals and preferred weights to offer guidance in individual misalignment of values. See Figure 36 for a radar plot example. From the radar plot a divided opinion regarding *technical, economic, environmental and social* priorities can be observed. Each participant is represented by one line, and each line represents a cummulative priority distribution of 1. As the radar plot is not providing clear numerical details, the box plot is suggested for more details.

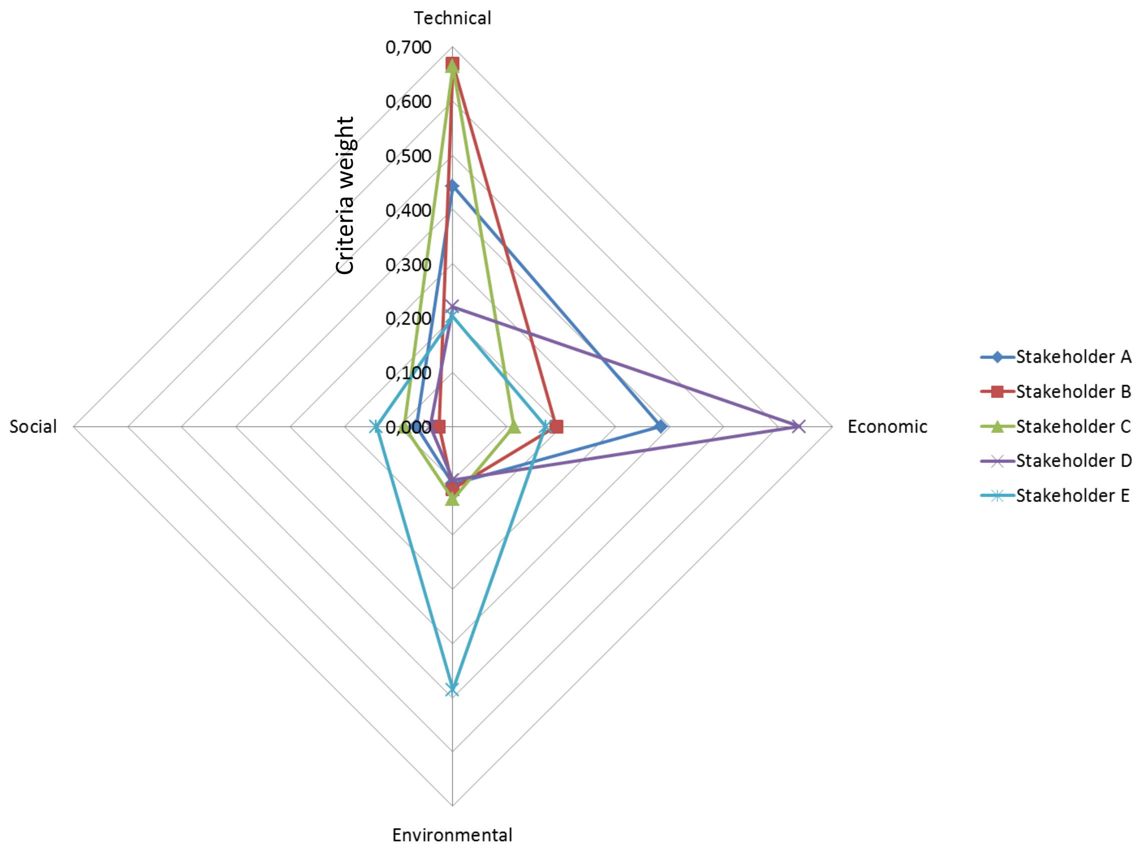


Figure 36 Radar plot example: four criteria and five participating stakeholders

Box plot: A box plot can present a more detailed overview of assigned weights for each criterion. The box plot thereby shows small spreads of weights that can be used to determine an average criterion weight without extensive dialogue, and large spreads that can form the basis for extensive discussions in an MDT. See Figure 37 for a box plot example of criteria categories. In the example, the weights of *social* are similar and the MDT could take the average weight. The weights of *technical* and *economic* strongly differ. A discussion to align these large spread of weights is recommended to establish consensus on values. The *environmental* distribution suggests the need to discuss the pioneering suggestion that stakeholder E may have in mind which caused the maximum outlier in the box plot or to conclude that the individual value perception of stakeholder E that may be proportionally different from the MDT.

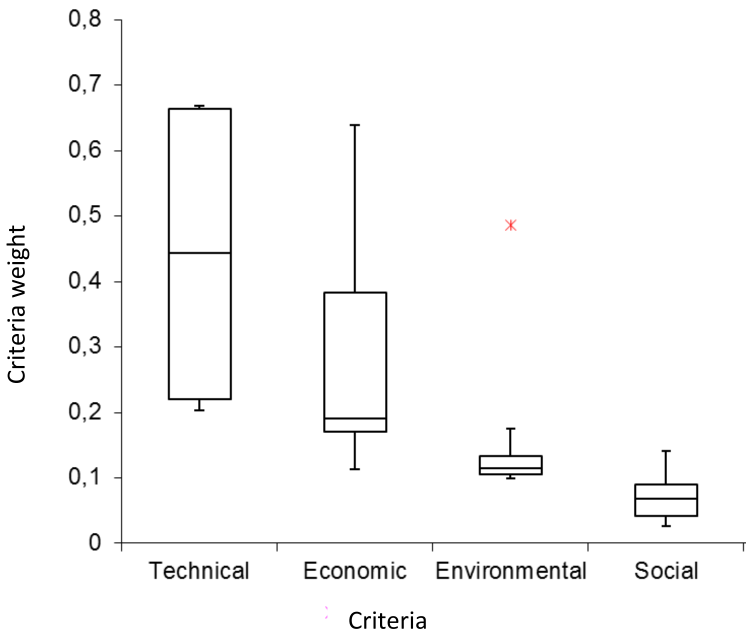


Figure 37 Box plot example: four criteria weight distributions

Note:
The *dialogue-based consensus approach* is simple in theory, while in practice this approach proves to be more challenging than the average-based approach: the individual weight distributions are discussed by means of a formal dialogue between all MDT actors and a group decision is made regarding a single criteria weight distribution through actor interaction. This may not be an easy and fast process. The corporate values and its strategies should be considered as a direction sign to overcome disputes on individual (or department) values and objectives. The acknowledgement and agreement of higher level goals regarding sustainability, societal dependency on DSO assets and long-term asset management strategies may steer the weighting dialogue towards a conclusion that fits the higher goals rather than individual goals. Hereby, individual actors may feel put aside. However, as long as all actors are aware of - and agree on - these higher goals, the conclusive set of weights can still be considered suitable for further use in the procurement process.

Note:
Criteria weighting is an iterative process. When more knowledge and information becomes available throughout the Initiation stage and Sourcing stage, the weight distributions of individual actors may change. In contrast to a static weight establishment process, multiple rounds of AHP and multiple dialogues may thus be needed over time to establish a weight distribution that truly represents the values of the DSO.

The final criteria weight distribution is one of the crucial steps in the procurement process as it will incentivise the supplier market to analyse the set of criteria. Generally speaking, suppliers aim to attain the highest overall ranking score with the least effort possible. Thus, suppliers will act strategically and choose to either score well on highly weighted criteria or get around those criteria through a high performance on other less weighted criteria that can still enable the supplier to score high(est). Considering this cost-benefit thinking of suppliers while determining the weight distribution may be of crucial importance to orchestrate the type of suppliers and alternatives that are considered desirable long-term partners and solutions.

Step 3: Assess alternatives

Step 3 of the AHP decision support tool supports **Activity 6.3 Assess and compare alternatives** in the assessment and comparison of alternative performances on the set of (weighted) distinctive criteria.

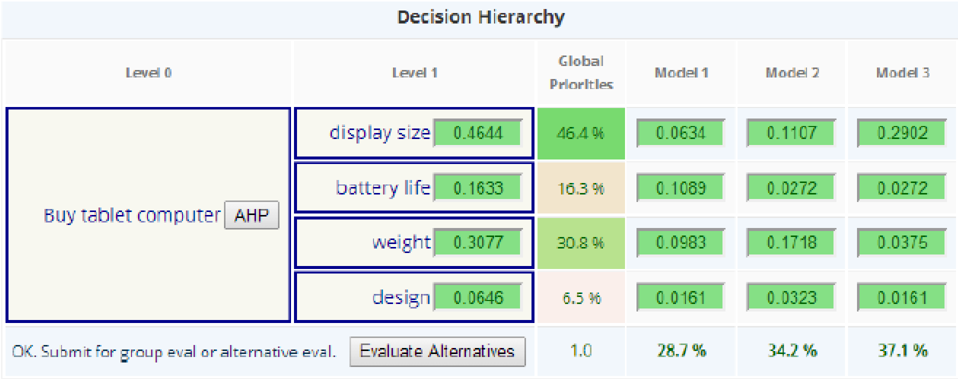
- **Define performance specifications of alternatives**
  The performance of each alternative per criteria is determined based on the alternatives specifications. This information is acquired through **Activity 6.2 Receive alternatives**.
- **Assess alternatives**
  After establishing consensus on criteria weights, the suppliers and their alternatives are assessed to determine their individual and/or relative performance. The AHP method compares the alternatives for a given criterion using the pairwise comparison approach as seen during the criteria weighting. Pairwise comparison scores can be used relatively or in a more absolute sense. The latter can prevent greenwashing of environmental and social performance of suppliers and alternatives.

  In this alternative assessment through pairwise comparison, expert judgement decisions on whether alternative A is better or worse than alternative B are required as well as the extent to which A is better or worse. To assist this assessment process, indicator-specific alternative specifications may need to be translated to the 1-9 scoring scale in order to assess quantitative performances (e.g. comparing technical reliability by rewarding each increase of 1% in performance with a +1 on the scoring scale).

  The alternative assessment in Figure 38 illustrates the pairwise comparison of alternatives in the AHP-OS software. Figure 39 shows how the weighted criteria (global priorities) are used to calculate the final ranking scores of alternatives (models) in percentages. Model 3 scores best in this decision process with preferred score of 37.1%.

	Criterion	Node	Glb Priorities	Compare	Model 1	Model 2	Model 3
1.	display size	Buy tablet computer	46.4%	AHP	0.333	0.333	0.333
2.	battery life	Buy tablet computer	16.3%	AHP	0.667	0.167	0.167
3.	weight	Buy tablet computer	30.8%	AHP	0.333	0.333	0.333
4.	design	Buy tablet computer	6.5%	AHP	0.333	0.333	0.333
				Total weight of alternatives:	0.388	0.306	0.306

Figure 38 Alternative assessment of three tablet computer models on four criteria



Decision Hierarchy

Level 0	Level 1		Global Priorities	Model 1	Model 2	Model 3
Buy tablet computer AHP	display size	0.4644	46.4 %	0.0634	0.1107	0.2902
	battery life	0.1633	16.3 %	0.1089	0.0272	0.0272
	weight	0.3077	30.8 %	0.0983	0.1718	0.0376
	design	0.0646	6.5 %	0.0161	0.0323	0.0161
OK. Submit for group eval or alternative eval.	Evaluate Alternatives		1.0	28.7 %	34.2 %	37.1 %

Figure 39 Phone selection example AHP-OS: alternative weighting

- **Compare alternatives and select solution(s)**
  Comparing the supplier and alternative scores per criterion enables the procuring organization to understand the total scores of each supplier and alternative relative to each other. By processing the AHP-OS output data in a stacked bar chart, the final results of the supplier selection and alternative assessment step are visualized clearly. See Figure 40 for a 100%-stacked bar chart example which summarizes the set of criteria and the final (relative) score of the two alternatives assessed. In the example, the domination of Alternative A on all but four criteria is clear. There would be little chance for alternative B to come up on top as there are too many criteria to improve on. Alternative B thus is the preferred choice to be contracted.

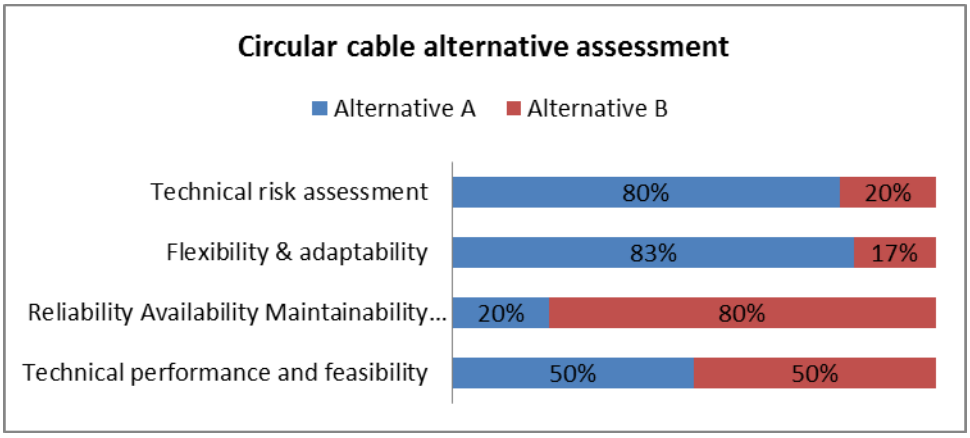


Figure 40 100%-stacked-boxplot example: four technical criteria and two alternative assessment

7.3 Conclusion

The sustainable procurement policy developed in this chapter consists of two elements: the procurement methodology and the decision support tool. In the methodology, three stages, eight phases with specific activities in each phase. Complementary quality assurance and control measures are also proposed. By following the methodology throughout the procurement process, the focus on sustainability is formally integrated in the process while regulatory compliance to European procurement guidelines is maintained. The most essential capabilities and/or steps in the policy are listed below:

- Dialogue throughout the policy exposes conflicting sustainability-related drivers of actors.
- Multiple actors participate in dialogues to conclude on procurement goals, functional needs of the solution, demands, business models, potential solutions, supplier selection and alternative assessment criteria weights and the selection of suppliers and assessment of alternatives.
- The wide range of demands are divided in categories of 'binding requirements, distinctive criteria and time-based demands'.
- Demands are ordered based on four dimensions: technical, economic, environmental and social.
- Asset material life cycle thinking is embedded deeply in the procurement process.
- Both quantitative and qualitative performances of alternatives can be assessed.
- Criteria weights are be determined transparently and rationally in collaboration with all actors involved.
- Different types of sustainable business models and alternatives can be assessed and compared.
- The uncertainty related to time-based criteria cannot be considered.
- Interdependencies between demands cannot be considered in the decision support tool.
- Motivation of weights cannot be documented automatically in decision support tool.

The most challenging elements in sustainable procurement are establishing a realistic and ambitious set of requirements and criteria, and weighting those criteria in correspondence with the organizational values and long-term corporate strategy. A collectively accepted priority in demands and subsequent weight distribution is not, by definition, the mean of all actor priorities. A criteria weight should depend on a collectively shared vision and strategy (for example, organizational goals). The weighting process therefore requires individuals who motivate and discuss individual priorities transparently to reach consensus as a group. The policy decision support tool facilitates this dialogue and establishment of consensus through documentation and visualisation of differences in values and interests among the multi-disciplinary procurement team.

Chapter 8: Sustainable procurement policy validation

The policy validation and evaluation is conducted in three steps, as shown in Figure 41. The intended added value, validity and feasibility of the proposed sustainable procurement policy is validated using two case studies: the finished procurement process of the *Fair Meter* (§8.1) and the currently ongoing procurement process of the *Circular Cable* (§8.2). The policy proposal is tested by consultation of a variety of subject matter experts within the DSO industry during workshops. In these workshops, the two legitimate procurement processes are repeated following the proposed sustainability-focussed policy, giving insights in the usability of the policy. This chapter concludes with the evaluation of the final policy by assessing the policy fitness and *compliance with the policy constraints and criteria* (§8.3).

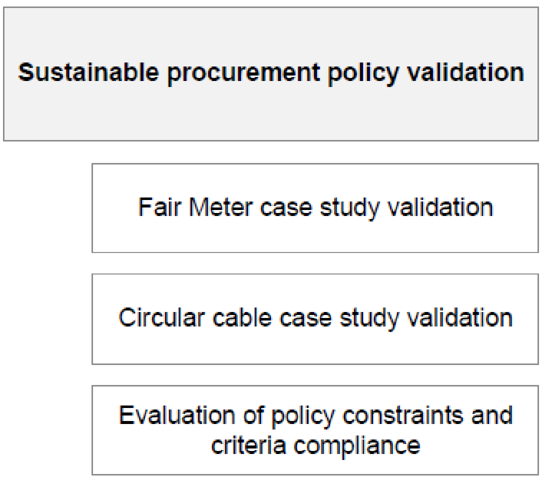


Figure 41 Content structure Chapter 8

8.1 Fair Meter case study validation

To test the theoretical policy proposal discussed in the previous chapter in practise, the Fair Meter procurement process is repeated using the developed sustainable procurement policy. Available information regarding the project goals, product demands, multi-functional team actors and general lessons learned from the procurement process are taken as case study inputs. Expert consultation is facilitated in a workshop session to discuss the feasibility of the sustainable procurement process. See §6.3 for a description of the workshop activities. The Fair Meter project is considered a pioneering project to explore sustainable procurement by Alliander and Stedin, the two DSOs collectively procuring the meter. This case study therefore has access to explicit sustainability goals, making the case highly relevant to validate the formal sustainable procurement policy proposal. The case study and validation is discussed in detail in Appendix V.

The case study is evaluated by discussing the general course of action of the procurement process, the added value of the methodology (§8.1.1) and decision support tool (§8.1.2) and by assessing the process quality management activities with regard to the case specific lessons learned (§8.1.3). Findings throughout the case study are used in the iteration process of the policy to improve on its quality.

8.1.1 General course of the Fair Meter case study

As the experts (i.e. sustainable purchaser and strategic purchaser at Alliander) involved in the case study workshop both actively took part in the procurement process of the Fair Meter, the case study workshop focussed on the lessons learned and the solutions that the sustainable procurement policy is able to offer. No dialogue-based consensus was established regarding the criteria weight distribution due to time limitations.

8.1.2 Sustainable procurement methodology and decision support tool validation

The sustainable procurement policy is capable of structurally integrating the Fair Meter sustainability principles in the procurement process by identifying the gap between sustainability views of the actors and the explicit consideration of organizational sustainability goals. The formal translation of these goals, among other procurement goals, into the multidimensional demand matrix enabled the experts involved to establish a clear overview of the complete set of demands. In the Fair Meter project, these demands translate into the Fair Meter principles with the related fair demands, and the conventional product and process demands.

The Fair Meter project stimulated different types of sustainable business models simultaneously. The decision support tool of the policy addresses and facilitated these sustainable business typologies in the alternative assessment step.

Achieving sufficient levels of consistency in pairwise comparison appears to be difficult due to conflicting, mutually exclusive and interdependent criteria. The capabilities of the decision support tool to identify and formally address these difficulties stresses the added value of the policy.

The pairwise comparison shows limited prioritization of environmental and social criteria. The weight distribution result corresponds with the profile of the experts participating in the case study, confirming its validity. It also stresses the importance of including environmental and social 'agents' and technical specialists to the criteria weighting process to complement the expert group, creating a multi-functional team that represents the diversity of corporate values of Alliander.

Alternative assessment of all criteria by multiple experts is undesirable. The assessment should be objective and therefore assessment results should not differ among experts. Expert assessments can be complementary, assigning sets of criteria to different subject matter experts to increase the validity of the assessment.

The experts concluded that the developed policy complies with regulated procedures of procurement processes.

8.1.3 Process quality management validation

The Fair meter procurement process was completed in June 2015 and evaluation of the procurement process by the two Fair Meter experts yielded 14 lessons learned, categorized in three topics. The added value of the policy with respect to the lesson is scaled by the experts in accordance with the scores in Table 15 and presented in Table 16.

Table 15 Policy relevance score definition

Score	Relevance of sustainable procurement policy
0	Capability to maintain or resolve lesson is unknown
--	Policy unable to maintain or resolve lesson learned
-	Policy likely unable to maintain or resolve lesson learned
+	Policy likely able to maintain or resolve lesson learned
++	Policy able to maintain or resolve lesson learned

Table 16 Added value of sustainable procurement policy with respect to Fair Meter lessons learned

Topic	Positive lessons learned	Score	Negative lessons learned	Score
General process quality & communication	The general procurement approach of an open and dialogue-centred process positively contributed to the end result.	++	Conflicts of interest among internal actors due to a limited level of transparency.	++
	Active communication via multiple websites (e.g. www.fairsmartmeter.com) and industry magazines contributes to external stakeholder support.	++	Dealing with both hard agreements and soft innovation freedom.	+
			Difficulties integrating the results of the supplier innovation process as a variable throughout the procurement process.	0
			Difficulties in defining the procurement process without a realistic estimate/ assessments of potential final alternative outcomes.	0
Criteria definition & weighting process	Utilizing the *best value procurement* method to execute the alternative assessment	++	Difficulties faced during the formulation of best value criteria, including the difference between ambitions and reality.	+
			Defining arrangements regarding the fair ambitions on: probability of achieving results, and the consequences if results are or are not achieved.	0
			Evaluation of environmental and social supplier indicators tends to become subjective within the selection criteria evaluation process.	++
Procurement result	Final result was very much in line with the desired result, partly due to the similar sustainability mindset of suppliers.	++	Realistic milestones for results over time are required to guide the *fair* ambition performance.	-
	Leadership role of Liander and Stedin towards the industry was essential to keep ambitions high.	++	Clear and convincing expression by Liander and Stedin regarding the binding character of (fair) agreements by suppliers to guarantee long term results.	+

8.2 Circular Cable case study validation

After the fair meter case study, a second case study validation is conducted. This case focusses on the ongoing procurement process of an electricity cable with partially circular material content. The procurement is within the strategic sourcing step of the Alliander procurement methodology. Similar to the previous case study, the available information of the procurement process are inputs. Expert consultation is facilitated in two workshop sessions to discuss the feasibility of the sustainable procurement process. One workshop with Alliander experts (a strategic purchaser, a technical policy adviser and four sustainability-related experts), and one workshop with ENEXIS experts (an asset policy expert and an innovation manager).

As with the Fair Meter case study, this case study is also evaluated by discussing the general course of action of the procurement process (§8.2.1), the added value of the methodology and decision support tool (§8.2.2) and by assessing the process quality management activities with regard to the case specific lessons learned (§8.2.3). The main findings and suggestions for the policy development iteration step are thereby described below. The case study and validation is discussed in more detail in Appendix W.

8.2.1 General course of the Circular Cable case study

The two workshop sessions combined a variety of expert inputs which represents the diverse range of goals of the actual ongoing procurement process. The limited detail of the information available due to the current procurement progress restricted the level of detail considered in the case study. However, the sustainability goals and general asset requirements proved to be sufficient to validate the policy. While the preliminary set of procurement demands is rather simple for this type of asset, the challenging aspect is the comparison of different types of business models and alternative characteristics according to regulated guidelines. By validating the policies capability to deal with this challenge, valuable insights in its added value are obtained during the case study. Due to time limitations, no consensus through dialogue is established regarding the criteria weights.

8.2.2 Sustainable procurement methodology and decision support tool validation

The step-by-step consideration of the methodology and decision support tool yielded multiple insights and stresses the added value of policy activities as well as the need for policy improvements. The results of the case study validation are covered briefly below.

In the initiation stage, the formulation of actor views on sustainability appears to be time-consuming. Views are related to the perception of feasible business cases for sustainability and thereby the deeply rooted individual and corporate differences and priorities. Many workshop participants were unable to formulate their personal view due to the wide scope and definition of sustainability. This confirms the need to discuss such terminology as ignoring different views will increase the criteria weighting process in a later stage.

Defining the procurement goals and demands from an organizational perspective resulted in a set of demands categorized in three out of four dimensions (see Table 17). Translating these demands in a more generic set of requirements and criteria (included in Appendix W) highlighted the importance of equal interpretations of requirement and criteria by different actors. This need for similar understandings stresses the need for thorough and iterative definition of demands in a group context. Another difficulty regarding the set of criteria is the interdependencies between level 2 criteria and the possibility of level 2 criteria to affect multiple level1 dimensions making pairwise comparison less straightforward than desired. These findings stress the limitations of the hierarchical structure of the AHP decision support tool. These limitations underpin the need for actor dialogue and the fact that the tool should be considered supportive rather than conclusive.

Table 17 Preliminary set of demands Circular Cable project

Sustainability dimensions	No.	Preliminary set of demands
Technical	1	Comparable or higher asset reliability and performance
Economic	2	Low life cycle costs with a minor (2% on TCO) willingness to pay for circular asset innovation
Environmental	3	High recycled material content
	4	High recyclability of material used
	5	Less material used for cable isolation
	6	Low CO_2 equivalent life cycle emissions
Social	-	No social demands set in the current stage of the procurement process

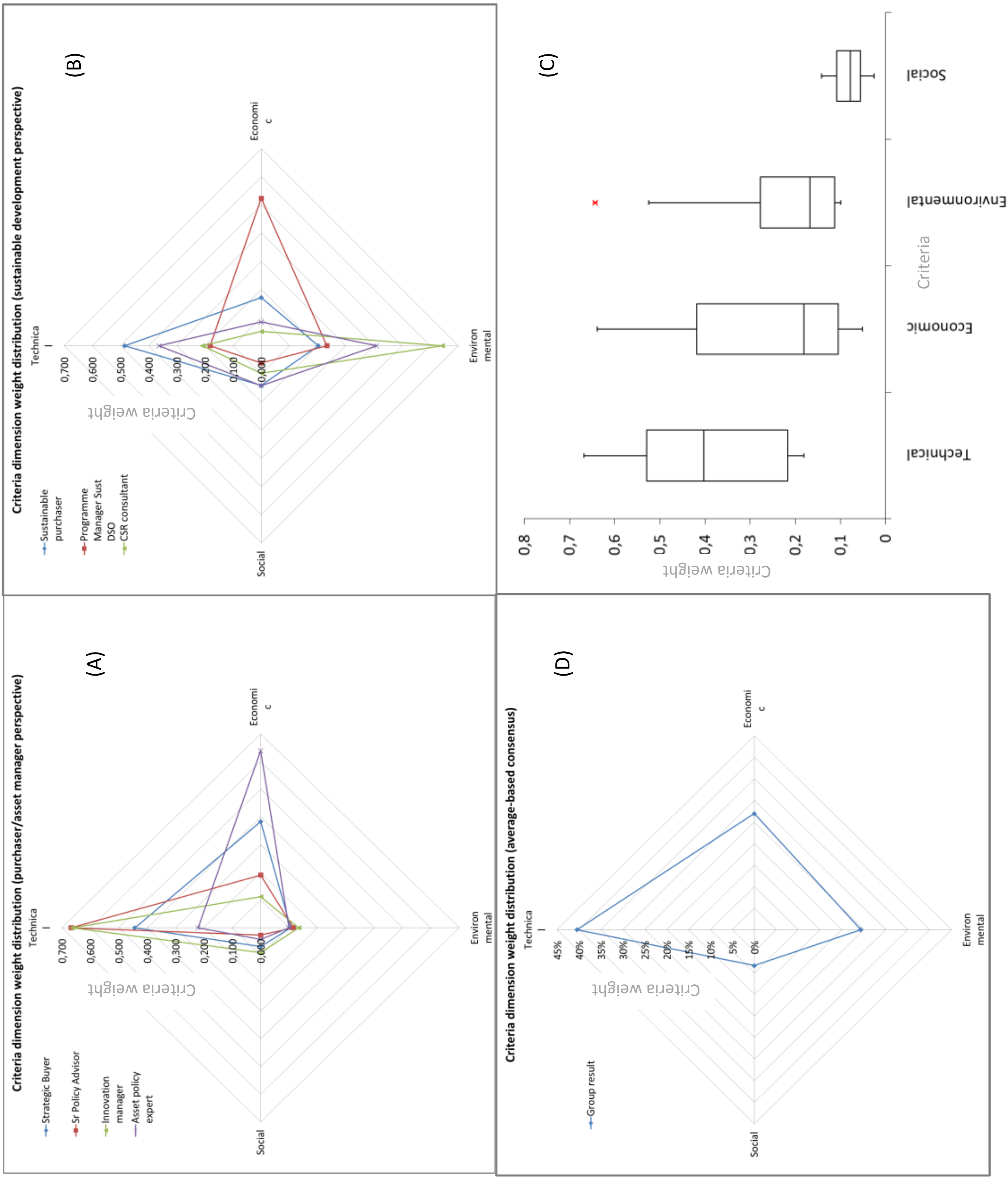
Estimation of priorities in pairwise comparison appears to be difficult due to actor's lack of knowledge. Internal actor network is not able to draw conclusions as they depend on the external actor network (i.e. asset material supply chain) for specific knowledge and information regarding the range of possible asset specifications.

While the corporate ambition to procure a more sustainable cable was clear from the assessment of functional need phase onwards, the MDT actors participating in the case study did not represent this change in procurement focus collectively in their distribution of weights (see the boxplot visualization of level 1 criteria dimensions in Figure 42-C).

Each actor prioritizes different criteria dimensions based on his or her personal preferences and drivers. Actors from each relevant discipline are required to successfully prioritize criteria in accordance with the corporate strategy. Figure 42-A and Figure 42-B confirm this need in radar plots where economic/technical and economic/environmental priorities align with the individual drivers of actors. The average-based weight distribution shows a final weight distribution that aligns better with the organizations procurement goals for the Circular Cable project. The need for dialogue-based consensus instead of average-based consensus for three out of four dimensions is illustrated by Figure 42-C, where large diversities in weight distributions are clearly visible. Taking the median weight value would only suffice for the social dimension. Similar insights on differences in criteria weight distributions are generated for level 2 criteria in Figure 43, where four criteria show negligible variations, five criteria show limited dispersion and four criteria show major spreads (i.e. tech. performance, RAMS, LCC and 6Rs). Both the average-based consensus (nine criteria) and dialogue-based consensus (four criteria) approach prove to be useful to establish a swift but commonly supported weight distribution. The policy requires the final weight distribution need to be verified using the organizations values and goals to secure acting from the perspective of the organization rather than an individual's perspective.

The assessment of the two cable alternatives in the case study was performed by a single expert as recommended in the Fair Meter case. Difficulties arose in this assessment as the assignment of AHP-conform pairwise comparison scale of 1 to 9 presented relative performances. In the alternative assessment a more quantitative approach is desired in which the performance of individual alternatives is scored. The need for detailed indicators representing the level 2 criteria becomes hereby apparent. The suggestion to transform indicator performance to performance ladders or scores, following by a relative conclusion on performance is considered for future case studies and research.

Figure 42 Visualization of multidisciplinary team priorities on demand dimensions (clockwise, starting in the upper left corner: 41-A shows the purchaser/asset manager perspective, 41-B shows the sustainability-related actor perspectives, 41-C shows the boxplots of all participants combined, 41-D shows the aggregated average-based weight distribution of all participants)



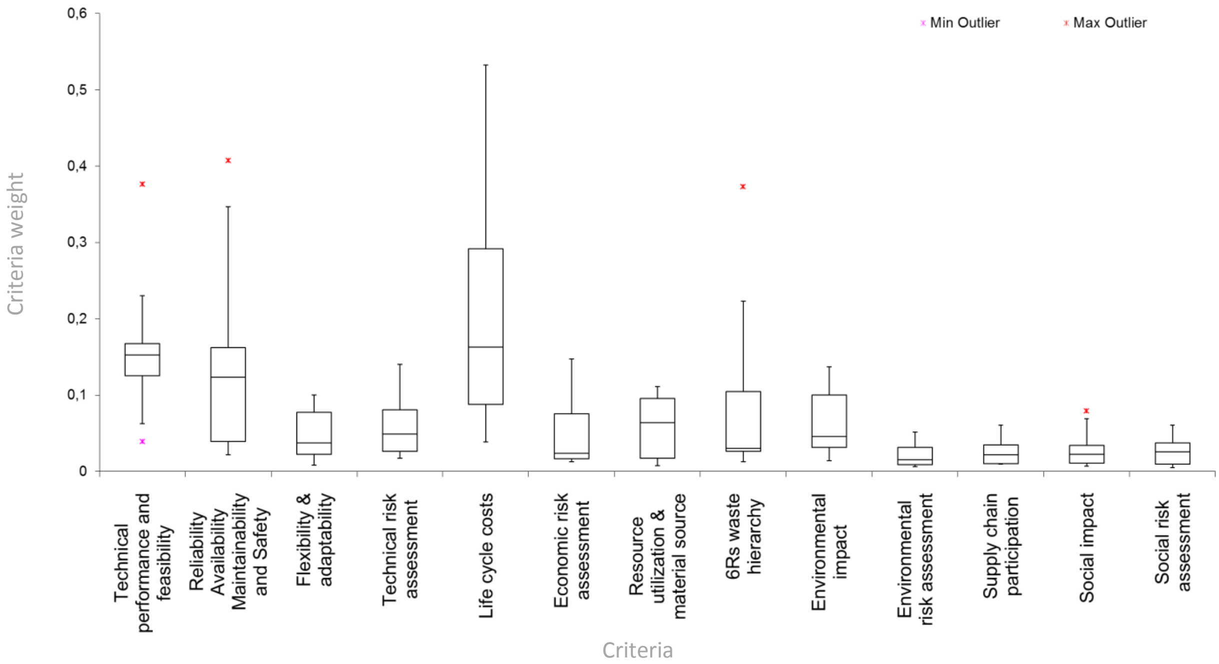


Figure 43 Visualized misalignment of the MDT participants priorities at level 2 criteria, shown in boxplots

The chosen set of criteria was able to compare both types of alternatives despite being different types (one alternative focussing on material and component reduction, while the other alternative is focussing on recycled material use). The current stage of the procurement process at Alliander did not allow an in-depth alternative comparison due to information scarcity. The general alternative assessment does however validate the proposed alternative assessment as Figure 44 shows an informative summary of alternative scores that may be a basis for an alternative selection.

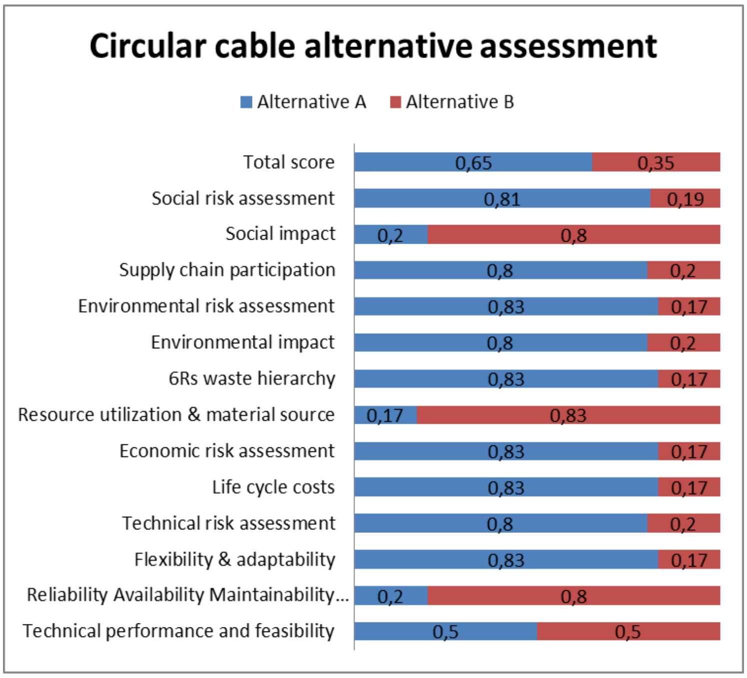


Figure 44 Visualization of the Circular Cable alternative assessment between Alternative A and B

8.2.3 Process quality management validation

The lessons learned throughout the early stage of the procurement process are presented in Table 18, and the added value of the sustainable procurement policy is validated by the experts involved in the case study in accordance with the scores in Table 15.

Table 18 Relevance of policy with respect to Circular Cable lessons learned

Topic	Positive lessons learned	Score	Negative lessons learned	Score
General process quality & communication	*Prior to the first pre-assessment step:* Transparent communication and a collaborative innovation approach stimulates the extent existing suppliers are willing to express their opinion on sustainable development.	+	Difficulties regarding the estimation of unknown future supplier mentality (preparedness and willingness to focus) on sustainability.	0
Criteria definition & weighting process			Currently experiencing difficulties with the translation of ambitions and demands to specified requirements and weighted criteria in the process steps to come, with specific difficulties regarding time-based criteria and their weights.	+
			Fear for a CAPEX costs out of proportion due lower relative weight of costs	0
Procurement result	No results yet		No results yet	

8.3 Evaluation of policy constraints and criteria compliance

After the application of the policy, an evaluation is required to determine its level of compliance with the policy development goals, constraints and criteria. The constraints and criteria around which the policy is developed are merged into Table 19. In this table the compliance with constraints is evaluated. Table 20-21 presents the policy performance on the defined criteria with a score between 1 and 5 per criterion. The policy is evaluated by the author based on the findings of the Fair Meter and Circular Cable case study and the consulted expert judgement during the cases.

Table 19 Policy evaluation form: policy constraint compliance

Constraint: policy boundary	**Compliance**
Policy development input: Sustainability in infrastructure asset procurement	
Allow for multiple interpretations of the concept of sustainable development and facilitate flexibility on terminology and sustainability-related concepts among the practitioners of the policy.	Yes
Explicit incorporation of environmental and social criteria in asset and asset material demands	Yes
Facilitate a balance between the positive impact on societies social foundation and the negative impact on the environmental ceiling.	Yes
Value judgement on different sustainable business models is subjective and priorities on business models therefore need to be based on quantitative advantages and disadvantages.	Yes
Allow the comparison of different types of alternatives and underlying (sustainable) business models	Yes
Facilitating new sustainable business models and asset material life cycle thinking within the procurement process	Yes
Prevent prohibited collaboration with individual actors as legal processes and regulations for public procurement	Yes
Consideration of both tangible and intangible multidimensional values in supplier selection and alternative assessment	Yes
Formulate asset demands based on the asset function that is needed	Yes
ISO14000 LCA compliance with general LCA bases. Recipe compliancy. Allow for 18 impact category use	Yes
Policy should be aligned with the ISO14001 environmental management system	Yes
Policy should be aligned with ISO26000 and the seven core subjects on social responsibility	Yes
Select suppliers and assess alternatives on both qualitative and quantitative performance indicators	Yes
Policy development input: Strategic DSO infrastructure asset management	
Requirements / criteria throughout the entire asset material life cycle are to be considered	Yes
Align procurement with life cycle asset management approach	Yes
Strategic decisions throughout the entire asset life-cycle need to be integrated in the procurement process	Yes
Multidimensional risks need to be assessed	Yes
Vision and strategy of procuring organization needs to guide prioritization of risk factors rather than individual opinions.	Yes
The role of each actor within the risk assessment process need to be discussed	Yes
Policy need to comply with ISO9001 and ISO55001 management systems.	Yes
Compliance with asset product/process specifications need to be secured	Yes
Policy need to comply with Procurement law and guide on proportionality, NTA8120, WON and National electricity and gas quality regulations	Yes
Policy development input: Decision-making in multi-actor networks	
Policy should facilitate, and stress the need of mutual trust, empathy and logic throughout the procurement process	Yes
Focus on a perceived win-win for all actors to secure collaboration and interdependency relations	Yes
Respect multiplism in policy activities	Yes
Facilitate the debate on individual values, conflicting interests and the organizational values	Yes
Policy development input: The current corporate context of Alliander	
Consideration of interests of Alliander and Alliander shareholders during the decision-making process	Yes
Connect sustainable procurement policy to formal SDG commitment (7, 11, 12) and other potentially relevant SDGs (3, 8, 9, 13).	Yes
Internal actor opinions and influences need to be considered throughout the policy development and validation process	Yes
Facilitation of transparent supplier selection and alternative assessment	Yes

Table 20 Policy evaluation form: policy criteria scores

Criteria: policy performance	**Score**
Policy development input: Sustainability in infrastructure asset procurement	
Recognition of all planetary boundaries desirable to prevent unsustainable trade-offs. Integrate societal impact generation with the business model of the organization.	2/5
Flexible definition of circular economy throughout the procurement process due to diversity of interpretations by different stakeholders.	5/5
Capability to evaluate business model proposals based on the generalized business model typology (and 6R principle)	4/5
Emphasize leadership role of corporate management team regarding the transition to sustainable business models in order to effectively change internal processes and external relations	3/5
Possibility to orchestrate the sustainability transition as the focal actor within the supply chain through procurement	5/5
Overcome information, bargaining and free-riding difficulties.	3/5
The barriers of lack of power, trust and collaboration need to be adressed and overcome to establish effective actor collaboration	5/5
Increase the utilization of suppliers and other external actors as information ‘resources’	4/5
Underlying problems to code of conduct requirements need to be identified and addressed in order to comply with the code of conduct.	2/5
Policy flexibility to select context dependent sustainability goals	5/5
Enlarging the solution space by shifting from precise to less precise problem formulation	4/5
Add social and environmental interests to existing (financially driven) decision-making processes by adding corresponding criteria	5/5
Prevent greenwashing by using representative scores	3/5
Effectively deliver visible results rather than promises to secure actor support over the long run through inspiring examples of sustainable procurement success stories	4/5
Policy development input: Strategic DSO infrastructure asset management	
Increase the focus on long term collaboration between supply chain actors	5/5
Transparent and objective assessment of risks	2/5
Decision-makers are identified and their preferences are assessed prior to the procurement process	5/5
Expert judgement-based risk assessment requires extensive experience and transparancy regarding worldviews, heuristics and risk perception. Acknowledge and reduce their impact on decisions	4/5
Willingness and capability of actors and decision-makers involved to change daily practises and adopt new procedures is limited. The Policy therefore needs to be as simple and straight-forward as possible	4/5
Incentivise each supplier, independent on their size and business share to respond to the tender	2/5
Different levels of asset and procedure complexities are to be expected in infrastructure asset procurement. A policy that is both a general and formal framework, with room for detailed interpretation and depth if required is needed.	5/5
Policy development input: Decision-making in multi-actor networks	
Focus on measurable input based on the negotiated knowledge principle throughout the policy	5/5
Overcoming the KPI focus of decisions is required to decide on the best interests of the organization as a whole. KPIs of the organisation determine to a large extend the investment logic of managers and thereby the costs and benefits considered.	3/5
Meet policy requirements of single and multi actor complexity	5/5
Facilitate strategic dialogues between actors	5/5
Consider actor perspectives as complementary instead of mutually exclusive	5/5
Measurable contribution towards KPIs of multiple departments simultaneously during the procurement process	5/5
Effectively facilitate and coordinate supplier collaboration in more sustainability-focussed procurement	5/5
Contribute to solving the prisoners dilemma regarding a more sustainable business operation of internal and external actor networks	1/5
Provide decision support and thereby expanding the room for dialogues and consensus building	5/5

Table 21 Policy evaluation form: policy criteria scores (continued)

Criteria: policy performance	Score
Policy development input: The current corporate context of Alliander	
Establish clear relations between procurement criteria and specific SDG impact progress document and monitor progress	4/5
Mitigation of internal and external actor power abuse in procurement process	4/5
Lack of knowledge regarding selection and assessment topics at individual actor and/or multi-dimensional procurement team need to be mitigated	4/5
Alignment of policy with existing Alliander procurement methodology	5/5
Acknowledge and integrate current activities and processes that aim at sustainability in daily operation (ALCM, LCC, material and resource passport, CO2, circulariteit)	4/5

It can be concluded based on the compliance with all constraints that the policy is an acceptable alternative to the current Alliander procurement methodology. The criteria scores show a variety of scores, implying that the policy is not yet performing 100% on all selected criteria. A more in-depth evaluation on policy strength, weaknesses opportunities and threats based on additional case studies of different procurement processes, and preferably also different organizations) is desirable.

The expected increase of decision-making quality has been realized through three focal points throughout the policy:

- Effectiveness and efficiency: the systematic follow-up of activities aim to reach consensus among actors involved in the decision-making process. These activities thereby lead to a more effective procurement process as the adaptations counter set-backs due to unforeseen blocking forces of stakeholders. The efficiency of the procurement policy is directly dependent on the individual capabilities, experience and willingness of the actors involved, to participate in collaborative decision-making. Case study results gave limited insight in the effectiveness and efficiency of the policy, mainly due to the limited depth of both cases (which was due to available time constraints). The potential added value of both the policy were recognized in the case studies.
- User satisfaction: policy practitioners may be less satisfied with the process due to increased complexity: the policy requires openness and willingness to collaborate, which requires effort from each actor, and more time is invested in the definition of the (functional) problem and the requirements/criteria of the required solution. It can, however, be assumed that this process results in an outcome that satisfies actors involved more than the existing policy due to the extensive formulation of needs and demands, the opportunity to create a participatory win-win outcome for each actor, and the transparent and logic-based alternative evaluation activities.
- Consolidation by authoritative selection: the policy is designed to enable decision-making based on all potential solutions to a functional problem. Actors involved should therefore be able to introduce all alternatives that are potential solutions to the problem and select the most suitable solution through logic-based decision-making. The policy thereby aims to stimulates authoritative selection.

Additional insights in the robustness and added value of the policy are also obtained by evaluating the development methodology of the policy, and thereby the research methodology followed throughout this report. The next paragraph discusses this research methodology into more detail.

Chapter 9: Conclusions and recommendations

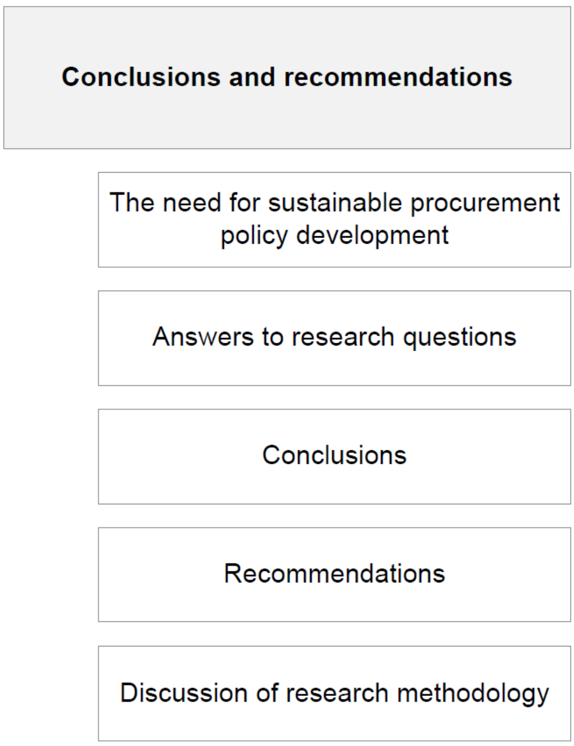


Figure 45 Content structure Chapter 9

In the concluding chapter of this report covers five conclusive subjects (see Figure 45): The need for the developed sustainable procurement policy is stressed (§9.1) prior to the presented answers to the six sub research questions (§9.2). The answers to these questions lead to the conclusive answer to the main research question (§9.3), followed by academic and industrial recommendations (§9.4). The discussion of the research methodology followed concludes this report (§9.5).

9.1 The need for sustainable procurement policy development

The need for more sustainability-focussed decisions, both small and large, is becoming apparent as worldwide climatic changes, rapid demographic developments, resources and material scarcity, negative ecological and social impacts, and growing waste piles are recognized. The possibilities to start acting more sustainably in the electricity and gas distribution infrastructure are significantly as large amounts of material intensive assets are purchased from large global supply chain networks and used for 20-80 years. Procure assets with sustainability-focussed demands thus offers the opportunity for distribution system operators (DSOs) to take their social responsibility and add environmental and social demands to the technical and economic demands in the procurement process.

Alliander, a major Dutch DSO, is taking a leading role in the Dutch infrastructure industry by setting ambitious sustainability goals, with an explicit focus on sustainable procurement. To meet these goals, the current procurement policy and decision-making guidelines is unable to effectively integrate environmental and social demands in the process. The need for a sustainable procurement policy is thereby introduced. The challenge of developing this sustainability procurement policy lies in the need for a decision-making process where multiple actors from different disciplines and with diverging priorities, interests, and levels of knowledge are collaborating throughout the procurement process. The challenge in solving this problem thus becomes the incorporation of the lack of consensus on value and knowledge between the individuals involved in the decision-making process and to develop a policy that enables actors to act from the organizations point of view while making procurement decisions.

Recent scientific literature also emphasises the great need of developing and testing sustainable assessment and sustainable procurement theories in practise, rather than adding new theoretical frameworks and ideas to the abundant amount of theory (Hoejmose & Adrien-Kirby, 2012). In addition to this need for applied theories and policy making, Komonen, Kortelainen, & Räikkönen (2012) describe the growing need in literature to connect asset management research to its business environment. The awareness of interactions between technology and the global supplier market as well as the emerging sustainable business models and long-term asset strategies is growing (De Bakker et al., 2005; Komonen et al., 2012). These topics come together in the research discipline of sustainable procurement.

This research contributes to both the industrial needs and scientific needs by aligning five major research areas in one policy: sustainable development, asset life cycle management, multi-actor networks, multi-criteria decision analysis and sustainable procurement. By putting the existing theory into practise through the systematically developed sustainable procurement policy discussed in this report, two major contributions are made: Firstly, the alignment and complementary role of the different theoretical knowledge areas is stressed and an attempt to combine the state-of-the-art literature of each area is made; Secondly, existing decision frameworks are put into practise and insights are obtained how sustainability assessment theory can be utilized by the industry.

The subsequent paragraphs provide the conclusive answers to the sub research questions as well as the main question. Recommendations and a brief discussion on the research methodology applied throughout this research conclude this thesis research.

9.2 Answers to research questions

The six sub research questions are answered in this section of the report. Each answer is first briefly summarized and followed by a more extensive conclusion.

A. *What is the state-of-the-art of academic literature of successful sustainable public procurement and associated research areas?*

The extent to which sustainability goals can be achieved through asset procurement largely depends on: (A) the explicit formulation and fitness of procurement objective with the core business objectives of the organization, (B) the acknowledgement of environmental and social added value in addition to technical and economic drivers, and (C) an appropriate scope and level of detail of sustainability principles, criteria and indicators that are utilized in the procurement process to set realistic and visible goals and stimulate sustainable business models in the supply chain.

A review of current literature on sustainable development, the circular economy concept, sustainable and circular business models, supply-chain management, sustainable procurement, and sustainability measurement and assessment provided insights in the complexity and diversity of relevant research areas when discussing sustainable procurement. Recent literature on sustainable development (SD) is shifting towards a holistic approach in which systems thinking enlarges the range of research areas considered in literature reviews. This expansion leads to a complex, diverse and still maturing literature base.

Literature proposes to integrate sustainable development thinking in the core activities of organizations to maximize the positive impact an organization is able to make towards society and the biosphere. Sustainability is often considered a triple bottom line of economic, environmental and social sustainability along which positive and negative sustainable impacts can be structured.

As each organization and individual is able to develop sustainably in its own way, a holistic view on sustainable development is required to which each actor can connect. Two models are considered that can function as sustainable development compasses: the Doughnut Economics model by Kate Raworth, which neatly describes the general and primal needs of our global society as well as the (environmental) limitations that need to be considered, and the 17 United Nations Sustainable Development Goals (SDGs) that translates these needs into a set of goals the global society can work towards to make the world a better and habitable place. By considering overarching concepts of sustainable development, individuals as well as organizations can set goals that service a higher goal of sustainable development of which not (only) the individual or organization benefits, but society and the biosphere as a whole.

The Circular Economy (CE) paradigm translates environmentally responsible physical product development into feasible business models and is rapidly finding traction in academics and society. The added value of the CE in procurement is its view of assets being materials with a temporary function rather than a product with a finite lifetime. Five general types of business models are defined: Dematerialization, dispossession, prolong lifetime, optimize functionality, and circularity & material loops. By exploring sustainable business models in asset procurement and expanding the concept of added value creation from techno-economic values with environmental and social values, a more diverse and progressive light is shed on the interpretation of what a feasible business model entails.

Sustainability factors often address topics throughout the total supply chain of the asset. Herewith, the scope of sustainability in procurement should include the total asset material life cycle.

The enlarged scope of relevant factors increases the complexity of procurement decision-making significantly. Procurement decisions become a complex equation in which monetary values, technical performance, environmental burden and social acceptance all need to be considered over a long and uncertain timeframe. A clear and urgent need for practical and systematic support in such complex decisions is addressed in literature and many scholars, public and corporate researchers are currently developing methods to facilitate decision-making processes in which sustainable development is considered.

Deciding on the most sustainable alternative in capital asset management results in the materialization of sustainable business models. Such business models may not be perceived desirable from conventional (non-holistic sustainable) point of view. A wide range of authors stress the importance of stubborn organizational leadership to overcome the aversion to change and inspire actors involved in the decision process, or actors affected by the decision. While top-down leadership, stimulation and the approval to explore sustainable business models is crucial, it is bottom-up culture change that is responsible for long-lasting changes to a more sustainable business operation. This culture change requires specific sustainability goals and tangible results in order to be rewarding and thereby long-lasting for individual actors.

Sustainable procurement should therefore focus on 'what (multidimensional) goals can be met realistically through the purchase of one alternative over the other?' to prevent decisions that aim for ideological goals with intangible or unclear results. Collaboration and transparent communication with relevant internal and external actors becomes essential in order to set up an ambitious yet realistic set of asset demands. These demands need to be based on static sustainability principles and consist of measurable asset material life cycle criteria and indicators to enable the procuring organization to compare multiple different types of alternatives in the procurement process. While multi-criteria decision methods allow the comparison of a wide range of alternatives through common assessment criteria, these methods do not provide undisputable answers to which alternative is best due to the large amount of expert knowledge and value-based judgements involved. Each type may yield a desirable (reduction in) impact which makes comparing these different types a difficult and subjective process based on expert value judgement. Assessing the alternatives available during the procurement process to select the most desirable solution has become significantly more difficult by adding environmental and social sustainability demands.

B. How do DSO asset life cycle management and multi-actor decision-making relate to sustainable procurement?

With an increased recognition of technical, economic, environmental and social factors, the scope of the asset life cycle needs to expand to the life cycle of asset materials to acknowledge causal relations between multidimensional demands. Decisions that relate to the asset design, raw material, and end-of-use also become relevant within the procurement phase. The focus on an asset's function rather than its operational specifications is required to allow sustainable and innovative alternatives in procurement. The inclusion of multidimensional demands impacts decision-making with multiple actors as individuals value and prioritize demands differently, depending on their disciplinary background and personal interests. Establishing unanimous consensus is therefore essential to put the interests of the organization above those of individual actors.

Sustainability-focussed DSO asset procurement is considered a group decision process with the purpose of purchasing the most useful asset. Both asset life cycle management and multi-actor decision-making need to be discussed to understand the context and complications of procurement:

Infrastructure asset management

The public dependency on electricity and gas supply places great emphasis on technical performance of assets. Therefore, the DSO infrastructure sector is regulated, risk-averse and performance-oriented. Asset reliability and continuous improvement of services provided are considered a priority within the sector. Both for customers and employees, operational safety is incontestable. Enlarging the concepts of direct operational safety and performance by considering indirect environmental and social dimensions increases the complexity of asset management decisions. As the short and long term impacts of asset procurement can be rooted in multiple disciplines, extensive attention needs to be payed to identifying these impacts in an early stage to make well-informed decisions. Consequently, the knowledge areas relevant to investment decisions become more diverse as multidimensional added value is considered. As DSO assets have useful lifetimes of 20 to 80 years, procurement decisions have an inevitable strategic nature with long term consequences on both the direct and indirect environment of the asset. In essence, procurement decisions should thus be made from a multidimensional asset material life cycle 'systems thinking' perspective to prevent the omitting of potentially relevant information.

A clear and detailed description of the functional demand of the solution to be procured is crucial to stimulate and ultimately procure an alternative that complies best with the predefined needs. Formulation of a functional need and sustainable demands often leads to the development of innovative alternatives by the supplier market. Adopting sustainable innovations within the DSO industry may encounter resistance because of the extensive regulations and safety culture.

In the DSO sector, (sustainable or circular) innovations, business models and business cases are developed and tested by merging knowledge and skills from multiple supply chain actors as the required information is multidisciplinary and dispersed. Purchasing a more sustainable asset from suppliers first requires those suppliers to be incentivised to develop such an asset. The dialogue with the supply chain market on realistic innovations and improvements in an early stage of the asset life cycle (the acquisition phase) is crucial to be able to make asset management more sustainable while simultaneously comply with the safety and performance demands and the need to be financially feasible on the long term. Collaboration and dialogue between the actors that will collect the asset material and produce the asset and the actors that will be using the asset is a vital ingredient for DSO asset procurement as is discussed below in more detail.

Socio-organizational complexity: multi-actor decision-making

DSO procurement requires collaborative and strategic decision-making as multiple actors are involved in the process, all with their individual (hidden) agendas. Making a successful decision needs both a successful process and a successful result. The quality of the process determines to a large extend the willingness of actors to maintain their collaboration and/or to work together in the future. The quality of the end result is the visible and measurable output that should fulfil the need(s) of the organization's clients.

Two groups of actors need to collaborate in the procurement process: External (inter-organizational) actors and internal (intra-organization) actors. The external actors has an outward orientation and comprises of actors related to the asset material supply chain. The DSO is the focal actor in this hierarchically structured actor group. The internal actors have an internal orientation and *refers to the multi-disciplinary procurement team (MDT) as well as other relevant actors within the organization. The internal actors are interdependent on each other's knowledge, expertise and approval due to the consensus-based culture within Dutch DSO organizations. There is, however, also a hierarchical order in the network, making managerial actors (and their priorities) more powerful.*

The variety of activities and responsibilities in the supply chain and the MDT causes knowledge dispersion and unequal resource and power distribution throughout the networks. This requires different corporations, departments and individuals to collaborate throughout the procurement process in order to enable (or limit) product and service innovations and therewith the transition to a more sustainable and more circular operation of the DSO. However, interdependencies between actors also enables them to act strategically to maximize personal gains that align with their own interests (e.g. personal key performance indicators used in yearly reports of the organization). Simultaneously, actors are aiming to behave transparently to build mutual trust and thereby maintain long term business relations. It can be concluded that both actor networks influence the acceptability of the business case for sustainability in procurement and that the procuring organization, or an individual within this organization, is unable to act sustainably on their own.

Collaboration to achieve collective gains for ´the greater good of a more sustainable future of society' requires abandoning personal interests and put more focus on the person-independent corporate and societal gains. However, negotiations and decision-making in both the internal and external actor arena also need to yield perceived win-win outcomes of decisions for each individual actor to maintain and stimulate the willingness for long-term and effective collaboration. The combination of individual and collective objectives stresses the importance of transparent documentation and substantiated motivation of individual priorities and opinions of actors to distinguish personal gains from the organizational and collective gains. Dialogue to establish group consensus before decisions are made is thereby crucial. The exchange of discipline-specific knowledge, transparent communication, and collective gains are three crucial factors in this dialogue.

Introducing sustainability-related demands to the asset procurement process increases the complexity of such value-based topics significantly. The difficulties of establishing a robust and unanimous consensus should therefore not be underestimated.

C. What are Alliander's current sustainable asset life cycle management goals, sustainable procurement practises and actors involved?

As Alliander owns a large amount of capital assets, the organization's potential to reduce negative impacts on the biosphere and society are also large. Alliander focusses on three sustainability-related objectives that align with the core values of a DSO: reduce CO_2 emissions, increase circular procured assets and increase supply chain transparency regarding environmental and social impacts of assets. To obtain these goals, visible and committed leadership is required from the three most powerful actors in the actor networks: Alliander's shareholders, the Dutch government and the corporate management team of Alliander.

Successful sustainable procurement requires a specified focus of the procuring organization within the wide spectrum of sustainable development to make visible and tangible contributions. The focus of Alliander's core business is to offer reliable, accessible and affordable performance of their electricity and gas distribution assets. Complementary to these techno-economic drivers, environmental and social goals are selected and defined based on three UN Sustainable Development Goals (SDG 7, 11 and 12).

These high-level and holistic goals translate in the following focal points:

1. *Reduce CO2 emission to become a CO2 neutral organization*
2. *Increase the quantity of circular procured assets*
3. *Increase supply chain transparency regarding environmental and social impacts of assets*

Progress towards these sustainability-related goals is made through multiple measures, including the adoption of best-value procurement, introducing environmental and social asset or supplier demands and requiring a mandatory bills of material for future asset purchases. These measures are introducing asset material life cycle thinking and sustainability within Alliander's procurement practises. Both topics are, however, not structurally integrated in the procurement process yet as the required culture change and decision-making processes with collective gain objectives requires a more thorough and fundamental organizational and motivational change of priorities.

Structural integration of sustainability in procurement and asset management in general needs te support of a multitude of external and internal actors. The most powerful actors in the networks are: Alliander's shareholders, the Dutch government and the corporate management team of Alliander. The visible support, leadership and intrinsic motivation of these actors is vital to more sustainable procurement in an industry dominated by deeply rooted customs and extensive technical and economic regulations.

D. What steps can be taken to develop an effective sustainable procurement policy for infrastructure asset operators, and for Alliander specifically?

The methodological steps to develop a robust sustainable procurement policy that is of added value to Alliander and contributes to the scientific developments regarding sustainable procurement are both theoretical and empirical methods applied throughout four policy analysis procedures of Dunn (1994) and Van de Riet (2003). Firstly, the problems encountered when integrating sustainability in procurement are explored through literature research, expert interviews and an actor analysis. Secondly, the policy is developed by merging theoretical decisions frameworks and policy inputs from the first procedure. Thirdly, policy validation through two case study applications is conducted which enabled multiple iteration rounds to improve the developed policy. Lastly, the policy is evaluated using the policy constraints and criteria inputs and expert consultation. By using theoretical and empirical methods complementary, the conducted research is able to generate practical insights as well as theoretical added value simultaneously.

E. What sustainable procurement policy allows for a sustainability-focussed procurement process within the DSO infrastructure industry?

The sustainable procurement policy described in this report consists of eight procurement phases and a set of activities per phase (Figure 46 below illustrates this methodology). The policy focusses on utilizing successful actor collaboration to combine knowledge from multiple disciplines throughout the procurement process. Key elements in this policy are:

- The multidimensional systems view on sustainability, asset function and utilization, and the consideration of the complete asset material supply chain
- Expansion of the perceived added value concept from technical and economic values to equally important environmental and social values

- Formulation of a multidimensional set of representative demands for both the tendering suppliers and the total asset material life cycle of the alternatives tendered
- Iteration between solution capabilities of the market and the functional demands demanded
- Make the subjective value-based weighting process transparent and documented to gain insights in decision-maker priority differences, which leads to:
  - Establishing unanimous consensus in decisions with diverging actor priorities to put the interests of the organization above those of individual actors, and to make long-term actor collaboration possible.
  - Limiting actor dialogue to major differences in actor priorities rather than discussing numerous minor or non-existent differences.
- Assess and compare different types of alternatives using a single set of hierarchic criteria

The sustainable procurement policy methodology and decision support tool can be operationalized without formal changes to the current Alliander procurement process as it is designed considering the European regulatory guidelines on procurement.

F. To what extend is the sustainable procurement policy able to successfully integrate sustainable asset material life cycle management in the procurement process?

The policy methodology and decision support tool comply with all the identified constraints. Both the procurement methodology and the decision support tool follow a systematic sequence of activities. The level of successful application therefore depends on the ability of actors involved in the process to apply systems thinking, focus on collective gains, apply the AHP method and manage the procurement process quality throughout these activities. Despite the importance of addressing causal relations between multidimensional demands, the policy is unable to formally address interdependencies between demands due to the hierarchical structure of asset procurement criteria throughout the policy.

The proposed policy methodology and decision support tool offer a structured procurement procedure that makes the consistent and transparent integration of sustainable asset material life cycle management goals in the procurement process possible. The level of success depends on the ability of actors involved in the process to apply systems thinking, focus on collective gains, apply the AHP method and manage the procurement process quality.

The policy methodology and decision support tool comply with regulatory constraints and both follow a systematic set of activities. The scope (e.g. time horizon, tiers of actors involved, invested monetary capital, invested other resources), set of goals and set of demands will differ for each product or service procured. The policy is developed such, that both simple (routine purchases with few actors involved and negligible conflicts of interest) and complex (innovative purchases with many actors and conflicting interests) procurement processes can utilize the policy.

Dialogue-based consensus is a core element of the policy and requires the intrinsic desire to collaborate and establish trust despite individual incentives to act strategically. This dependence on personal commitment is thereby no formal integration of sustainability in procurement and therefore offers no guarantee for successful sustainable procurement processes and results. Another undesirable property of the policy is its disability to formally deal with interdependencies between demands due to the hierarchical structure of asset procurement criteria throughout the policy.

9.3 Conclusions

In this research a sustainable procurement policy was developed to enable Dutch infrastructure operators and the distribution system operator (DSO) Alliander in particular. This policy was developed to incorporate the triple bottom line of economic, environmental and social sustainability in their technology-based asset management activities. The main research question addressed the need to determine how sustainability can be integrated effectively in an asset purchasing process:

How can sustainability goals be incorporated in the multi-actor decision-making process of infrastructure asset procurement by Dutch distribution system operator Alliander?

Alliander has the potential to significantly contribute to a more sustainable and circular (Dutch) society as this organization uses large amounts of finite resources in their capital assets. Alliander also has large investment capabilities being a public organization. In addition, the large supply chain network offers the opportunity to improve the social sustainability (e.g. labour conditions) throughout the supply chain. While the procurement policy is developed for Alliander, the policy may also be applicable to other infrastructure operators.

The procurement process, and the purchasing decision of assets in particular, determines to a large extend the (strategic) course of the asset's life cycle. The procurement decision is therefore capable of setting out a more sustainable course in asset management.

Prior to discussing the sustainable procurement policy, the pre-requisites for the policy to be successful and accepted within Alliander need to be understood. Effective sustainability-focussed procurement goes beyond the procedural adoption of a sustainable procurement policy. Organizational leadership, formal integration, systems thinking and the willingness of actors are critical success factors for the policy:

- Visible commitment and leadership of influential (high power and high interest) actors
- Formal integration of sustainability within the organizations processes
- Apply systems thinking: Recognize and acknowledge interdisciplinary interactions and causal relationships throughout the asset material life cycle
- Willingness of actors involved in the procurement process to collaborate and strive for collective and organizational goals rather than individual priorities

The developed policy consists of a procurement methodology with eight phases and a decision support tool to operationalize this methodology (see Figure 46 below). The policy objective is to facilitate actor dialogues to reach consensus on procurement goals, scope, demands and criteria weight distributions.

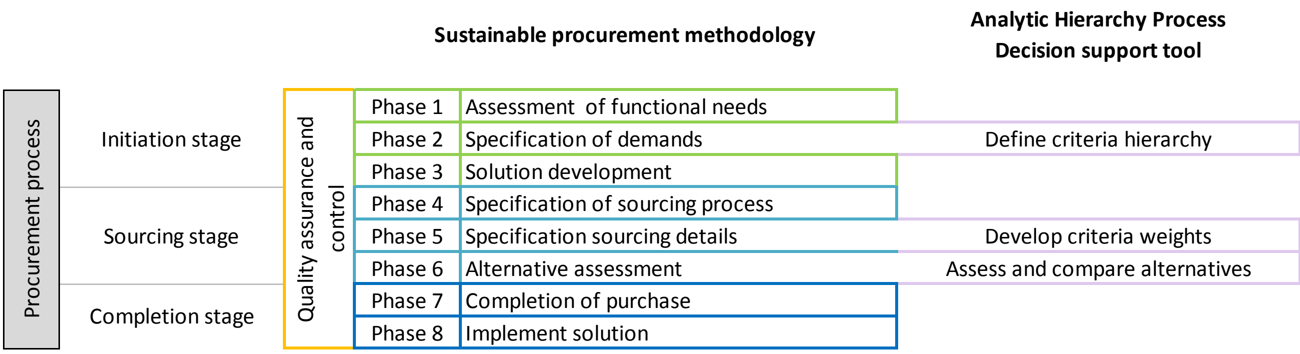


Figure 46 Sustainable procurement policy overview

Applying the policy in corporate infrastructure investment practices assist in overcoming decision challenges by structural communication, documentation and visualization of actor interests and utilizing multidisciplinary expert judgement.

The policy comprises of 33 sequential activities. The most fundamental elements of the policy are discussed below. The proposed set of means enables decision-makers to incorporate sustainability goals in the decision-making process of DSO asset procurement effectively:

Phase 1: Collective formulation of goals and asset function
Collective determination and explicit formulation of procurement goals and the required asset function with a multi-disciplinary procurement team.

Phase 2:Multidimensional demands throughout the asset material life cycle scope
Procurement requirements and criteria need to cover the full asset material life cycle rather than the asset life-cycle, and can have a technical, economic, environmental or social dimension. The set of requirements and criteria needs to represent the corporate values and sustainability principles.

Phase 2 and 5: Expand the concept of added value creation
Integrating demands regarding environmental sustainability and social sustainability to the existing technical characteristics and economical sustainability demands of an asset by expanding the concept of added value creation in the core values of the organization rather than considering environmental and social sustainability less valuable.

Phase 5: Reaching consensus on procurement demand priorities
The combination of multi-actor decision-making and the set of multidimensional procurement demands lead to (conflicting) interests, objectives and value judgements among actors. Establishing unanimous consensus is vital effective actor collaboration. Consensus is reached by following a structured and logic-based decision-making approach: Actor-specific value judgements, drivers and priorities are made explicit by transparent documentation and visualization of individual criteria weight distributions. The differences between individual and group priorities regarding asset demands hereby become clear. The actor dialogue can thereby be limited to major differences in actor priorities rather than discussing numerous minor or non-existent differences. The starting point for each dialogue needs to be the mutual organizational procurement goals rather than the personal priorities of the actors.

Adopting the sustainable procurement policy increases the quality and swiftness of the decision-making process and thereby increases the overall success rate of the procurement process. The alignment with the current Alliander Procurement Methodology and the regulatory compliance of the policy enables Alliander to formally integrate the developed policy in its daily operation. The general systemic characteristics of both the policy methodology and the decision support tool also allow infrastructure operators in different industries to adopt the policy.

The alignment of the scientific knowledge areas of sustainable development, asset life cycle management, multi-actor networks, multi-criteria decision analysis and sustainable procurement resulted in a policy proposal deeply rooted in state-of-the-art scientific literature. And the development of the policy provided insights in the complementary role these areas have when discussing the interdisciplinary topic of sustainable procurement in the Dutch electricity and gas distribution infrastructure asset management context.

9.4 Recommendations

Recommendations for future work are made towards academics (§9.4.1) and the industry (§9.4.2).

9.4.1 Recommendations to academics

To continue the development of scientific research on sustainability in procurement, and in infrastructure assets explicitly, the following recommendations are made:

- **Sustainable procurement as a multi-actor decision problem**
  The incorporation of environmental and social demands in procurement requires a different view on procurement due to value-based actor incentives and the required group collaboration. It is recommended to conduct research on procurement from a multi-actor decision problem point of view rather than take a rational multi-criteria decision approach.
- **Asset life cycle management and life cycle sustainability assessment**
  Decision-making in the capital asset procurement process largely depends on information from the asset life cycle management (ALCM) and life cycle sustainability assessment (LCSA) bodies of knowledge. In order to counteract the dissemination of knowledge areas, research into the role of LCSA within ALCM is desirable.
- **Sustainable and circular business models for infrastructure assets**
  Research is required on sustainable and circular business models for long lifetime capital assets to complement the currently emerging business models for short lifetime consumer products within circular economy literature.
- **Formulate demand of asset function**
  To stimulate the focus on, and acceptability of, functional performance rather than asset specifications during procurement, it is recommended to conduct additional research on the formulation and specification of functional demands and functional units of DSO infrastructure assets.
- **Integrate uncertainty and sensitivity analysis**
  An increased focus on sustainability demands leads to the inclusion of lower quality and quantity of information on which decisions are made. The formal integration of uncertainty and sensitivity analysis in sustainable procurement process activities is therefore strongly recommended to recognize the (in)accuracy of data, expert judgement estimations and methods of obtaining information. The role sensitivity analysis may have in criteria weighting process may also be explored, as sensitivity analysis may enable the procurer to determine which demands impact the decision process significantly, and which are less important.
- **Considering interdependencies between variables in asset procurement decision-making**
  The interdependencies between decision objectives and procurement demands remained underexposed in this research. Making the 'most sustainable' decisions is highly context dependent. A more matured understand of the interdependencies between infrastructure asset characteristics, their life limiting factors, and the current and future societal needs of the assets is desirable. Future research regarding the effective consideration of interdependencies and feedback loops is required to gain insight into the causal relations and hereby the actual complexity of sustainable procurement as a multi-criteria decision analysis process. The integration of the Analytic Network Process as a substitution for the Analytic Hierarchy Process in the decision support tool is recommended to address criteria interdependencies.

9.4.2 Recommendations to the industry

The following recommendations are made to implement the policy at Alliander:

- **Taking the lead: adopt sustainability within the core values of the organization**
  It is recommended to include environmental and social sustainability in the corporate perception of corporate 'added value creation'. Thereby, sustainability can be integrated into the core of business strategies and decision drivers, in addition to the currently dictating technical and economic values in decision-making. Doing so requires a strong, convincing and long lasting leadership role regarding the structural integration of sustainability in procurement processes by powerful Alliander actors and with the support of external supply chain actors.
- **Iterative and open dialogue among multidimensional experts**
  Enlarging the scope of procurement demands from the asset life cycle to the life cycle of materials is recommended to integrate environmental and social demands that often lie outside the asset life cycle scope. To enable systems thinking and the consideration of multidisciplinary factors and actors constructively, continuous, open and constructive dialogue among experts is recommended to share knowledge to achieve organizational goals rather than individual goals.
- **Collaborating with the supply chain**
  Trustworthy collaboration with supply chain actors is required to make multidimensional sustainability values 'business-as-usual'. Constructive dialogues with supply chain actors is therefore recommended to explore the mutual opportunities and threats of sustainability in DSO asset management and thereby set realistic expectations and define achievable ambitions for he asset supply chains.
- **Collective adoption of sustainable procurement by the infrastructure industry**
  To overcome passive actor network attitudes regarding the commitment to sustainable procurement, collectively adopting sustainable procurement in the DSO sector and the infrastructure sector in general is recommended to demonstrate the commitment of infrastructure operators rather than the single actor pioneering of Alliander. Asset suppliers and regulatory authorities may only willingly collaborate when large scale adoption of sustainability in procurement is taking place.
- **Adoption of multi-criteria decision analysis methods in daily operation**
  Knowledge and skills are required to work with MCDA methods and an investment in the competences of the procurement department actors is recommended to effectively utilize MCDA methods to their fullest potential.
- **Additional case studies to explore policy suitability**
  Conducting additional case studies are recommended to determine the suitability and added value of the policy for types and levels of complexity of procurement processes, to determine when the policy improves the effectiveness of the process and when the policy makes the process undesirably more complex and difficult. Specific attention needs to be paid to the effectiveness of dialogue-centred activities.

9.5 Discussion of research methodology

As a closure of the conducted research, the research methodology followed is discussed: the strengths, weaknesses and complementarity of the methods is elaborated on to conclude on the fitness of the research methodology. The added value, robustness and contribution of the findings throughout this report finally comes down to a well-designed and structured research design and execution. Therefore, a critical discussion of the general procurement development methodology in §9.5.1 and each of the four procurement development procedures in §9.5.2-9.5.5 is of importance to conclude on the validity of the sustainable procurement policy from an academic research point of view.

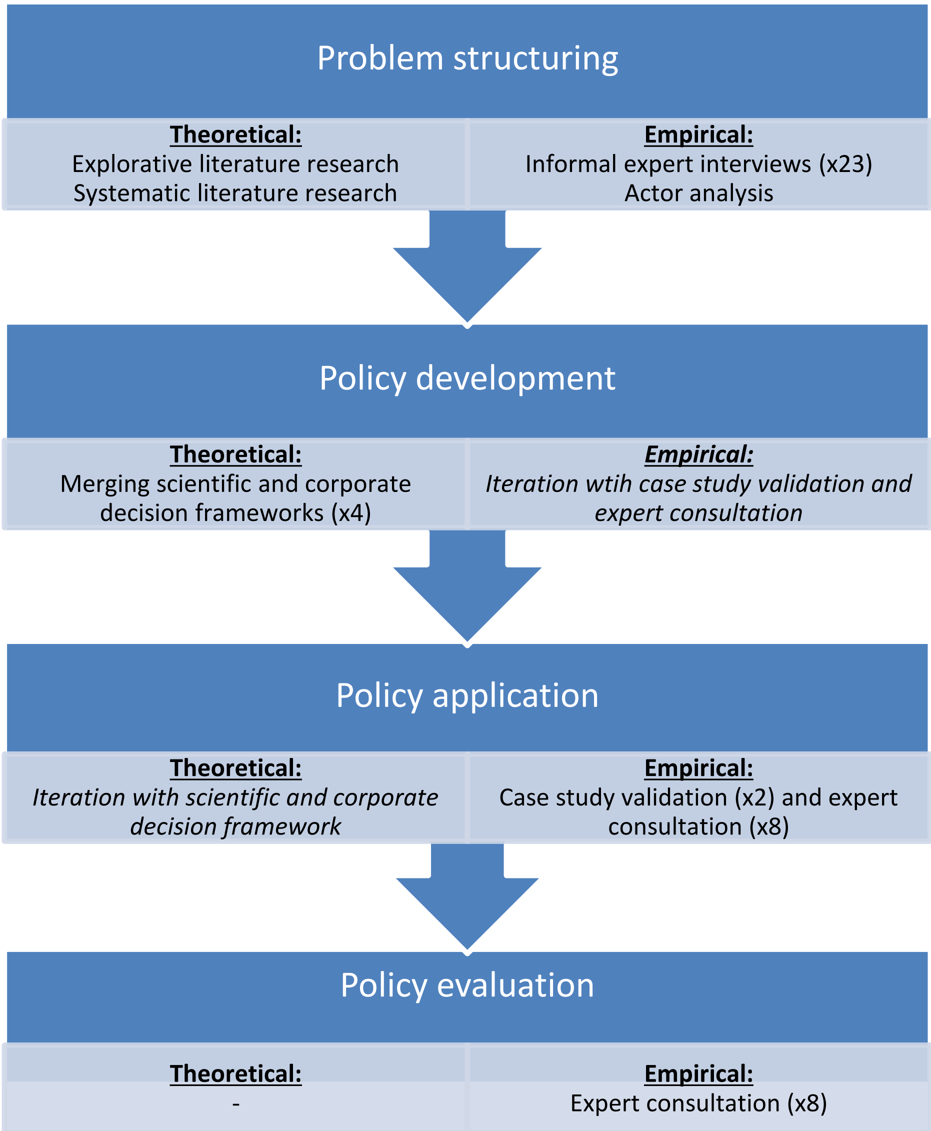


Figure 47 Research methodology overview

9.5.1 General procurement development methodology

Following the methodological steps of the policy analysis topology of Dunn (1994) and Van de Riet (2003), as discussed in Chapter 1, provided clear guidance in the policy development process. However, as the strength of this policy analysis methodology lies in the development and comparison of multiple different policies, and to ultimately select the most appropriate policy. As only one policy is developed in this research, this strength is not be utilized, leaving a relatively simple methodological framework. The adaptations made to the original methodology are limited to considering one policy suggestion and the policy development steps are not changed.

By taking a combined theoretical and empirical approach throughout the methodology, multiple research methods have been utilized within the general methodology: exploratory and systematic literature research, informal expert interviews, stakeholder analysis, case studies and expert consultation. Figure 47 shows the methods used throughout the four policy development procedures. The complementary character of these methods provided the author with a diverse and broad perspective throughout the research. This lead to an end result that is developed by following the simple and structured procedures, and combines a large spectrum of information sources.

9.5.2 Problem structuring

In the problem structuring procedure, theoretical and empirical methods complement each other to establish a clear view on the problem within the large and multidisciplinary scope. Where the theoretical literature research methods present ideal and optimal policy goals, constraints and criteria, more practical policy input are provided through empirical interviews and actor analysis.

The literature research considered a large scope of potentially relevant topics. The systems view, extensive amount of literature reviewed and time available lead to a high level consideration of topics rather than the detailed consideration of literature. Combined with the researcher bias regarding topics relevant to discuss, the objective identification of the most critical insights from literature during the problem structuring procedure proved to be difficult.

Empirical methods provided support in the scoping and structuring of the problem and the selection of relevant topics. Informal interviews with a variety of experts (characterized by their different disciplines, expertise, drivers, interests and power) enabled the prioritization of literature research topics through insights of current obstacles perceived when integrating sustainability in procurement.

Political and organizational insights regarding the practical application of the literature was limited or non-existent due to the focus on asset management, sustainable development, and decision models in the literature research. To the understand of the political interdependencies and different drivers of actors in this research, the empirical interviews and actor analysis approach proved to be effective by analysing the political and organizational power and interest of the actors involved. The insights regarding differences in power and interest lead to the focus on decision theory and consensus building among actors, proving the added value of continuous iteration between theoretical and empirical insights throughout the problem structuring procedure. It can be concluded that additional literature research rooted in sociology or behavioural sciences may be desirable to complement the empirical findings.

9.5.3 Policy development

The development of the procurement policy methodology and decision support tool focused on both the compliance with pragmatic contextual constraints and the exploration of progressive means to stimulate sustainable development throughout the entire procurement process. The balance between both pragmatic and progressive goals, constraints and criteria has been found by means of the framework merge (procurement methodology) and the utilization of the existing AHP multi-criteria decision method (decision support tool).

The alignment and merge of existing frameworks and theories into one policy framework benefitted from the added value of multiple frameworks by using the elements fit for asset procurement in each single framework. Merging and 'cherry picking' specific steps or activities from multiple frameworks was possible as each of the four frameworks had similar structures. The theoretical merging method was complemented with the empirical case studies and industry expert consultation to gain a deep and complementary understanding of the situation and insights in the 'forces at work'. This understanding made policy iteration and changes in the developed policy possible.

During the development of the policy, three major assumptions are made that have a significant influence on the developed policy: Each actor involved in procurement is assumed to (I) be intrinsically motivated to collaborate with internal and external actors, (II) understand the need for technical, economic, environmental and social dimensions in asset management and procurement, and (III) be willing to follow organizational objectives rather than individual objectives. These assumptions may simplify the reality of multi-actor collaboration too much, making the applicability of the policy in an environment that does not fit the assumed actor motivation, understanding and willingness contestable.

A multi-criteria decision analysis method was selected for the decision support tool that could be applied to its full extend, maintaining all matured characteristics of that method and thereby benefitting from a proven and well-established multi-objective, multi-actor decision method.

Using a more complex MCDA method (e.g. Analytic Network Process) was desirable from a theoretical point of view to counter potential harmful AHP limitations (e.g. not consider criteria interdependency, weighting regardless of decision-maker experience). However, the simplicity of AHP, the availability of suitable and free software tools, its maturity (i.e. proven applicability in a wide variety of situations) and the limited time frame of the research conducted made the AHP method preferable over a more sophisticated method.

For a thorough application of MCDA in procurement, using and comparing multiple MCDA methods may be desirable to overcome single method limitations. The time and knowledge available to practitioners of the policy may however limit the expansion of the procurement process with more complex methods. Additional case studies and future applications of the policy can provide insights in the feasible level of complexity of MCDA methods and thereby the need for such methods.

9.5.4 Policy application

Putting the theoretical procurement policy into practice through two case studies provided insights in the validity and added value of the policy methodology and decision support tool. The case studies also shed light on polity limitations and dysfunctionalities which then could be taken care of by adapting the developed policy in two iteration rounds. Within the timespan available, two procurement case studies within Alliander have been conducted. Several limitations with regard to these cases have been encountered.

Firstly, the selected case studies both are not fully representative for business-as-usual procurement process. The Fair Meter project has a pioneering character with shared sustainability-focused ambitions central to the project, creating an above-average level of commitment of all actors involved. The Circular Cable project has not been completed yet, causing a lack of extensive information regarding the case study and thereby the disability to estimate the added value using actual case study data and lessons learned.

Secondly, in both case studies, no actor dialogues and group discussions to establish criteria weight distributions consensus took place due to time restrictions in the workshop. Dialogue to overcome diverging priorities is a crucial element of the policy, which makes the absence of validating this particular element of the policy a significant shortcoming within the policy validation process.

Lastly, both cases focused on large scale procurement projects. The added value in procurement of simpler assets or procurement processes less prone to diverging value judgements and priorities among actors is thereby not validated. It can be expected that the developed policy proposes a fairly complicated methodology and tool when a small multidisciplinary procurement team is involved and knowledge, interests and priorities do not differ among the actors.

Despite the shortcomings of both cases, the Fair Meter and Circular Cable case studies were the most suitable for a policy focussing on sustainability-focussed procurement considering corporate environment of Alliander in which this research is conducted, the limited time available to conduct the case studies, and the experts available to participate in the workshops.

Overcoming the shortcomings of the two cases is advisable by validating the policy in additional procurement projects, offering additional in-depth insight in the suitability of the policy in practise.

9.5.5 Policy evaluation

The added value and fitness of the sustainable procurement policy is evaluated based on its compliance with the policy inputs, referred to as policy goals, constraints and criteria, set during the problem structuring procedure. These policy inputs are rooted in both theoretical and empirical findings, providing a set of pragmatic and progressive policy development guidelines. The structured and systematic approach of defining policy inputs, and using these inputs to evaluate the developed end product secures the clear and transparent connection between the development and evaluation procedures.

The feedback received from the variety of experts that were consulted and involved in the policy development process has provided the author with continuous suggestions and practical insights during each of the four methodological procedures. The policy development thereby implicitly benefitted from a continuous quality assurance process.

Policy compliance with the constraints, and the policy performance on criteria are both based on the author’s insights that were gained throughout the case studies, and the consultation of the experts involved in those case studies. In addition, the extent to which design inputs are integrated in the policy is also evaluated by assessing the alignment of theoretical literature research findings with the developed policy.

While the evaluation of the feasibility of the policy could be considered subjective due to the consideration of expert judgement, the systematic documentation and evaluation of policy constraints and criteria present a transparent policy evaluation approach that presents a clear assessment of the added value of this sustainable procurement policy.

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Appendices

Appendix ALiterature research result documentation

Figure 48-50 depicts the literature research process and the results found. Search results are listed for two literature bases for each search query, using the following notation: (number of Scopus hits/number of SciendeDirect hits). If search results were not refined or selected in a follow-up search step, this is noted by a hyphen mark, "-".

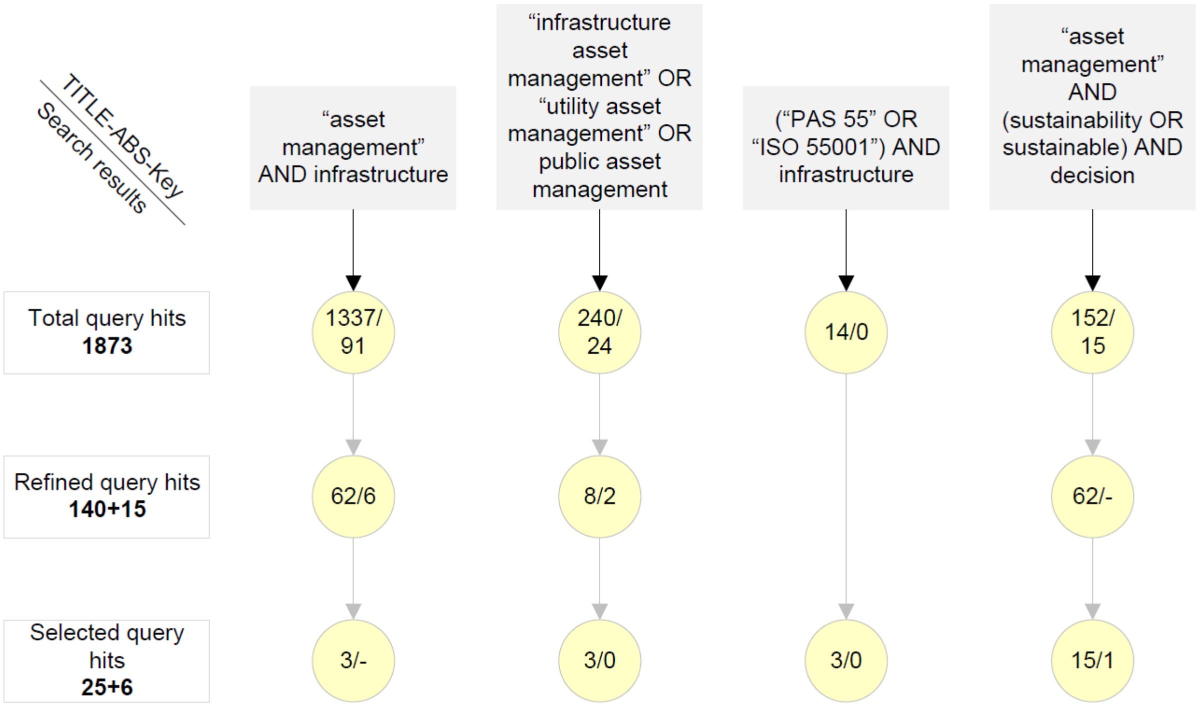


Figure 48 Literature search: infrastructure asset management

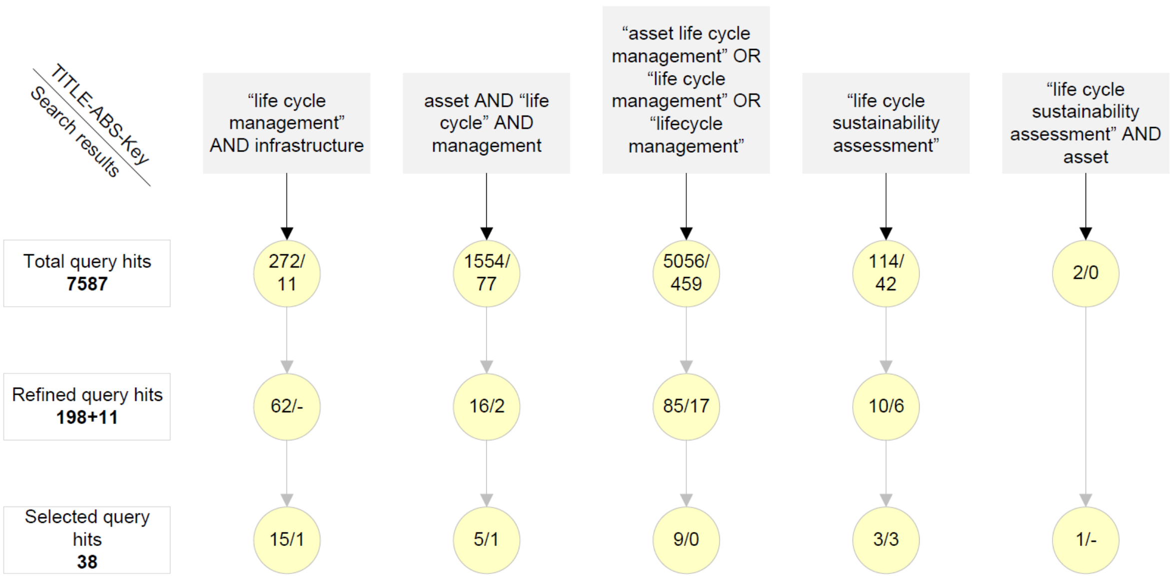


Figure 49 Literature search: Sustainable asset life cycle management

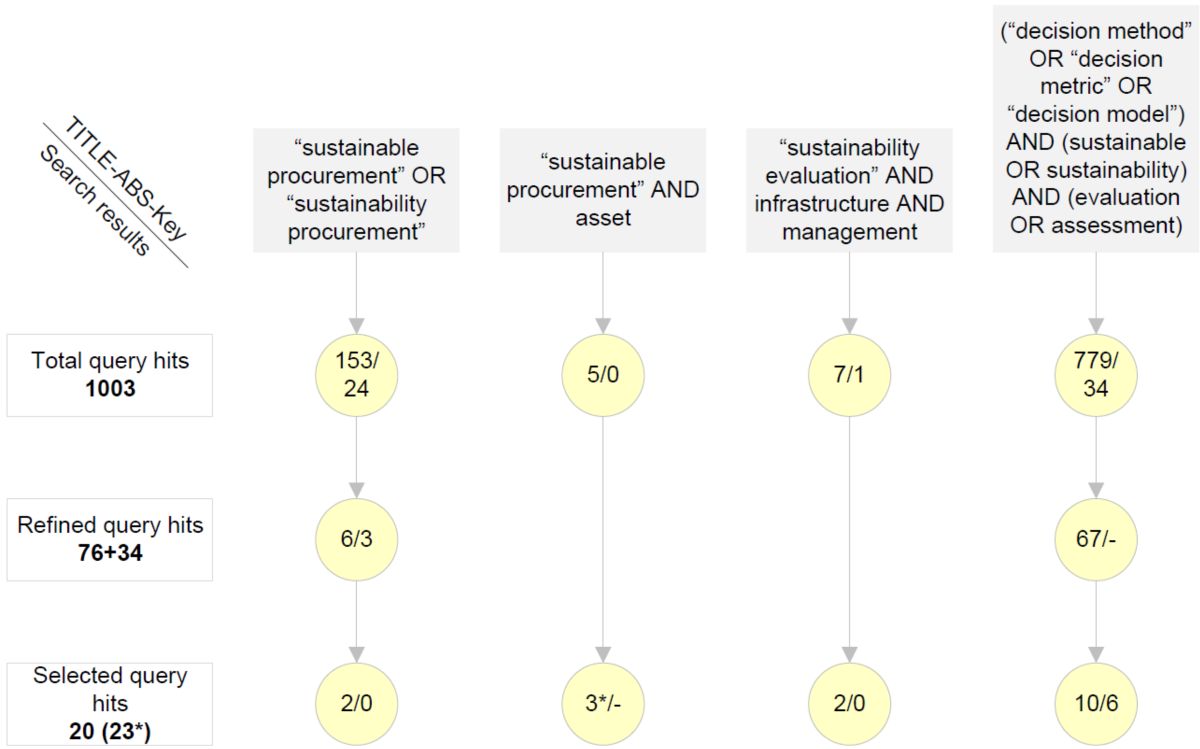


Figure 50 Literature search: sustainable procurement and decision making (*search results could not be accessed)

Detailed documentation of the literature researches is required to give insights in and justify the scope boundaries throughout the literature research. Table 22 and Table 23 present these details.

Table 22 Detailed literature research search query documentation

Topic	Query and filter	Results Scopus	Results SD
Infrastructure asset management	TITLE-ABS-Key "asset management" AND infrastructure	1337	91
	Document type: Review	62	6
	TITLE-ABS-Key "asset management" AND infrastructure AND energy	7	-
	Review title, sources, abstract	3	-
	TITLE-ABS-KEY("infrastructure asset management" Or "utility asset management" OR "public asset	240	24
	Document type: review	8	2
	Review title, sources, abstract	3	0
Infrastructure standards	TITLE-ABS-KEY(("PAS 55" OR "ISO 55001") AND infrastructure)	14	0
	Review title, sources, abstract	3	-
Sustainable asset management	TITLE-ABS-KEY ("asset management" AND (sustainability OR sustainable) AND decision)	152	15
	Document type: review OR book chapter OR article	62	-
	Review title, sources, abstract	15	1

Table 23 Detailed literature research search query documentation (continued)

Topic	Query and filter	Results Scopus	Results SD
(Infrastructure) asset life cycle management	TITLE-ABS-KEY("life cycle management" AND "infrastructure")	272	11
	TITLE-ABS-KEY("life cycle management" AND "infrastructure") AND (urban OR civil OR public OR structure))	150	-
	Document type: review OR book chapter OR article	40	-
	Review title, sources, abstract	4	1
	TITLE-ABS-KEY (*"asset"* AND *"life cycle"* AND *"management"*)	1554	77
	Citations: >50	16	-
	Document type: review	-	2
	Review title, sources, abstract	5	1
	TITLE-ABS-KEY ("asset life cycle management" OR "life cycle management" OR "lifecycle management")	5056	459
	Document type: review	322	17
	Citations: >2	85	-
	Review title, sources, abstract	9	0
Sustainable procurement	TITLE-ABS-KEY("sustainable procurement" OR "sustainability procurement")	153	24
	Document type: review	6	3
	Review title, sources, abstract	2	0
	TITLE-ABS-KEY("sustainable procurement" AND "asset")	5	0
	Review title, sources, abstract	3*	
Sustainability evaluation methods	TITLE-ABSTR-KEY(("Decision method" OR "decision metric" OR "decision model")) and TITLE-ABSTR-KEY((Sustainable OR sustainability) AND (evaluation OR assessment)).	779	34
	TITLE-ABS-KEY(("Decision method" OR "decision metric" OR "decision model") AND (Sustainable OR sustainability) AND (evaluation OR assessment)) AND (LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ENER") OR LIMIT-TO (SUBJAREA,"BUSI") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"MULT"))	67	-
	Review title, sources, abstract	10	6
	TITLE-ABS-KEY (*"sustainability evaluation"* AND *"infrastructure"* AND *"management"*)	7	1
	Review title, sources, abstract	2	0
	TITLE-ABS-KEY("life cycle sustainability assessment")	114	42
	Document type: review	10	6
	Review title, sources, abstract	3	3
	TITLE-ABS-KEY("life cycle sustainability assessment" AND "asset")	2	0
	Review title, sources, abstract	1	-

Appendix BCurrent state of pressure ecological ceiling

Figure 51 illustrates the major overshoot of four ecological ceilings and another two ceilings of which the overshoot is not quantified. A shortfall in all 12 social foundations is also shown.

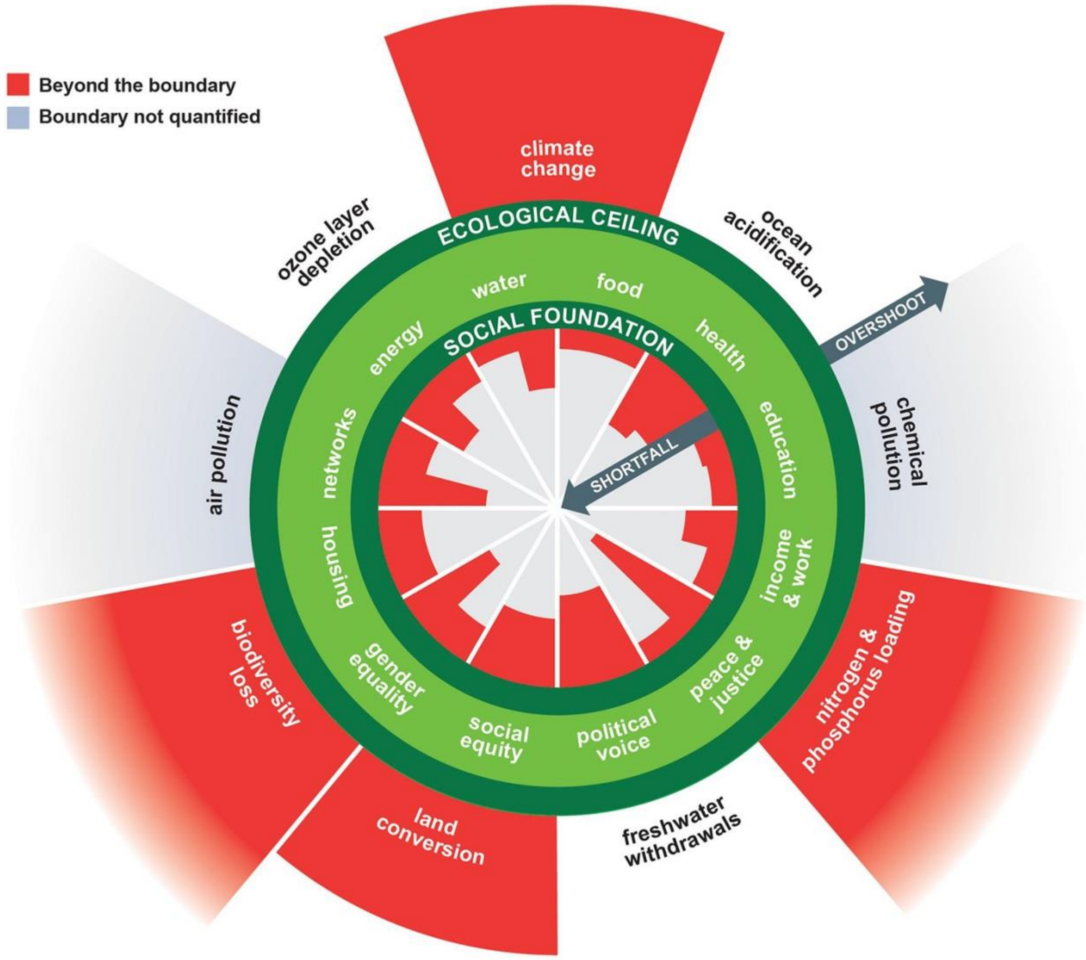


Figure 51 Visualization of the overshoot and shortfall of planetary boundaries and social foundations (adapted from Raworth, 2014, p. 46)

Appendix CThe UN Sustainable Development Goals at Alliander

Table 24 summarizes the sustainable development goals as defined by the United Nations

Table 24 The 17 Sustainable Development Goals of the United Nations (2016b)

SDG	Description
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure Availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

The three SDGs currently selected by Alliander to make contributions towards through their core business activities, listed in Figure 52, are described below.

SDG	Uitleg	Relevantie voor Alliander	Hoe kan Alliander een bijdrage leveren?
7 AFFORDABLE AND CLEAN ENERGY	VERZEKER TOEGANG TOT BETAALBARE, BETROUWBARE, DUURZAME EN MODERNE ENERGIE VOOR IEDEREEN	Wij streven naar een energievoorziening die iedereen onder gelijke condities toegang geeft tot betrouwbare, betaalbare en bereikbare energie voor iedereen	• Open duurzame netwerken bieden • Vergroenen netverlies door investeren in duurzame opwek • Inzicht bieden aan energieverbruik met Smart meter en opties voor applicaties op meter • Deelname aan internationale initiatieven gericht op kennisdelen en technologieontwikkeling en toepassing
11 SUSTAINABLE CITIES AND COMMUNITIES	MAAK STEDEN EN MENSELIJKE NEDERZETTINGEN INCLUSIEF, VEILIG, VEERKRACHTIG EN DUURZAAM	Wij ondersteunen onze klanten in de bebouwde omgeving met de omschakeling naar een duurzaam energiesysteem	• Verbeteren luchtkwaliteit door schoon elektrisch transport te faciliteren • Duurzame gebiedsontwikkeling, ambitieuze huisvesting door transitiegebouwen • Groene Allianties
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	VERZEKER DUURZAME CONSUMPTIE- EN PRODUCTIEPATRONEN	Alliander werkt aan een maatschappelijk verantwoorde bedrijfsvoering (ook in de keten) en ondersteunt duurzame gebiedsontwikkeling	• Duurzaam aanbesteden • Klimaatneutraal in 2023 • Verlagen energie-intensiteit en vergroten energie-efficiency bedrijfsvoering • Circulaire netbeheerder • Samenwerking en participatie Groene netten • Schone bedrijfsmobiliteit

Figure 52 The selection of SDGs applicable to Alliander (2016b, p.1)

Appendix D Problems and solutions in sustainable procurement

A code of conduct describe a set of binding rules that describe the way people and organizations are required to behave. While performing well through codes of conduct can lead to competitive advantage (Preuss, 2005), implementation often encounters problems:

- Compliance issues due to lacking procurer and supplier commitment (Pedersen & Andersen, 2006)
- Compliance issues due to not addressing the fundamental causal problems within the supply chain. Suppliers are asked (or forced in case of powerful procurers) to comply with the code of conduct, leading to undesirable consequences and compliance issues if underlying problems are not addressed. Hoejmose & Adrien-Kirby (2012, p.237) concludes that "codes of conduct often fail because they are merely written requirements that do not deal with the underlying factors and which only create friction between buyers, suppliers and their respective employees".
- Codes of conduct are mostly defined by policies only. Ineffective monitoring and systematic implementing of the policy requirements stated within the code of conduct (Pedersen & Andersen, 2006).
- As discussed earlier, managers may not be willing to invest tangible costs in the intangible environmental and social benefits that SERP may lead to. The connection between SERP and the performance of the organization is not made clear yet (Preuss, 2005).
- Barriers are also encountered in the diversity of institutional frameworks of different countries and cross-cultural diversity in cultural beliefs and value perceptions of trust and ethics (Hofstede, Hofstede, & Minkov, 2010b).

Solutions to the above mentioned problems are proposed in literature:

- ✓ To overcome the principal-agent problem, Pedersen & Andersen (2006) propose to include appropriate incentives and penalties in the procurer and supplier relationship as rewards for compliance and penalties for failure are often absent.
- ✓ Building the relationship of stakeholders on trust, collaboration and communication may also be effective in achieving SERP, using procedural justice approaches (Boyd et al., 2007). Such relationship also can promote innovation and reduce risk, leading to an improved performance and consequently higher profits due to an effective relationship (Zhu et al., 2007). Cultural differences may however play a disruptive role in building trust and transparent communication (Hofstede et al., 2010b).
- ✓ Third-parties can offer guidelines, standards and certification related to social and environmental responsibility. The ISO standards focus on certification of (environmental) management systems and processes.
- ✓ In line with the problem of intangible environmental and social performance addressed by Preuss (2005), explicit inclusion of such indicators in the performance of an organization can stimulate managers to incorporate intangible costs and benefits in their cost-benefit analysis.
- ✓ The organizational culture influences the behaviour of its employees and stakeholders (Cambra-Fierro et al. 2008). Top management support for SERP can thereby influence the intrinsic value perception of individuals which is required to systematically adopt a code of conduct.
- ✓ Hoejmose & Adrien-Kirby (2012, p.238) discusses that "… [SERP] should be contextualized for its purpose and cultural setting" as social and environmental issues are highly depending on

their context and cultural environment. Successful implementation of SERP therefore also depends on the issues selected based on their context.

- ✓ Powerful procurers are able to encourage (or to a certain extend also force) the supplier to behave socially and environmentally responsible which leads to a higher impact, Preuss & Walker (2011) discusses.
- ✓ Enlighten stakeholders with the potential sustainable business model that SERP offers, including waste and material cost reduction due to recycled material input or reuse of products, environmentally sound activities are connected to economic value creation (Fiksel, 2006). The costly perception of CSR hereby turns into a business opportunity.
- ✓ MVO Nederland 2016 (through the publication of the work of Kruisbergen (2016)) defined obstructions and critical success factors of implementing circular procurement in practise. The obstructions, or challenges, are:
    - Absence of internal support
    - Time requirements and delay of change
    - Controlling and responsibility distribution
    - Unfamiliarity leads to undesirability
    - Finance
    - The perceived cost of more sustainable
    - Volume of market demand

  The critical success factors are:
    - Dialogue with the market and the supply chain
    - Vision, support and culture change
    - Collaboration with supply chain
    - Functional specification of demand
    - Honesty and transparency
    - Ask the right questions
    - Enthusiasm and courage
    - Critical interpretation of information

To inspire and motivate other organizations to adopt sustainability in their formal procurement, organizations are publishing their lessons learned on sustainable procurement. See the work of institutions (European Commussion, 2010; Finnish Ministry of employment and the economy, 2014; Melissen & Reinders, 2012; J. Thomson & Jackson, 2007; Padding et al., 2015; Levi & Pease, 2013) that aim to guide the transition to a more sustainable procurement. Melissen & Reinders (2012, p. 34), in their reflection on the Dutch Sustainable Public Procurement Programme (SPPP), for example state that "… the current Dutch SPPP lacks a clear vision on how public procurement can contribute to achieving long-term ambitions with respect to sustainable development".

Appendix E Overview of sustainability assessment publications

The overview in Table 25-26 lists works on sustainable evaluation tools as well as related sustainability tools that are currently dominating the research on applied sustainability principles. Ultimately, the tools listed are instruments aiding the decision makers by providing and evaluating information about social and environmental (and economic) effects of the proposed project or process. The aim of these tools is to improve the quality of the decision-making process. They are to be seen as instruments that stimulate the inclusion of omitted information to the scope of the decision maker, not as deterministic and conclusive additions to the existing process.

Table 25 Overview of sustainability assessment publications

Topic	Reference
Product sustainability evaluation scoring method overview	(Jayal, Badurdeen, Dillon, & Jawahir, 2010)
DuboCalc sustainable construction calculator	(Cenosco, Royal HaskoningDHV, & Rijkswaterstaat, 2017)
Sustainable supply chain model review: LCA-based models, equilibrium models, multi-criteria decision making, Analytic hierarchy process applications	(Seuring, 2013)
Metrics for sustainable supply chain management	(Clift, 2003)
Indicators of a circular economy	(European Academies' Science Advisory Council, 2016)
Categorization of circular business models	(Accenture, 2016); (N M P Bocken et al., 2013)
Opportunities and obstacles of the circular economy in the Netherlands	(Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013)
Circularity calculator	(Ellen MacArthur Foundation, 2015a)
Cradle to cradle	(McDonough & Braungart, 2013)
CSR performance ladder	(Foundation Sustained Responsibility, 2013); (Reed, 2012)
Macro and industrial park level indicator system	(Geng, Fu, Sarkis, & Xue, 2012)
SEPA and NDRC indicator system	(Su, Heshmati, & Geng, n.d.)
Resource passport	(Damen, 2015)
OPAi and MVO Nederland	(OPAi & MVO Nederland, 2014)
CO2 performance ladder	(SKAO, 2015)
Differences and interrelations between industrial ecology, life cycles and supply chains	(Seuring, 2004)
Sustainable supply chain leadership and learning	(Gosling, Jia, Gong, & Brown, 2016)
CSR and the role of environmental and social standards in supply chain governance	(Mueller et al., 2009)
Sustainable supply chain framework	(Seuring & Müller, 2008)
Social sustainability in supply chain decisions	(Hutchins & Sutherland, 2008)
Fundamental change towards sustainability in corporations	(Lee, 2010; Porter & Kramer, 2011)
Sustainability assessment in UK water infrastructure	(Butler et al., 2003)

Table 26 Overview of sustainability assessment publications (continued)

Topic	Reference
Eco-efficiency analysis	(Vermeulen, Witjes, & Reike, 2014); (Rüdenauer & Griefihammer, 2005)
Effects-method indicator	(Moriguchi, 2007)
Reuse potential indicator	(Park & Chertow, 2014)
Reutilization score indicator	(McDonough & Braungart, 2013)
Comprehensive reutilization rate indicator	(Li, Zhang, & Liang, 2013)
Resource and material flow and productivity indicator	(Geng et al., 2012); (Eurostat, 2013)
ABC-x method	(McDonough & Braungart, 2013)
Life-cycle Design Strategies wheel	(Worrell & Reuter, 2014)
Framework for Strategic Sustainable Development	(Broman & Robèrt, n.d.)
Quantitative models for forward sustainable supply chain management	(Brandenburg, Govindan, Sarkis, & Seuring, 2014)
Sustainability criteria for decision support	(Foxon & McIlkenny, 2002)
Framework of impact measurements in circular procurement	(Vermeulen et al., 2014)
framework linking sustainable public procurement and sustainable business models	(Witjes & Lozano, 2016)
overview the different approaches for evaluation of urban infrastructure sustainability	(Zavrl & Zeren, 2010)
sustainability systems engineering as a support to the circular economy	(Romero & Noran, 2015)
score metric for supply chain sustainability in the design phase	(Mokhtar, Omar, & Nor, 2016)
Strategies and ecosystem view for industrial sustainability	(Despeisse, Ball, & Evans, 2013)
Integrated Systems Modelling Framework for Life Cycle Sustainability Assessment	(Halog & Manik, 2011)
Review of performance indicators for collaborative business ecosystems	(Graça & Camarinha-Matos, 2017)
Indicator development: pressure-state-response (PSR) model and environmental indicators	(Hukkinen, 2003)
Environomic design and synthesis of energy system process integration methodology	(Gerber, Fazlollahi, & Maréchal, 2013)
Circular economy indicators and eco-innovation	(Smol, Kulczycka, & Avdiushchenko, 2017)
Multi-criteria methods in system sustainability	(Diaz-Balteiro, González-Pachón, & Romero, 2016)
Templates for sustainable product development	(Ny, Hallstedt, & Rob, 2008)
Assessment of sustainability integration in strategic decision systems for product development	(S. Hallstedt, Ny, & Robe, 2010)
Sustainability criteria and sustainability compliance index in product development	(S. I. Hallstedt, 2017)
Development of an identification key to aid Sustainability assessment method selection	(M. Zijp et al., 2015)
Assessment tool based on Stage-Gate model, Toyota's Set-Based approach and EoL sustainability principles	("Combining Stage-Gate model using Set-Based concurrent engineering and sustainability end-of-life principles in a product development assessment tool," n.d.)
Fairness evaluation tool	(Stigter, 2016)
Solution-focused sustainability assessment	(Michiel C Zijp et al., 2016)
Integrated Model for Assessing Sustainability of Complex Systems	(Gamage, Boyle, & McDowall, 1995)
Sustainability Evaluation Checklist	(Schröter, 2010)

Appendix F Decision principles, criteria and indicators

Sustainable decision principles

Sala, Farioli, & Zamagni (2013, p. 1658) present an overview of factors that "lead to the sustainable development dilemma". Sustainability principles, based on their factors, are:

- Precautionary principle
- Irreversibility regeneration
- Substitutability
- Critical loads/carrying capacity
- Holistic approach
- Polluter pays
- Future generations
- Good governance: Subsidiarity, proportionality and public participation

Other scholars have defined similar sets of sustainability principles (e.g. Butler et al., 2003; Foxon & McIlkenny, 2002) which all strive to formulate an exclusive set of principles that cover the idea of sustainable development. Taking these principles as a starting point for sustainability measurement will not provide a context of measuring based on consensus due to differences in values and goals. However, it provides a clear set of "normative definitions or goals that provide the direction of sustainable development" (Foxon & McIlkenny, 2002, p. 288) and offers a basis for reasoning and action (FAO, 1996).

Sustainable decision criteria

Foxon & McIlkenny (2002) developed a set of five guidelines to assist the formulation and selection process of general and specific criteria in the context of the UK water infrastructure industry. These guidelines, presented in Table 27, are used to draft the general set in for this policy and are recommended to be used as guidelines in the criteria definition process during the procurement process as well.

Table 27 Criteria selection guidelines (adapted from Foxon & McIlkenny (2002, p. 295))

Guideline	Description
Comprehensiveness	Criteria need to cover all relevant dimensions of sustainability (i.e. technical, economic, environmental and social) and need to be able to accurately measure performance towards or away from sustainability.
Applicability	Criteria need to apply to the alternatives under consideration to enable alternative comparison based on the criteria.
Tractability	Sufficient amounts of quantitative and/or qualitative data needs to be (made) available to utilize the criteria in alternative comparison.
Transparency	Criteria selection should be a transparent process involving relevant stakeholders in order to make stakeholders understand the criteria and ensure the comprehensiveness, applicability, tractability and practicability of criteria.
Practicability	Criteria should be practical in their use and respect (i) the purpose of the decision; (ii) tools, time and resources available to acquire criteria-related data; (iii) tools, time and resources available to analyse and assess alternatives.

Sustainable decision indicators

Indicators are the parameters or variables that can be considered the data of a criterion and therefor the performance regarding a specified sustainability principle. When formulating indicators that align with their criterion, the capability to measure past, current and assess future performance need to be considered. To be able to measure and verify the data or information of an indicator, reliable sources of this data or information and appropriate means to make data or information available are required. (Zijp et al., 2015) present a methodology to be used in the sustainability data generation method identification and selection process. For the extensive introduction to this method identification instrument the reader is forwarded to the open access article of Zijp et al. (2015).

Indicators largely depend on the desired function of an asset and the sustainability principles and (sub-)criteria that are considered. A general set of sustainability indicators will therefore not be complete nor will it be an accurate representation of the range of the type of indicators.

Appendix G Sustainable procurement policy inputs

The complete set of policy inputs, ordered per goal, constraint and criteria as well as the paragraph in which the input is discussed (see Table 28-33).

Table 28 Policy input Chapter 2

Policy development input: Sustainability in infrastructure asset procurement

§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
2.2	More focus on sustainable development as a philosophical principle on a society scale within procurement processes	2.2.2	Allow for multiple interpretations of the concept of sustainable development and facilitate flexibility on terminology and sustainability-related concepts among the practitioners of the policy.	2.2.3	Recognition of all planetary boundaries desirable to prevent unsustainable trade-offs. Integrate societal impact generation with the business model of the organization.
		2.2	Explicit incorporation of environmental and social criteria in asset and asset material demands		
		2.2.3	Facilitate a balance between the positive impact on societies social foundation and the negative impact on the environmental ceiling.		
2.2.1, 2.2.5	More explicit corporate social responsibility-related business opportunities	2.2.5	Value judgement on different sustainable business models is subjective and priorities on business models therefore need to be based on quantitative advantages and disadvantages.	2.2.4	Flexible definition of circular economy throughout the procurement process due to diversity of interpretations by different stakeholders.
2.2.4, 2.2.5	Wider range of acceptable sustainable business model types in the procurement process	2.2.4, 2.2.5	Allow the comparison of different types of alternatives and underlying (sustainable) business models	2.2.4, 2.2.5	Capability to evaluate business model proposals based on the generalized business model typology (and 6R principle)
		2.2.5	Facilitating new sustainable business models and asset material life cycle thinking within the procurement process		
2.2.6	Broader concept of value gains in supply chains			2.2.6	Emphasize leadership role of corporate management team regarding the transition to sustainable business models in order to effectively change internal processes and external relations
2.2.6	More effective supply chain collaboration			2.2.6	Possibility to orchestrate the sustainability transition as the focal actor within the supply chain through procurement

Table 29 Policy input Chapter 2 (continued)

§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
2.2.6	More effective actor collaboration			2.2.6	Overcome information, bargaining and free-riding difficulties.
				2.2.6, 2.2.7	The barriers of lack of power, trust and collaboration need to be adressed and overcome to establish effective actor collaboration
				2.2.6	Increase the utilization of suppliers and other external actors as information 'resources'
2.2.7	More functionality-focussed procurement	2.2.7, 3.6, 5.6	Prevent prohibited collaboration with individual actors as legal processes and regulations for public procurement		
		2.2.7	Consideration of both tangible and intangible multidimensional values in supplier selection and alternative assessment	2.2.9	Underlying problems to code of conduct requirements need to be identified and addressed in order to comply with the code of conduct.
		2.2.4, 2.2.7	Formulate asset demands based on the asset function that is needed	2.2.3, 2.2.10	Policy flexibility to select context dependent sustainability goals
				2.2.4, 2.2.5, 2.2.7, 2.2.8	Enlarging the solution space by shifting from precise to less precise problem formulation
2.2.8, 2.2.9	Increase acceptability of sustainability-focus among decision-makers and within formal management guidelines	2.2.9	ISO14000 LCA compliance with general LCA bases. Recipe compliancy. Allow for 18 impact category use		
		2.2.9	Policy should be aligned with the ISO14001 environmental management system		
		2.2.9	Policy should be aligned with ISO26000 and the seven core subjects on social responsibility		

Table 30 Policy input Chapter 2 (continued)

§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
2.2.6, 2.2.10	Increase in supply chain transparency on multidimensional asset (material) life cycle performance and higher tier supplier activities	2.2.10	Select suppliers and assess alternatives on both qualitative and quantitative performance indicators	2.2.10	Add social and environmental interests to existing (financially driven) decision-making processes by adding corresponding criteria
				2.2.10	Prevent greenwashing by using representative scores
				2.2.10	Effectively deliver visible results rather than promises to secure actor support over the long run through inspiring examples of sustainable procurement success stories

§	Goal	§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
Policy development input: Strategic DSO infrastructure asset management							
2.2.4, 2.2.10, 3.2, 3.3, 3.4	Increase in systems-thinking	3.2, 3.3	Larger procurement scope including asset and asset material life cycle	2.2.10, 3.2	Requirements / criteria throughout the entire asset material life cycle are to be considered	3.1, 3.3, 4.3	Increase the focus on long term collaboration between supply chain actors
		2.2.3, 3.2, 4.3	Broader and more diverse view on procurement topics that are involving multiple actors and multiple disciplines	2.2.7, 3.2	Align procurement with life cycle asset management approach	3.4, 3.5	Transparent and objective assessment of risks
				3.2, 3.3, 2.2.10	Strategic decisions throughout the entire asset life-cycle need to be integrated in the procurement process.	3.3, 4.3, 5.5	Decision-makers are identified and their preferences are assessed prior to the procurement process
		3.4	Larger scope of risk assessment	3.4, 3.5	Multidimensional risks need to be assessed		
		3.5	More emphasis on organizational (actual) risks than on individual (perceived) risks	3.5	Vision and strategy of procuring organization needs to guide prioritization of risk factors rather than individual opinions.	3.5	Expert judgement-based risk assessment requires extensive experience and transparancy regarding worldviews, heuristics and risk perception. Acknowledge and reduce their impact on decisions
		3.5, 3.6	More transparent documentation of procurement decisions and their reasoning	3.5	The role of each actor within the risk assessment process need to be discussed	3.6, 4.1, 5.6	Willingness and capability of actors and decision-makers involved to change daily practises and adopt new procedures is limited. The Policy therefore needs to be as simple and straight-forward as possible
				3.6	Policy need to comply with ISO9001 and ISO55001 management systems.		
				3.6	Compliance with asset product/process specifications need to be secured		
				3.6	Policy need to comply with Procurement law and guide on proportionality, NTA8120, WON and National electricity and gas quality regulations		
						3.7	Incentivise each supplier, independent on their size and business share to respond to the tender
						3.1, 5.6	Different levels of asset and procedure complexities are to be expected in infrastructure asset procurement. A policy that is both a general and formal framework, with room for detailed interpretation and depth if required is needed.

Table 31 Policy input Chapter 3

Policy development input: Decision-making in multi-actor networks

§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
4.1, 4.2, 4.3	More emphasis on actor collaboration and actor interdependencies throughout the procurement process	4.2, 4.3	Policy should facilitate, and stress the need of mutual trust, empathy and logic throughout the procurement process	4.2	Focus on measurable input based on the negotiated knowledge principle throughout the policy
		4.3	Focus on a perceived win-win for all actors to secure collaboration and interdependency relations	4.2, 4.3	Overcoming the KPI focus of decisions is required to decide on the best interests of the organization as a whole. KPIs of the organisation determine to a large extend the investment logic of managers and thereby the costs and benefits considered.
		4.2	Respect multiplism in policy activities	4.1, 4.2, 4.3	Meet policy requirements of single and multi actor complexity
		4.2, 4.3, 5.3	Facilitate the debate on individual values, conflicting interests and the organizational values	4.3	Facilitate strategic dialogues between actors
				4.1, 4.2, 4.3	Consider actor perspectives as complementary instead of mutually exclusive
				4.3	Measurable contribution towards KPIs of multiple departments simultaneously during the procurement process
				2.2.6, 2.2.8, 4.3	Effectively facilitate and coordinate supplier collaboration in more sustainability-focussed procurement
				2.2.6, 4.3	Contribute to solving the prisoners dilemma regarding a more sustainable business operation of internal and external actor networks
				4.3	Provide decision support and thereby expanding the room for dialogues and consensus building

Table 32 Policy input Chapter 4

Policy development input: The current corporate context of Alliander

§	Goal: problem to be solved	§	Constraint: policy boundary	§	Criteria: policy performance
5	High level of fitness within current organizational sustainable development, procurement and asset management practises	3.2, 5.2, 5.3, 5.4	Consideration of interests of Alliander and Alliander shareholders during the decision-making process	2.2.10, 5.3.1	Establish clear relations between procurement criteria and specific SDG impact progress document and monitor progress
		5.3.1	Connect sustainable procurement policy to formal SDG commitment (7, 11, 12) and other potentially relevant SDGs (3, 8, 9, 13).	5.5	Mitigation of internal and external actor power abuse in procurement process
		5.5.1	Internal actor opinions and influences need to be considered throughout the policy development and validation process	3.5, 4.3, 5.5	Lack of knowledge regarding selection and assessment topics at individual actor and/or multi-dimensional procurement team need to be mitigated
		5.6	Facilitation of transparent supplier selection and alternative assessment	5.6	Alignment of policy with existing Alliander procurement methodology
				5.7	Acknowledge and integrate current activities and processes that aim at sustainability in daily operation (ALCM, LCC, material and resource passport, CO_2, circulariteit)

Table 33 Policy input Chapter 5

Appendix H PESTLE and TECCO views on lifetime impacts

Taking a TECCO perspective on the lifetime of an asset may thus lead to a clear understanding of the need for an assets function and thereby the strategic need (or redundancy) of assets. The TECCO approach is proposed in combination with the development of asset life cycle plans that aim to support asset managers in making long-term strategic decisions (Ruitenburg et al., 2017). Komonen et al. (2012) identified a set of lifetime impact factors with a similar scope. Table 11 aligns the factors and perspectives. Estimations and assumptions on the useful lifetime of assets are the basis for strategic CAPEX and OPEX investment decisions.

Table 34 Alignment of asset lifetime impact factors (Komonen et al., 2012, p. 49) and TECCO perspective (Ruitenburg et al., 2017, p. 266)

Asset lifetime impact factors	TECCO lifetime impact perspectives
Changing demand	Economic, commercial
Changing competitive environment	Commercial
Modified product	Technical, organizational
Economic obsolescence	Economic
Changing operational requirements	Compliance
Wear and aging	Technical, Economic
Technical obsolescence	Technical
Environmental obsolescence	Economic, compliance

Another well-known analysis tool to broaden the scope of decision-making input in general strategic decision-making is the PESTLE approach (Jurevicius, 2013), see Table X.

Table 35 Example of PESTLE factors adapted from Jurevicius (2013, p.1)

Political factors	Economic factors
Government stability and likely changes Bureaucracy Corruption level Tax policy (rates and incentives) Freedom of press Regulation/de-regulation Trade control Import restrictions (quality and quantity) Tariffs Competition regulation Government involvement in trade unions and agreements Environmental Law Education Law Anti-trust law Discrimination law Copyright, patents / Intellectual property law Consumer protection and e-commerce Employment law Health and safety law Data protection law Laws regulating environment pollution	Growth rates Inflation rate Interest rates Exchange rates Unemployment trends Labor costs Stage of business cycle Credit availability Trade flows and patterns Level of consumers' disposable income Monetary policies Fiscal policies Price fluctuations Stock market trends Weather Climate change
Socio-cultural factors	**Technological factors**
Health consciousness Education level Attitudes toward imported goods and services Attitudes toward work, leisure, career and retirement Attitudes toward product quality and customer service Attitudes toward saving and investing Emphasis on safety Lifestyles Buying habits Religion and beliefs Attitudes toward "green" or ecological products Attitudes toward and support for renewable energy Population growth rate Immigration and emigration rates Age distribution and life expectancy rates Sex distribution Average disposable income level Social classes Family size and structure Minorities	Basic infrastructure level Rate of technological change Spending on research & development Technology incentives Legislation regarding technology Technology level in your industry Communication infrastructure Access to newest technology Internet infrastructure and penetration
Environmental (ecological)	**Legal**
Weather Climate change Laws regulating environment pollution Air and water pollution Recycling Waste management Attitudes toward "green" or ecological products Endangered species Attitudes toward and support for renewable energy	Anti-trust law Discrimination law Copyright, patents / Intellectual property law Consumer protection and e-commerce Employment law Health and safety law Data Protection

Appendix I Asset strategy flowchart

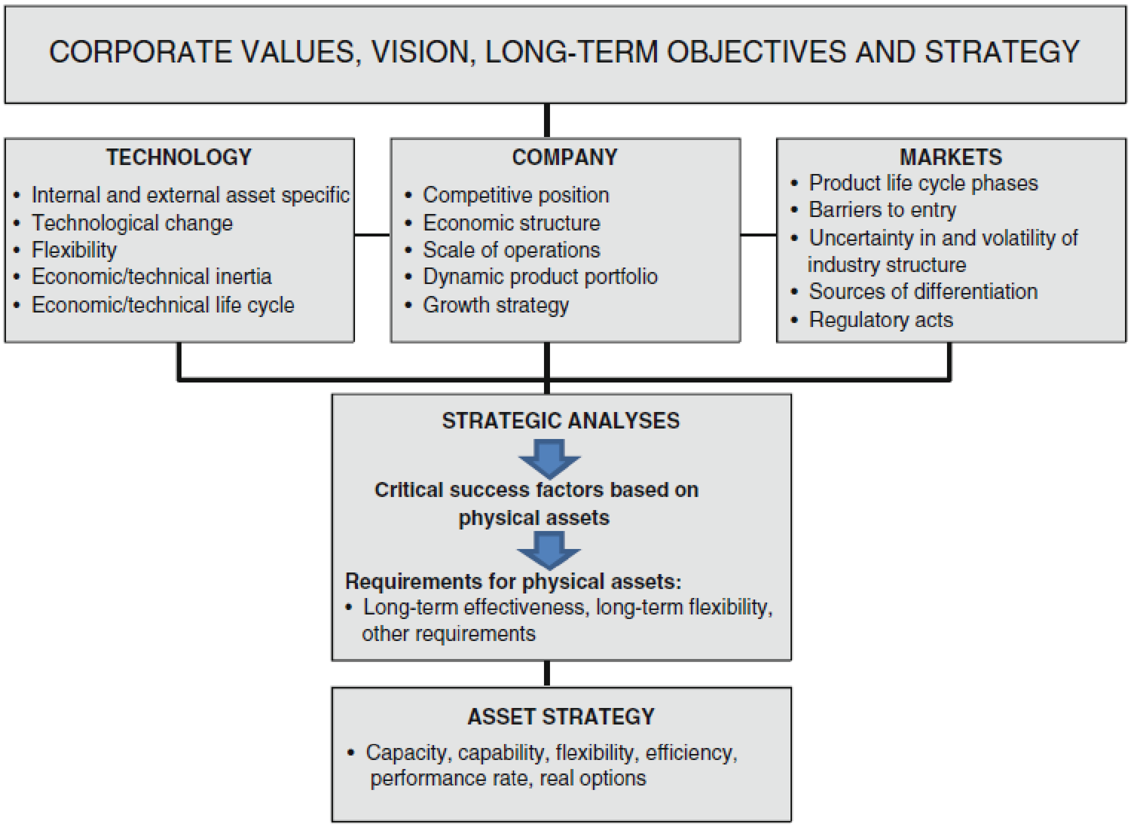


Figure 53 General overview of influencing factors for corporate asset strategy formulation, adapted from Komonen et al. (2012, p.50)

Appendix J Sustainability, the ALARP principle and risk matrix

This appendix discusses two commonly used tools and their limitations to incorporate sustainability to show potential problems of merging sustainability and risk assessment techniques: The ALARP risk acceptance principle and the risk matrix.

The ALARP principle

The ALARP principle (an acronym for “as low as reasonably practicable”) is used to classify risks in three regions and thereby judge whether the risk event is acceptable or not. Figure 18 illustrates the regions and their descriptions. A risk in the unacceptable region requires mandatory mitigation measures, for a risk in the tolerable region the risk mitigation measures are desirable and risks in the acceptable region do not need risk reduction measures. Risk acceptance classification tools are value-based, making the inclusion of sustainability related risks difficult. Questions like *What level of environmental or social harm is considered acceptable?*, *What price is considered disproportionate when human well-being or climate change topics are addressed?* become relevant when sustainable factors are considered. To address sustainability effectively, environmental and social risks need to shift from the ‘acceptable’ and ‘tolerable’ to the ‘unacceptable’ region.

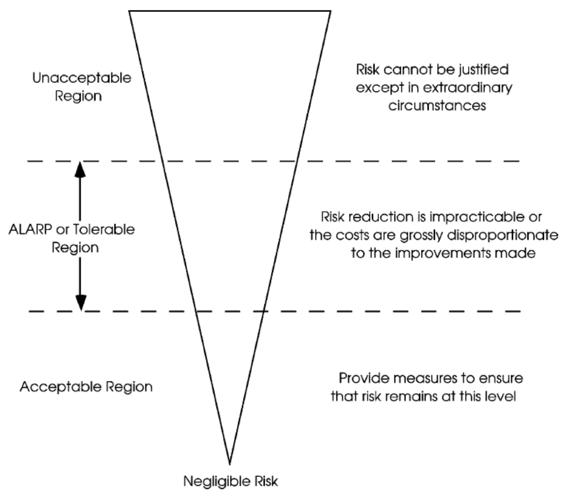


Figure 54 Tolerable risk and ALARP principle (Faber & Stewart, 2003, p. 179) based on (Melchers & Stewart, 1993)

Risk matrix

Risk events are often organized in risk matrices (see Figure 19). The consequence and probability (or frequency) of the event are assumed to be independent of time. This assumption significantly reduces the usefulness of a risk matrix when sustainability-related events are placed inside the scope of the risk assessment. Dynamic consequences (e.g. fluctuations in labour conditions between acceptable and unacceptable) or consequences with time horizons (e.g. short-lived versus long-lived greenhouse gasses or well-being of future generations) cannot be organized effectively.

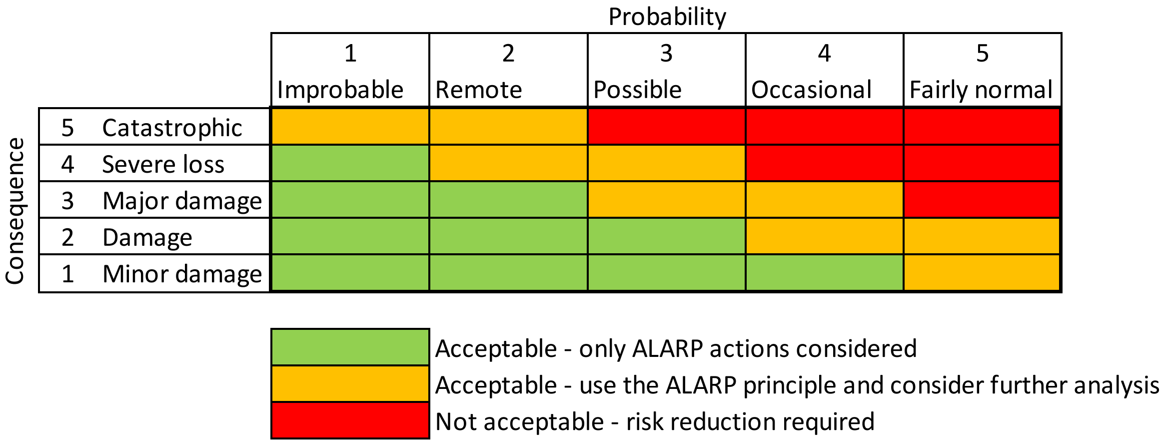


Figure 55 Risk matrix visualization, adapted from (Rausand, 2011, p. 101)

Appendix KInfluencing factors of expert's perception of reality

Expert judgement is influenced by many factors, which makes their judgement far from objective. This appendix introduces the hierarchist, egalitarian, fatalist and individualist worldviews, five types of heuristics (framing, motivational bias, availability heuristics, anchoring and simulation) and the principle of risk characteristics that all influence an experts perception of reality.

Worldviews

The different 'glasses' through which people see the world as it is are coloured by the culture(s), believes and attitudes of those people. It is thereby commonly argued in cultural theory that worldviews influence the risk perception of people. Four common worldviews and their relation to risk perception are discussed by Pidgeon et al. (1992):

- **Hierarchists** are willing to set acceptable risks and bend or change rules as long as decisions are made in socially approved ways (e.g. by experts).
- **Egalitarians** value equality among people and emphasize risks related to technological development and economic growth.
- **Fatalists** are unwilling to take risks but accept what comes their way. Counterpart of the hierarchists.
- **Individualists** realize that risks and opportunities are directly connected.

Heuristics

Intuition and rule-of-thump reasoning patterns in decision-making are referred to as heuristics. Decision-makers or experts can utilize their experience to make quick an reasonably accurate estimations. However, heuristics can also yield large and undesirable elimination of logic (Skjong & Wentworth, 2001). Five overarching heuristics principles are covered to illustrate the influence of heuristics in risk and sustainability expert judgement.

Framing

Framing in social science describes the conscious or unconscious (mis)presentation of little details which may yield significant consequences in the interpretation by others (Plous, 1993). Generally speaking, people are sensitive to great detail and insensitive to omitted details which has direct consequences for risk assessment: detailed quantitative (probability) estimations tend to receive more attention than the scope of events considered throughout the assessment (Skjong & Wentworth, 2001).

Motivational biases

The personal connection or dependability a person may have with the outcome of a decision may influence the motives and level of objectivity of that person.

Availability heuristics

The human mind tends to estimate the frequency and probability of event based on the ease in which that or a similar event can be brought to mind (Tversky & Kahneman, 1973). Skjong & Wentworth (2001, p. 3) argue that the availability heuristics depends on the level in which a person can identify themselves with the event, which can be broken down in three factors: distinctiveness, ease of visualization and obviousness of an event.

Anchoring

The anchoring heuristics describes the phenomenon of (overly) relying on a piece of information available to the decision-maker prior to the estimation made. This 'anchor' of information is considered as the starting point from which values or assumptions are adjusted to account for other influential factors.

Simulation

The extent to which the decision-maker can exemplify the consequences of decisions or can picture scenarios influences the perception and decision of the decision-maker. Prior experiences are the basis of the simulation heuristic.

Risk characteristics

Risk events can be characterized using the risk characteristics of Green et al. (1998) and Litai (1980) in Table 12. The perception of a risky event is based on the characteristics of that event. The individual or societal acceptability of an event depends on the scale of the characteristic. Two examples of an acceptable and unacceptable risk are, respectively, an occasional, clear and luxurious risk, and a catastrophic, known and controllable risk. The parallel to sustainability-related events can be drawn. The risk characteristics then become descriptive aids that make the formulation and assessment of acceptable or unacceptable sustainable events more structured. Using the scales of the characteristics gives insight in the type of events and the possible consequences of that event, without the need of extensive quantitative information.

Table 36 Risk characteristics and perception fright factors (Litai, 1980), adapted from Skjong & Wentworth (2001, p. 4) and Green et al. (1998).

Characteristic	Scale	Author
Volition	Volutary vs. involutary	Litai, Green
Inequitable distributed	Own benefit vs. others benefit	Green
Severity, dreadfulness	Ordinary vs. catastrophic	Litai, Green
Origin	Natural vs. man-made	Litai, Green
Effect manifestation	Delayed/hidden/irreversible vs. immediate	Litai, Green
Future generations	Current generation vs. future generation	Green
Exposure pattern	Regular vs. occasional	Litai
Controllability, Inescapable	Controllable vs. uncontrollable	Litai, Green
Relation to victims	Identifiable vs. anonymous	Green
Familiarity	Old/known vs. new/unknown	Litai, Green
Benefit	Clear vs. unclear	Litai
Necessity	Necessity vs. luxurious	Litai
Statements of responsible sources	Contradictory vs. uniform	Green

Appendix L The legal and regulatory framework of Dutch DSOs

To understand the environment in which asset management activities are executed, the legal, regulatory and standards framework is the basic point of departure: Compliance with these guidelines is undisputable. The goal of such documents is to guarantee a safe, reliable, sustainable and well-organized operation of assets. For Dutch DSOs the relevant (regulatory) boundaries in which the operation is optimized consists of:

- NTA 8120
- ISO 55001
- Procurement law (*in Dutch: Aanbestedingswet*)
- Guide on proportionality, according to the Procurement law
- Independent network operation law (*in Dutch: Wet Onafhankelijk Netbeheer (WON)*)
- Regulation of quality aspects of electricity and gas network operation (*in Dutch: Regeling kwaliteitsaspecten netbeheer elektriciteit en gas*)

Other relevant standards for this research are the sustainability-focused ISO 14001 (environmental management system), ISO 20400 (sustainable procurement) and ISO 26000 (guidance on social responsibility). While these standards are not directly related to the core business of the infrastructure operator, their relevance to this research is clear: these standards set out to include environmental and social aspects in the operation of organisations.

NTA 8120

The NTA, Netherlands Technical Agreement provides performance requirements to operators of transmission and distribution systems of electricity and gas in the Netherlands. The objective of the NTA 8120 is threefold (Nederlands Normalisatie-instituut, 2014, p. 7):

1. Prevent nonconformities, failures and incidents by providing requirements on safety, quality and capacity management systems
2. Control the consequences of any nonconformities, failures and incidents by providing corresponding requirements on safety, quality and capacity management systems
3. Assure the safety, quality and capacity of electricity and gas transmission and distribution throughout the life cycle of the asset network

NTA 8120 is an addition to ISO norms and guidelines on asset management.

ISO norms and guidelines: ISO 55001, ISO 14001, ISO 26000

ISO "creates documents that provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose" (ISO, 2017, p. 1). While organisations can benefit from norms by implementing their content without being certified properly, actual certification by a third party that is authorized to perform the certification is a strong signal to stakeholders that the organisation values the specific norms and is prepared to commit itself to complying with these norms in its daily operation. An important remark is that compliance with (ISO) norms does not guarantee that quality, assets, the environment or social responsibility is effectively managed.

ISO 55001: Asset management system

The international ISO 55001 norm is the successor of the PAS 55 asset management standard. Where PAS 55 focused on the management of physical assets, ISO 55001 has expanded its scope to cover anything that is of (potential) value to organizations. By outlining the entire organizational structure of an asset management organization, the ISO 55001 presents a blueprint or management system standard. By complying with its requirements, an organization is able to be ISO 55001 certified. ISO norms are revised every 5 years in consultation and collaboration with a wide and diverse range of organizations. Assuming that the latest ISO 55001 represents the state-of-the-art guidelines of asset management practises is therefore justified. In each industry, the norm is adapted to fit the specific context of its application. The urban infrastructure/DSO context adopts the ISO 55001 norm as its management system is a holistic and standardized system, customizable to the specific needs of this context. Four key areas are fundamental to the ISO 55000 norm family:

1. The alignment of (strategic) objectives on organizational level to daily asset management activities
2. Asset management with a focus on the complete asset life cycle
3. Risk-based decision-making
4. The importance of leadership, competency development, knowledge management and information management

In addition to the ISO55001 standard, the ISO standards on quality management (ISO 9000) are adopted to formally structure quality governance in large Dutch DSO organizations.

ISO 14001: Environmental management system

The ISO 14001 norm focusses on an environmental management system. As it is compatible with ISO 55001, this management system can easily be integrated into those systems (International Organization for Standardization, 2015). To be ISO 14001 compatible, an organisation needs to consider "[…] all environmental issues relevant to its operations, such as air pollution, […], waste management, soil contamination, climate change mitigation and adaptation, and resource use and efficiency" (International Organization for Standardization, 2015, p.3). The standard brings both qualitative and quantitative benefits to the organisation using it. Current users indicate that ISO 14001 improves company reputation, engagement of employees, competitive and financial advantage through improved efficiencies and reduced costs and encourages a better environmental performance of suppliers by integrating them into the organization's business systems (International Organization for Standardization, 2015). The latest improvements in the ISO 14001:2015 version has specifically included a focus on life-cycle thinking. By doing so, the environmental impact from development to disposal is now addressed. Inclusion of requirements regarding sustainable resource use and climate change mitigation are clear signals of the sustainable direction of this norm, which makes discussing its implications directly relevant in the context of this study. In the ISO 14000 family, standards are directly related to the environmental dimension of sustainable development.

ISO 20400: Sustainable procurement

In 2017, ISO will publish a standard on sustainable procurement. This standard aims to help organizations integrate sustainability in their procurement decisions. While the content of this standard is expected to be highly relevant to this research, it is omitted from the literature study as it is not yet published.

ISO 26000: Guidance on social responsibility

ISO 26000 provides guidance on social responsibility within an organization. This standard is not developed based on requirements and is thereby not suited for certification purposes. The commitment to ISO 26000 is thus voluntarily. ISO 26000s intend is "to assist organizations in contributing to sustainable development. It encourages them to go beyond legal compliance, recognizing that compliance with the law is a fundamental duty of any organization and an essential part of their social responsibility programme" (ISO, 2014, p. 4). This intend indicates the relevancy of this ISO norm towards this study: the social sustainability dimension is the core of this norm.

In the ISO 26000 norm, seven core subjects are discussed that embody the contribution to the sustainable development of an organization when adopted:

- Organizational governance
- Human rights
- Labour practices
- The environment
- Fair operating practices
- Consumer issues
- Community involvement and development

By integrating ISO 26000 in an organization, better social performance can be achieved. Specific improvements are related to the productivity, commitment and morale of people internal to the organization and relationship and reputation to actors (e.g. government, suppliers, the media) external to the organization.

ISO 26000 aids the operationalization of social responsibility by understanding the principles in the specific context of the organization and proposing structural integration within the organizations strategy, culture, policies and operation (ISO, 2014).

Procurement law and Guide on proportionality

The European Union (2009) drafted the legal procedures which public procurement is required to follow. The optimal quality-cost ratio serving as a general guideline for the procurement decision making process is also discussed in the Dutch Procurement law (Ministerie van Economische Zaken & Ministerie van Veiligheid en Justitie, 2012). Under the Procurement law, a variety of additional, more specific and less strict, laws are embedded to offer guidance throughout procurement processes.

The Guide on proportionality, recently updated by Sloots, Keulen, De Koning-van Rutte, Stuijts, & Hebly (2016), sets regulations, guidelines and presents examples on a variety of procurement-specific matters. The Guide includes, among other things, the following topics (PIANOo, 2017):

- Purchasing cooperation
- Selection of procurement procedure
- Grounds for exclusion
- Eligibility requirements
- Selection and evaluation criteria
- Terms and deadlines

The regulations that set the procurement context are, due to their legal character, considered to be out of the scope of this research. They do however determine to a large extend the foundation on which sustainable procurement policies are built.

Independent network operation law (WON)

As of 2011, the Dutch electricity and gas network are operated by a regional DSOs and the WON is entirely adopted. Alongside the major implications that the WON had on the organization of the Dutch network operation, one detail is of specific interest for the transition to a sustainable DSO operation: all strategic activities, including asset maintenance, are to be carried out by the DSOs themselves.

Regulation of quality aspects of electricity and gas network operation

The Dutch Ministry of Economic Affairs has set extensive quality assurance regulations (Brinkhorst, 2004). The explicit content of those regulations is outside the scope of this research.

Appendix M Project-based and process-based decision processes

Project-based and process-based decision processes differ significantly. Being aware of these differences can support decision-makers in steering the process in the desirable direction, depending on the type of procurement process. Table X and X list the differences in problem formulation and goals in a network of actors respectively.

Table 37 Comparison of project-based and process-based decision processes in actor networks (adapted from De Bruijn & Heuvelhof, 2008, p. 61)

Project-based decision making	Process-based decision making
There is a problem, so a substantive analysis is required	There is a problem *perception*, so the perception has to be influenced; 'priming'
Delineating the problem sharply	Formulating the problem in broad terms, problem complexes; 'linkages', couplings
Reducing complexity	Raising complexity
Problem steers the solution	Solution steers the problem
A problem is solved when it arises	The moment of the problem formulation is a strategic choice; the 'window of opportunity' has to be open.

Table 38 Decision goals in a network (adapted from De Bruijn & Heuvelhof, 2008, p. 65)

Project-based decision making	Process-based decision making
The goal is *the* point of reference during the entire project and is formulated beforehand	The goal is moving continuously and is formulated when learning processes have been completed
The goal is related to the problem, is – ideally – fixated	The goal is related to stakeholders; 'goal stretching'
The content of the problem determines the substantive description of the goal	Naming and framing is determined not only by the content; multi-targetting
Boundaries and scope are formulated beforehand and are firm	Boundaries and scope emerge during the process; 'rubber' preconditions

Appendix N Informal expert interview overview

The experts listed in Table XX are consulted through individual informal interviews with a duration of 30-90 minutes.

Table 39 Overview of consulted experts

Expert name	Function	Organization
Co den Hartog	Innovation manager, policy and standardization, asset management	Alliander
Koen Eising	Manager CSR	Alliander
Dominique Hermans	CSR consultant	Alliander
Hendrik de Vries	Sustainability consultant	Alliander
Marcel de Nes-Koedam	Project manager energy transition and circularity	Alliander
Bart Vogelzang	Manager Gas and Architecture, Assetmanagement	Alliander
Rob Nispeling	Senior Policy Advisor Gas, Assetmanagement	Alliander
Camiel Oremus	Manager Elek., Telecom & Cyber Sec., Assetmanagement	Alliander
Nico Steentjes	Senior Consultant, Elek., Telecom & Cyber Sec., Assetmanagement	Alliander
John van Slogteren	Senior Consultant, Elek., Telecom & Cyber Sec., Assetmanagement	Alliander
Ihsan Karakoc	Senior Consultant, Elek., Telecom & Cyber Sec., Assetmanagement	Alliander
Kees Heida	Senior Consultant, Elek., Telecom & Cyber Sec., Assetmanagement	Alliander
Rob Beukeboom	Director of purchasing	Alliander
Bert Smallenbroek	Strategic purchaser	Alliander
Willem Janssen van Doorn	Strategic purchaser	Alliander
Hendrik van Zantvoort	Programme manager sustainable procurement	Alliander
Piet Soepboer	Senior policy expert assets	ENEXIS BV
Tjeerd Broersma	Innovator	ENEXIS BV
Leo Posthuma	Professor on environmental risks and sustainable development	RIVM, Centre for Sustainability, Environment and Health (DMG), Dpt. of Environmental Science
Michiel Zijp	PhD student sustainability assessment	RIVM, Centre for Sustainability, Environment and Health (DMG)
Willem Haanstra	PhD student life-cycle costing	Liander, University of Twente
Richard Ruitenburg	PhD student asset life cycle management	Liander, University of Twente
Phil Brown	PhD student circular value networks	Delft University of Technology

Appendix O Impact analysis of Alliander

The largest positive impacts in 2015 were: payments to suppliers (financial capital), value added to industrial and household clients (manufactured capital) and offering new business models and open platforms of innovation (intellectual capital). Large negative impacts were costs of household clients (financial capital), utilization of scares resources and contributions to climate change (natural capital). Both positive and negative impacts include impacts through (part of) the asset supply chain. The negative impacts underline the importance of a more sustainable operation of Liander.

Table 40 Impact analysis overview of Alliander (adapted from Alliander, 2016)

Impacts onderverdeeld in 6 kapitalen

Kapitaal	Informele beschrijving van dit kapitaal	Voorbeelden van impacts
Financieel	De geldvoorraad	• Toename in de kasreserve • Belastingbetalingen door Alliander • Ontvangen salarissen van werknemers
Geproduceerd	De voorraad materiële zaken gemaakt door mensen	• Verandering in de economische waarde van het netwerk van Alliander door netverzwaring • De waarde van het nieuwe hoofdkantoor van Alliander in Duiven
Intellectueel	De voorraad niet-materiële zaken gemaakt door mensen	• Nieuw opgedane kennis binnen Alliander door de investering in nieuwe markten • De ontwikkeling van een nieuw technologisch ontwerp voor een DC net binnen Alliander
Natuurlijk	Alles wat natuur en milieu betreft	• Bijdrage aan klimaatverandering door CO_2 emissies vanuit de energiesector • Een afnamen van schaarse materialen in de natuur door het verbruik van fossiele brandstoffen • Vermindering van de kwaliteit van lucht door luchtvervuiling
Sociaal	Alles wat met netwerken en gemeenschappen (groepen) te maken heeft	• Verhoging van de sociale cohesie in buurten door wijkinitiatieven gericht op duurzaamheid • Verbetering van de reputatie van Alliander
Menselijk	Alles wat met het directe welzijn van personen betreft (incl. werknemers)	• Een toename van het welzijn van werknemers door de invoering van flexibele werktijden • Een positieve bijdrage aan de gezondheid van personen door de beschikbaarheid van elektriciteit

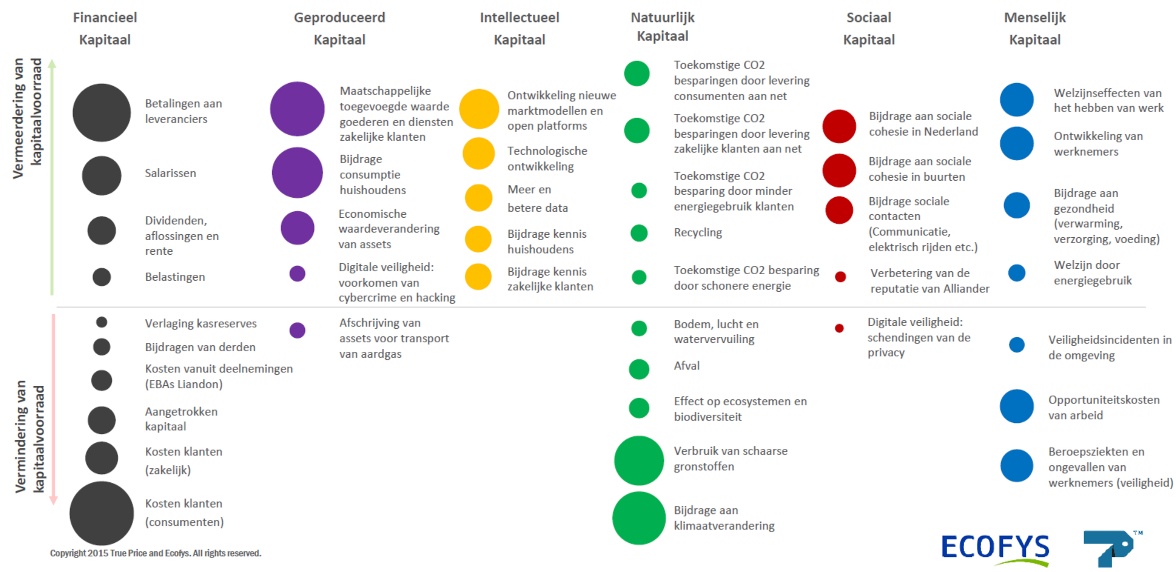


Figure 56 Impact hotspot analysis of Liander by Ecofys and True Price (adapted from Alliander, 2016b)

Appendix P Ambitions in circular safety clothing tender

Table 41 Alliander's sustainability focus in the ongoing safety clothing procurement process (adapted from Copper8 & Alliander, 2017)

			Omschrijving	Ambitie
Technisch (product)	Materialen	Toxiciteit	Minimaliseer toepassing van toxische stoffen in product.	Geen toxische stoffen in de producten.
		% hergebruikt	Verhoog het percentage van hergebruikte (of hernieuwbare) grondstoffen en materialen als basis voor het nieuwe product; verlaag de totale hoeveelheid benodigde grondstoffen.	100% van de grondstoffen en materialen is afkomstig van hergebruikte (of hernieuwbare) bronnen.
		% her-te-gebruiken	Verhoog het % grondstoffen dat na levensduur hoogwaardig is her te gebruiken; houd de balans tussen hergebruikte basismaterialen en her-te-gebruiken (of hernieuwbare) materialen (in de toekomst) in het oog.	100% van de grondstoffen is na levensduur hoogwaardig her te gebruiken.
	Ontwerp	Optimale functionaliteit	Ontwerp dat materiaalgebruik minimaliseert, en circulair gebruik en hergebruik stimuleert	Een ontwerp dat zorgt voor maximale functionaliteit tegen zo min mogelijk materiaal.
		Levensduur	Ontwerp dat levensduur maximaliseert, en/of de beste balans tussen levensduur en circulariteit creëert	
Productie en gebruik (Proces)	Productie-proces	Productieproces	Reductie materiaal-, water-, en energiegebruik in productieproces, minimaliseren van productieafval en gebruik van minder en schonere(niet toxische) grondstoffen	Een productieproces zonder negatieve impact op milieu.
		Logistiek	Minimaliseren van milieu impact van de distributie en logistiek (ketenemissies)	Een logistiek proces zonder negatieve impact op milieu.
	Samen-werking	Ketenregie	Verregaande samenwerking in de keten, waardoor gefundeerde afwegingen kunnen worden gemaakt die circulair gebruik stimuleren.	Een proces dat zorgt voor maximale circulariteit met zo min mogelijk negatieve impact op het milieu 5
		Borging circulariteit	Creëren van incentives in de keten voor de verschillende ketenpartners; door de juiste afspraken wordt circulariteit 'gestimuleerd'	

Appendix Q Actor analysis of the internal and external multi-actor networks

Activities, interests and influence of the internal multi-actor network

The role of different actors within Liander can be linked to the actor's interest and power regarding the integration of sustainability in asset procurement. The five following internal actors are considered most relevant: the asset management department, CSR department, purchasing department, the corporate management team and the operational department. The actor specific activities, interests and influences are discussed into more detail below:

- **Asset management** *(economist)*
  Asset manamgenent is responsible for the technical well-being of assets to guarantee asset operational readiness within the (financial) resource limitations. AM as an actor is therefore mainly interested in technical and economic factors. Risk management focusses on technical and economic risks, with a minor role for CO_2 equivalent emission. Life cycles of assets are long and asset-related decisions therefore tend to have large and long-lasting impacts which results in decisions focussing on minimal risk and maximal performance. Throughout the asset life cycle, introducing innovations and improvements may be desirable. Most innovations aim to increase the (sustainable) performance of the asset. AM craves to implement such innovations. However, proof is needed to guarantee the usability of innovations. From AM perspective, long term collaboration with stakeholders (e.g. to introduce reliable innovations to the asset base) and function-based performance of assets is a central theme in asset life cycle management. As the core business activities of an infrastructure operator depend on highly reliable assets, the point of view of AM is of significant importance.

- **Corporate social responsibility** *(social environmentalist)*
  Within Alliander, the CSR department fulfils three roles: Inform and create awareness, inspire and support decision-making processes. Within each of those roles, the sustainability-related responsibility of the organization is highlighted, leading to a strong emphasis on environmental and social matters. As CSR is reporting directly to the executive board of Alliander, the CSR operates independent from other departments. To ensure a large sustainability impact, CSR needs to effectively collaborate with core business departments as it is not able to generate a large impact on its own. By strategic communication and by inspiring others, CSR can however include environmental and social priorities in the technical and economic mind-set of actors. CSR representatives can be seen as *change agents*, reminding the organization and its individual employees of the responsibilities they have towards our societal environment. Main drivers are mostly environmental, social and partly organizational and political.

- **Operations** *(economist)*
  The operations department of Alliander covers multiple disciplines, including but not limited to logistics, operational activities, asset IT and (smart) information flow management. Activities and responsibilities related to operations directly involve the availability and performance of the asset base. Changes in asset types, standardized processes and innovative pilot projects directly affect the department. As Alliander is organized and built on democratic consensus-based decision-making in which each related department is involved

in the decision process, the support of Operations regarding more sustainable practises is required. and The conservative and risk-averse attitude causes a general intrinsic resistance to change, making innovative sustainable business models undesirable. By acting passive and cautious, Operations takes a reserved stance towards sustainability in asset management when it involves unfamiliar and/or uncertain changes. Main drivers of Operations are technical and economic.

- **Purchasing** *(political economist)*
  The purchasing department of Liander is the connection between the supply chain stakeholders and the (internal) organization. Publishing Requests For Information (RFIs) for product and service needs and drafting transparent and objective evaluation criteria and weighting factors forms the basis for a rapid and mutually beneficial settlement and relationship. The requirements set depend on the other actors involved. Current requirements are mostly based on asset specifications. This specification-based procurement stimulates the competition of suppliers on (technical and economic) asset performance. If requirements on environmental and social performance throughout the entire life cycle are integrated in the procurement process, a higher level of knowledge of corresponding criteria is demanded. The procurement department namely needs to compile distinctive and stimulating criteria that correspond with the current capabilities of the suppliers on the market. Knowledge to formulate those criteria is not (yet) available within the department. The prioritization of criteria by means of weighting values can directly steer an asset tender process to technical, economic, environmental or social focussed competition among the suppliers. Weights are important to the objective and transparent evaluation of offers. The definition of these weights, however, becomes complicated when conflicts of interest between stakeholders appear. The corporate strategy of the organization therefore has a major role in this steering process. Intrinsic value judgement, DSO policies and corporate KPIs all affect the weighting and thereby the potential impact the purchasing department can deliver on any desired set of requirements and sustainability dimensions in general, as long as these fit the capabilities of the market. As the purchasing department is directly depending on the willingness, capabilities and collaboration with the supply-chain stakeholders, its main drivers are mostly political and economic.

- **Corporate management** *(political economist)*
  From ethical and personal point of view, sustainability is placed high on the priority list of (top) management, shareholders and governmental bodies who collaborate with infrastructure operators. Corporate management sets out the strategic direction of the organization, while line management translates the strategic direction to operation. The corresponding resources that are required by line managers and operational departments of the organization are however crucial to operationalise these sustainability priorities into practise. Sustainability is to be achieved within the existing resource budgets without negative impacts on existing performance of the organization. Thus, the lower corporate management commitment, the more difficult sustainability prioritization becomes. In general, top management resource allocation depends on the added value created by the departments. Current perception of value mainly relates to technical and economic performance, reflected in Lianders core values which are *reliability, affordability and accessibility* of their services. Corporate management, being in control of the strategic direction of the organization, is able to prioritize sustainability if the concept of value creation is expanded beyond technical and economic values. And the Alliander management,

in turn, largely depends on other stakeholders/shareholders, namely regulatory authorities, competitors (other DSOs) and customers (including public and industrial clients) and NGOs. The general level of interest of the management team therefore depends on the level of priority of influencing stakeholders/shareholders. Personal levels of interest among corporate managers can also influence the general level of interest of the management team and thereby the strategic direction of the organization. Corporate management mainly has organisational, political and economic drivers.

Activities, interests and influence of external multi-actor network

The external actor activities, interests and power which describes the roles and influences of actors regarding sustainable procurement is discussed in more detail below:

- **Customers** *(all-round perfectionist)*
  While customers typically have a strong influence on the corporate management strategies as they are the target group that Liander aims to satisfy, the Dutch utility distribution is characterized by its very high performance, making reliability and affordability important goals. The intrinsic motivation and willingness of customers to increase costs in order to address sustainability as a priority can have a minor influence towards a sustainable strategy. Interest in addressing the need for a more sustainable strategy differs among customers.

- **Suppliers** *(economist)*
  Liander has a large amount of direct (tier 1) and indirect (tier 2+) suppliers. Asking the "right" question typically leads to stimulating suppliers to contribute to a (more) sustainable asset life cycle. The extent to which environmental and social sustainability dimensions can be incorporated within the evaluation and selection of alternatives also depends on supplier-related externalities. These externalities determine the (level of) information that supply chain stakeholders want to, or can, provide. Examples of externalities are:
    - The absence of intrinsic motivation to integrate multidimensional sustainability in their operation
    - The cost-benefit ratio of providing sustainability-specific information, directly related to the potential profit of winning the tender
    - The horizontal or vertical character of the market and the share of the DSO in that market
    - The inability and ignorance of stakeholders with the principle of information transparency and the related resistance to change and (extensively) document or provide more and/or sensitive information (e.g. intellectual capital)

  In general, suppliers that are dependent on Liander have higher interests in adopting sustainability principles and lower power to obstruct such requests, while large suppliers for whom Liander is no significant client, typically have a lower interest and higher power. Suppliers who are able and willing to explore sustainability (and more specifically: circularity) as feasible business cases, can distinguish themselves from less adaptive suppliers. Powerful suppliers with sustainability initiatives are hereby able to influence the corporate strategy on sustainability. Long term partnerships with sustainability-minded suppliers create the mutually beneficial opportunity to learn how to integrate sustainability in asset procurement. The intrinsic motivation and ability to show leadership introduces a large diversity among suppliers.

- **Waste processors** *(economist)*
  Industrial waste processors collect, sort and recycle assets at the end of their useful life. The major increase in waste, combined with the increased demand for non-virgin materials present significant market opportunities for waste processors. Where landfill used to be the end of a materials lifetime, this 'urban mine' of resources is becoming a crucial node in the supply chain network due to circular and sustainable business models. Societal transition to more sustainable procurement is therefore of high interest to this industry. Dependability of asset suppliers on non-virgin material availability, supply assurance and necessary supply chain collaboration in a Circular Economy makes waste processors increasingly more powerful. The main driver for this type of actors is economic.

- **Co-DSOs / Competitors** *(political economist)*
  Liander, together with Enexis, Stedin and Enduris, cover the majority of the Dutch electricity and gas network. The Dutch benchmark regulations make sure prices remain comparable and compatible between DSOs. Strategic decisions to become a more sustainable DSO are perceived differently by each DSO. Positive or negative influences of Co-DSOs on the integration of sustainability in procurement can mainly be appointed to influences of corporate management, customers and suppliers (L. Schneider & Wallenburg, 2012). A collective adoption of sustainability overcomes the individual restrictions the benchmark poses and shows a uniform demand for sustainable asset life cycle consideration towards suppliers. The blocking power each Co-DSO has regarding such collective strategic decisions requires a consensus on the direction of all Dutch DSOs on sustainability. That consensus is obstructed by the individual (competitive) strategies of DSOs and their own perception of sustainability, resulting in external actors in a network organization that are all both powerful and have high interests.

- **NGOs** *(social environmentalist)*
  Non-governmental organizations, in this context considered to be not-for-profit organizations that represent the public long-term wellbeing, can advocate their opinion freely. This enables NGOs to influence the government, public consumers and regulatory authorities as well as corporate management, suppliers and Co-DSOs (L. Schneider & Wallenburg, 2012). The level of influence largely depends on the strength and effectiveness of the NGO lobby. NGOs may behave mainly as change agents that stimulate a sustainable mind-set among other stakeholders.

- **Shareholders** *(economist)*
  The shareholders of Alliander are Dutch provinces, municipalities and cities. These shareholders represent the interests of their residents and have general preferences to highly reliable electricity and gas grid services for a low price. From a shareholder position, higher annual profits generally corresponds with a higher dividend. As convincing dedication to sustainability goals is likely to reduce Allianders profits due to higher costs, shareholder acceptance and willingness to accept lower dividend is a prerequisite for shareholder support to ambitious sustainability targets. The desirability of more sustainable DSO asset management therefore strongly depends on the intrinsic motivation of shareholders, which depends on individual priorities of these actors. Main drivers of shareholders are political and economic,

- **Government** *(political all-round perfectionist)*

The Dutch government plays a major role in setting the political and regulatory context in which corporate and public organizations define their strategies. National ambitions and targets are translated to action and stimulus via the Dutch ministries, authorities and related organizations. The governmental responsibility to set out a long term course with the proverbial 'spot on the horizon' also relates to sustainability goals. Different governmental bodies have different levels of priority towards sustainability topics. While potential power of the government is high, interests regarding sustainable procurement therefore vary.

The dependency of customers on DSOs cause an unequal power relation. It is therefore the responsibility of the government to represent these customers and play a dominant role in advocating the will of customers regarding a more sustainable network operation. Network operators, however, have little room to charge customers more for more sustainable operation, because sustainability is not reward or desired in the current benchmark regulations on DSO pricing set by the governmental Authority on Customers and Markets (ACM) (see §3.1.7). Infrastructure operators in the Netherlands are capable of generating a large collective impact regarding sustainability if facilitated by the government, which stimulates complicated and in-depth discussions regarding the current and future regulatory context. The government has political and organizational drivers in general and situation-dependent economic, environmental and social drivers.

- **Regulatory authorities** *(minimalist)*
  Regulatory authorities refer to independent (inter)national authorities as well as governmental agencies that set out and enforce technical, economic, environmental, social and organizational regulations. Their independent and authoritative role makes them powerful actors that control the rate of change within the DSO industry. Strict regulations limit the strategic directions DSOs may want to take. As (L. Schneider & Wallenburg, 2012) discuss, regulatory authorities can strongly influence the integration of sustainability in procurement processes by influencing DSO management, customers, suppliers and competitors. Regulations are, however, almost exclusively aimed at guaranteeing a highly reliable, affordable and accessible electricity and gas network. The interest of regulatory authorities in sustainable procurement is thereby low. Only by external influences of governmental goals (i.e. SDGs, Paris climate accord), direct and uniform demand of all DSOs and/or NGOs, the regulatory authorities receive the incentives positively use their influence. Adopting new, or changing old regulations takes a considerable amount of time. The experimental phase in which sustainable procurement and circular business models currently are imply that regulation still has to be formed. Therefore, regulations and legislation lags behind with regard to sustainability targets and ambitions of the Dutch government. A conservative attitude adopted by the authorities to avoid constantly changing regulations and to make sure that the right rules are implemented. This causes circular reasoning as the industry requires new regulations to transform experimental practise into maturing daily operation, while a steady state of daily operation is required to set definite regulations. Drivers of DSO regulatory authorities directly relate to the topic of interest of the authority and can thus be technical, economic, environmental, social, organizational and legal.

Appendix R Current Alliander Procurement Methodology

The methodology illustrated in Figure X represents the current procurement steps taken at Alliander.

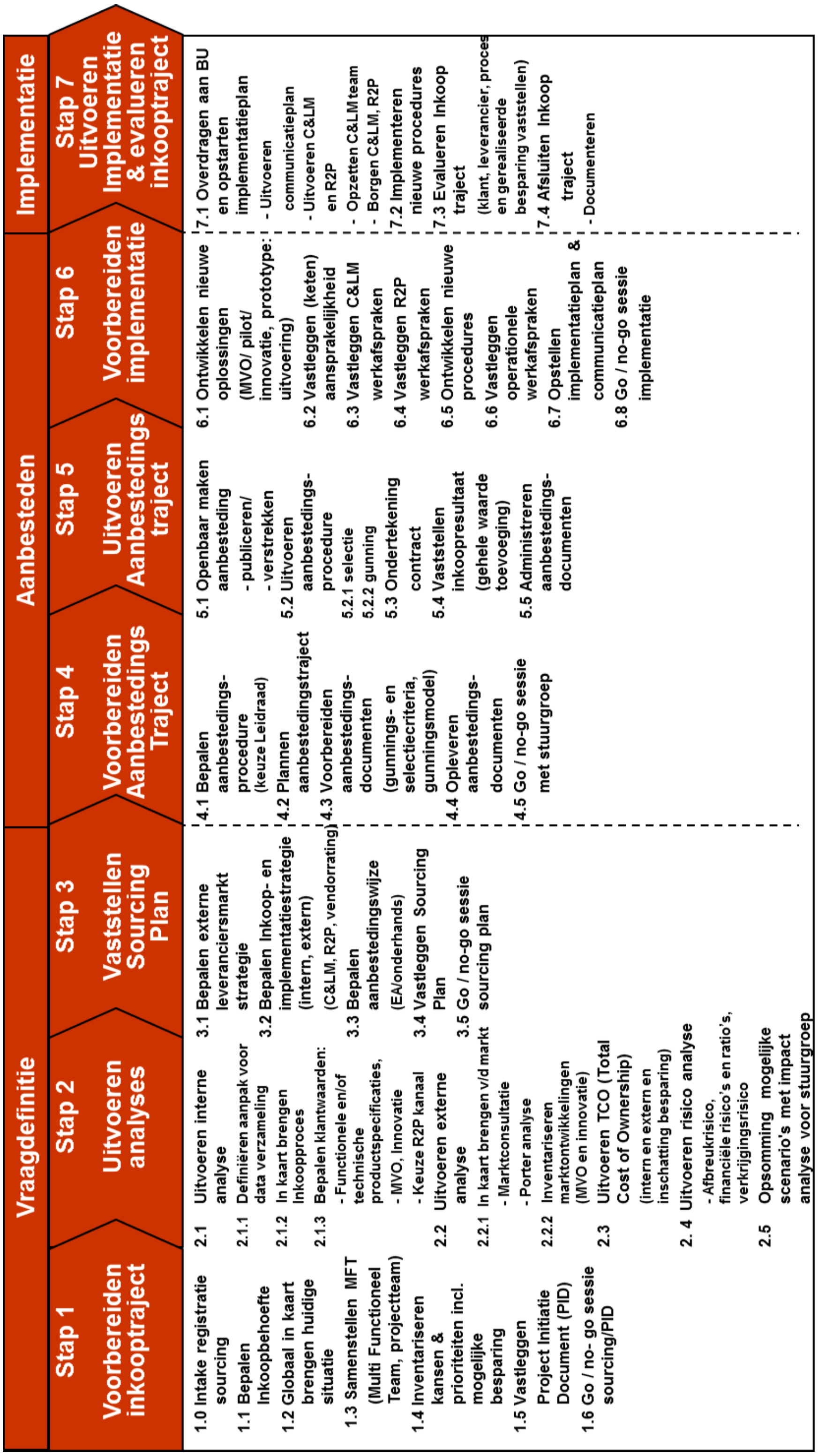


Figure 57 Alliander Procurement Methodology (Alliander, 2016a)

Appendix S Overview of multi-criteria decision analysis methods

Table 42 Multi-criteria decision analysis method comparison, adapted from Cinelli et al. (2014)

MCDA methods performance with reference to the sustainability-related indicators: + = good, strength of the set of methods, ○ = intermediate, depends on the method within the set or the author's judgment – = poor, weakness of the set of methods.

Comparison criteria domain		Comparison criteria	MAUT	AHP	ELECTRE	PROMETHEE	DRSA
Scientific soundness	Related to input data	Use of qualitative and quantitative data	+ Possible[5,6,11]	+ Possible[5,6,11]	+ Possible[5,7,11]	+ Possible[1,5,7]	+ Possible[27,28]
		Life cycle perspective	+ Possible[4]	+ Possible[4]	+ Possible[4]	+ Possible[4]	+ Possible[25,27,28]
	Related to calculation method	Weights typology	– Trade-offs[1,3,4,7,8,9,10,11,12]	+ Importance coefficients[11] – Trade-offs[3,4,7,8,12]	+ Importance coefficients[3,4,7,8,11,12,13]	+ Importance coefficients[4,7,12,15,16,17] – Trade-offs[8,14]	+ Not needed[27,28]
		Threshold values	– Not possible[5,8] + Possible[6,18]	– Not possible[5,6]	+ Possible[1,5,7,11,12,13,15]	+ Possible[1,5,6,7,10,12,15]	+ Possible, obtained from the decision rules[25,26,28]
		Compensation degree	– Full[1,2,3,5,7,8,9,12]	– Full[2,3,5,7,8,12]	+ Null[1,2,3,5,7,12,13] / ○ Partial[1,2,8]	○ Partial[1,5,7,8] – Full[2]	+ Null[26]
		Uncertainty treatment/ Sensitivity analysis	+ Possible[4,5,6,7,10,11]	+ Possible[9,20,21] ○ Partially possible[4,5,6]	+ Possible[4,5,7,13]	+ Possible[4,5,7,10,13,19]/ ○ Partially possible[6]	+ Possible[28,29,30,31]
		Robustness	+ No rank reversal is possible[5,8]	○ Rank reversal can occur[5,8]	○ Rank reversal can occur[5,8]	○ Rank reversal can occur[5,8]	○ Possible for the choice and ranking problems[27,28]
Feasibility		Software support and graphical representation	+ Software available with some graphical capabilities [5,6,11,19,20]	+ Software available with good graphical capabilities [5,6,9,11,19,20,21]	○ Software available, but with poor graphical capabilities[5,13,20,22]	+ Software available with good graphical capabilities[5,6,15,19,20,23]	○ Software available, but with poor graphical capabilities [33, 34]
		Ease of use	+ High[6,19] – Low[7,8]	+ NHigh[6,19] ○ Medium[5] – Low[7]	–Low[1,4,5,7,8,11]	○ Medium[1,5,6,7,8,19,23]	+ High[25,26,27,28]
Utility		Learning dimension	– Difficult[5,6]	– Difficult[5,6]/ + Possible[24]	–Difficult[5]	+ Simple with scenario analysis[5,6,23]	– Difficult[31,32]

[1]: (Benoit and Rousseaux, 2003), [2]: (Teghem et al., 1989), [3]: (Munda, 2005), [4]: (Belton and Stewart, 2002), [5]: (Antunes et al., 2012), [6]: (Buchholz et al., 2009), [7]: (Polatidis et al., 2006), [8]: (Munda, 2008), [9]: (De Montis et al., 2000), [10]: (Raju and Pillai, 1999), [11]: (De Montis et al., 2005), [12]: (Rowley et al., 2012) [13]:(Figueira et al., 2005b); [14]: (De Keyser and Peeters, 1996); [15]: (Brans and Mareschal, 2005); [16]: (Brans et al., 1986); [17]: (Le Teno and Mareschal, 1998); [18]: (Danielson et al., 2007); [19]: (Linkov and Moberg, 2012); [20]: (Weistroffer et al., 2005); [21]: (InfoHarvest, 2014); [22]: (Merad et al., 2013); [23]: (Geldermann and Zhang, 2001); [24]: (Fernandez, 1996); [25]: (Slowinski et al., 2009); [26]: (Roy and Słowiński, 2013); [27]: (Greco et al., 2001b); [28]: (Slowinski et al., 2012); [29]: (Greco et al., 2001a); [30]: (Dembczyński et al., 2009); [31]: (Błaszczyński et al., 2013); [32]: (Szelag et al., 2013); [33]:(Slowinski and Blaszczynaki, 2014); [34]: (Slowinski and Szelag, 2014).

Appendix TBPMSG's software tool: conducting a group session

The AHP Online System tool can be used for group decision-making sessions. The instructions in Figure X below indicate how the tool need to be applied.

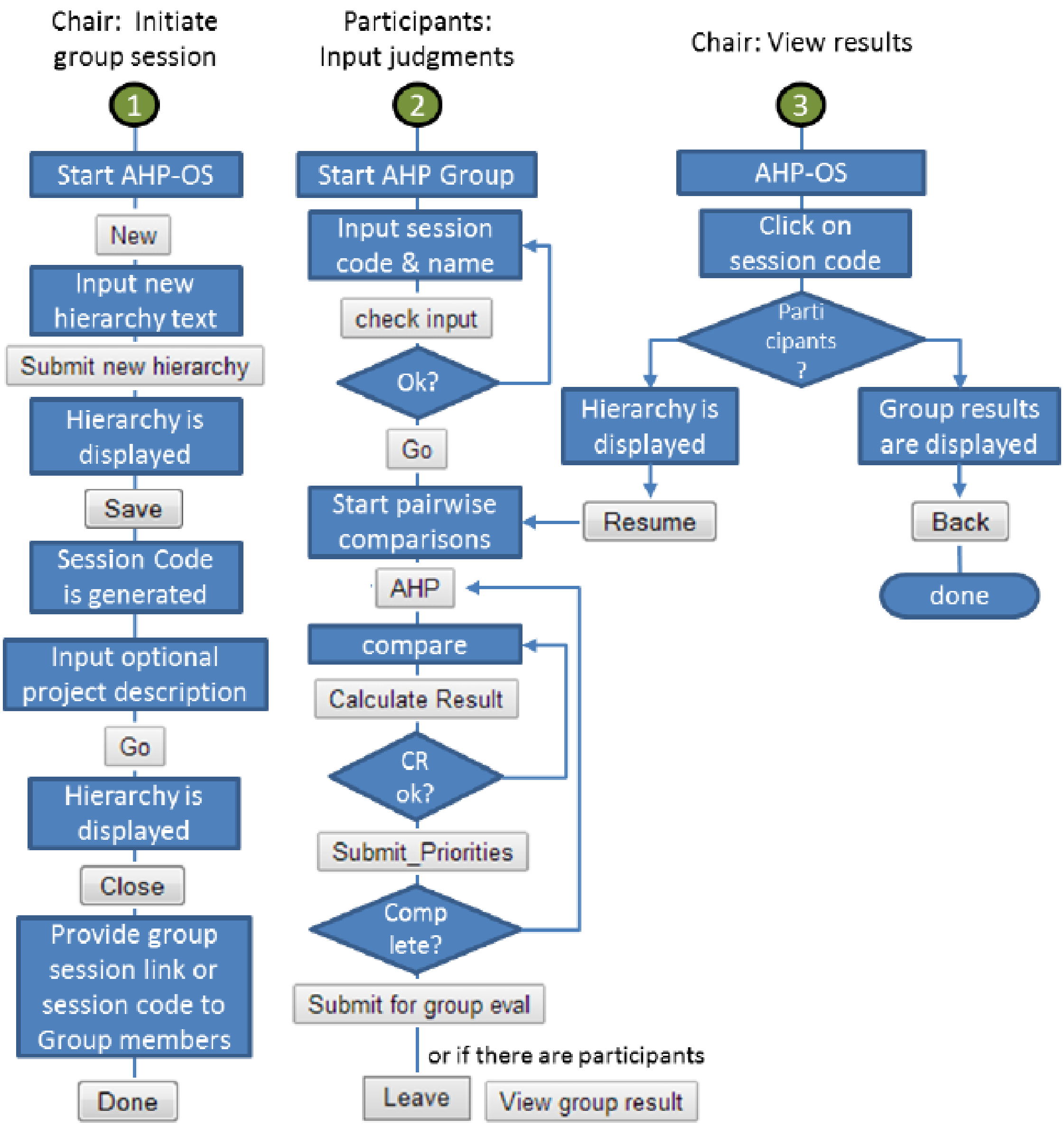


Figure 58 Flowchart of BPMSG's AHP-OS tool instructions for group use

Appendix U Decision support tool visualization

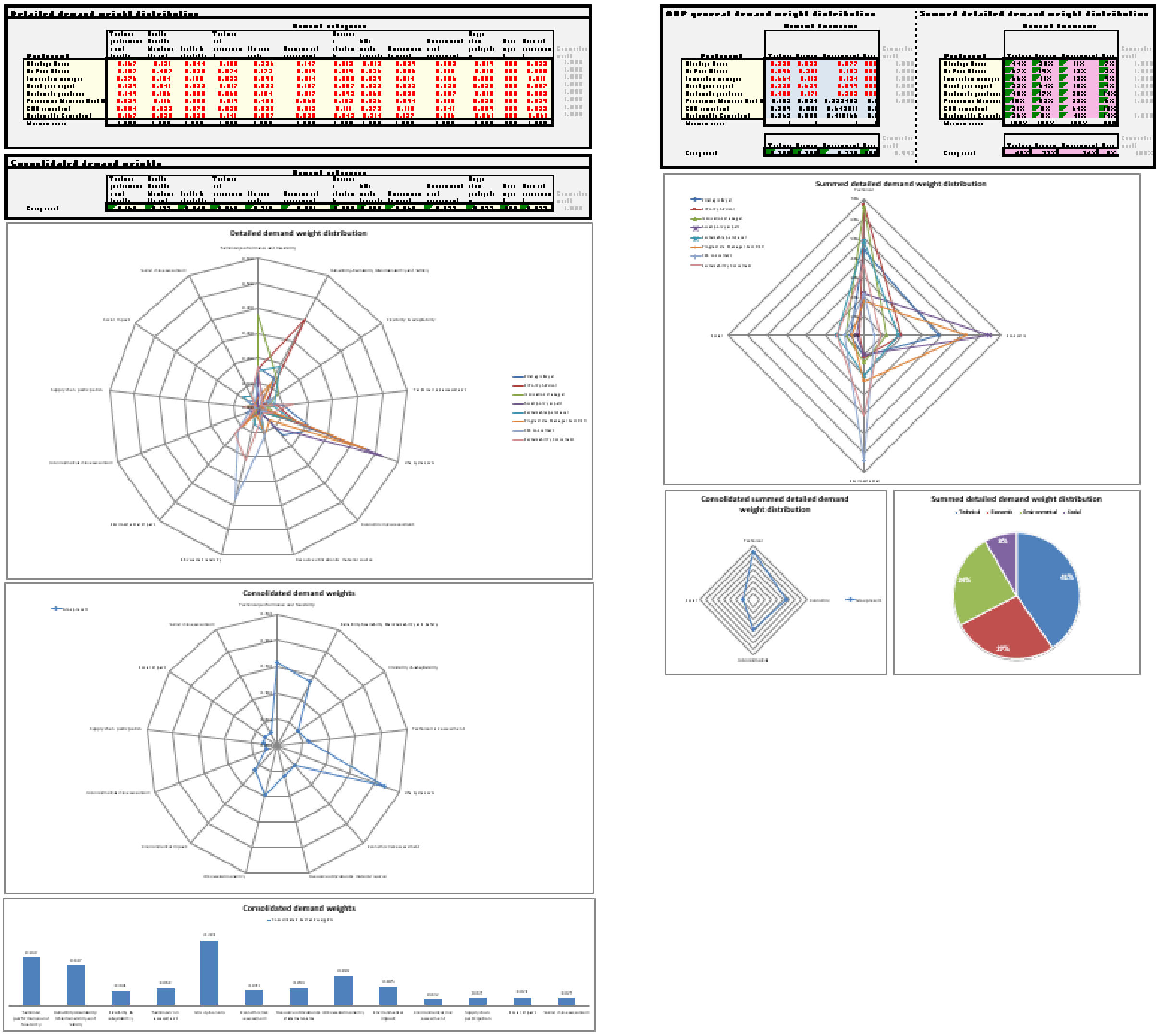


Figure 59 Overview decision support tool AHP output visualization

Detailed demand weight distribution

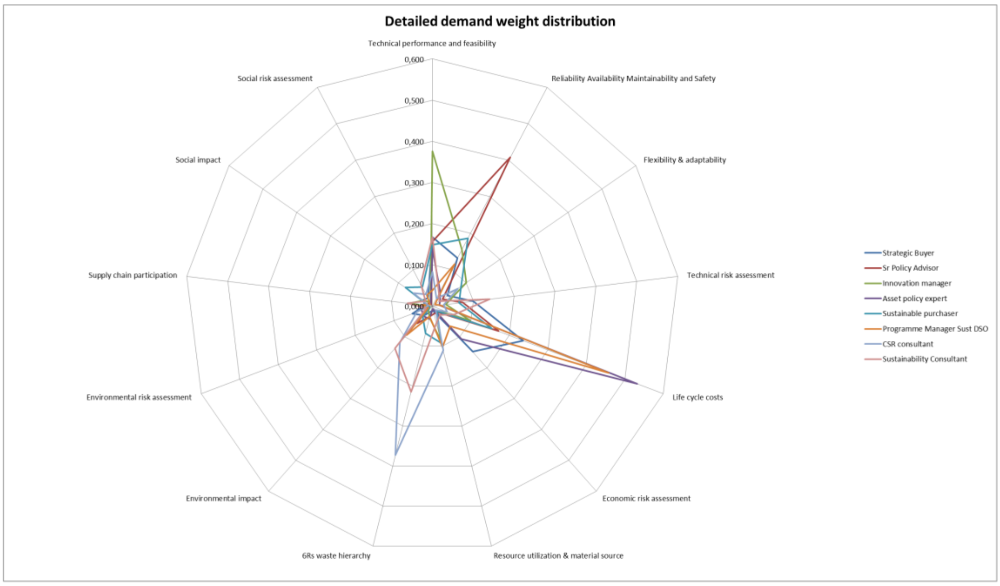
Demand categories

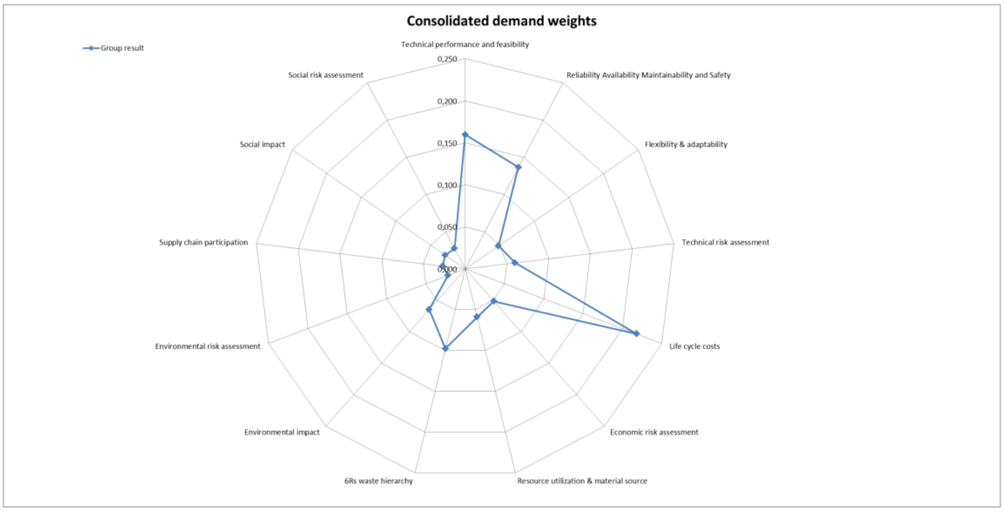
Participant	Technical performance and feasibility	Reliability Availability Maintainability and Safety	Flexibility & adaptability	Technical risk assessment	Life cycle costs	Economic risk assessment	Resource utilization & material source	6Rs waste hierarchy	Environmental impact	Environmental risk assessment	Supply chain participation	Social impact	Social risk assessment	Cummulative weight
Strategic Buyer	0.167	0.131	0.044	0.100	0.236	0.147	0.013	0.013	0.029	0.052	0.019	0.027	0.022	1.000
Sr Policy Advisor	0.157	0.407	0.030	0.074	0.172	0.019	0.019	0.026	0.056	0.015	0.010	0.012	0.005	1.000
Innovation manager	0.376	0.154	0.100	0.033	0.098	0.014	0.085	0.029	0.014	0.006	0.055	0.024	0.011	1.000
Asset policy expert	0.139	0.041	0.023	0.017	0.533	0.107	0.007	0.032	0.032	0.028	0.028	0.007	0.007	1.000
Sustainable purchaser	0.149	0.186	0.085	0.065	0.154	0.017	0.093	0.068	0.035	0.007	0.010	0.079	0.052	1.000
Programme Manager Sust DSO	0.039	0.116	0.008	0.019	0.458	0.065	0.103	0.026	0.094	0.010	0.025	0.007	0.029	1.000
CSR consultant	0.084	0.022	0.075	0.028	0.038	0.013	0.111	0.373	0.118	0.041	0.009	0.055	0.032	1.000
Sustainability Consultant	0.167	0.035	0.020	0.141	0.057	0.028	0.042	0.214	0.137	0.016	0.061	0.020	0.061	1.000
Maximum score	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Consolidated demand weights

Demand categories

	Technical performance and feasibility	Reliability Availability Maintainability and Safety	Flexibility & adaptability	Technical risk assessment	Life cycle costs	Economic risk assessment	Resource utilization & material source	6Rs waste hierarchy	Environmental impact	Environmental risk assessment	Supply chain participation	Social impact	Social risk assessment	Cummulative weight
Group result	0.160	0.137	0.048	0.060	0.218	0.051	0.059	0.098	0.065	0.022	0.027	0.029	0.027	1.000





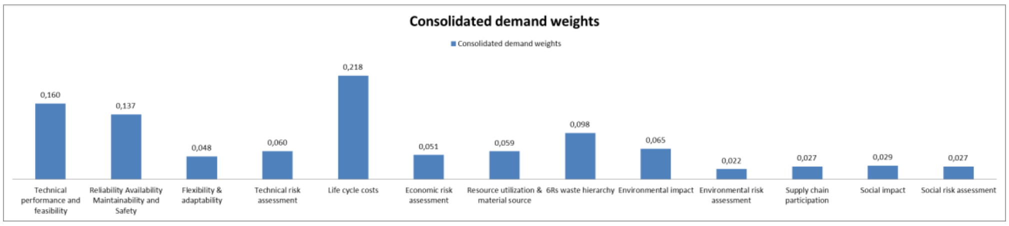
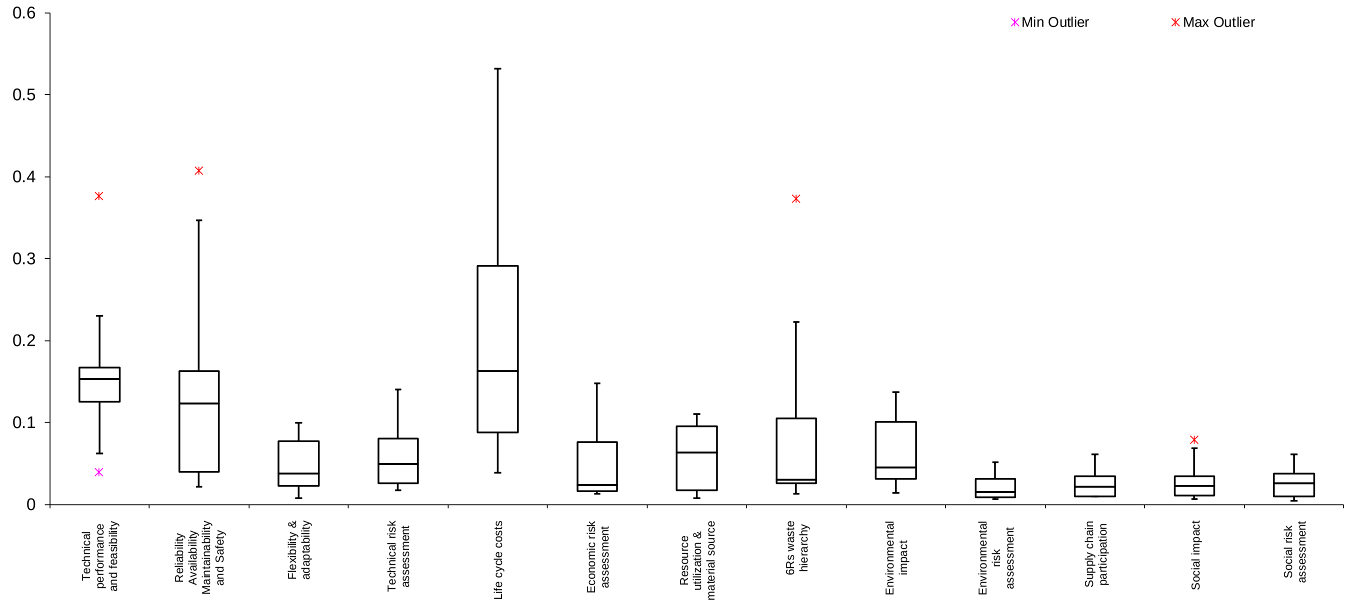


Figure 60 Decision support tool AHP output visualization: level 2 criteria radar plots

Box Plot Template



Labels	Technical performance and feasibility	Reliability Availability Maintainability and Safety	Flexibility & adaptability	Technical risk assessment	Life cycle costs	Economic risk assessment	Resource utilization & material source	6Rs waste hierarchy	Environmental impact	Environmental risk assessment	Supply chain participation	Social impact	Social risk assessment
Min	0.038792	0.021594	0.007959	0.01735	0.038	0.013	0.007	0.013	0.014	0.006	0.009	0.007	0.005
Q_1	0.12534175	0.039243	0.0224405	0.0261175	0.08799	0.01635725	0.017182234	0.026258151	0.031258304	0.00903725	0.00984543	0.010482298	0.00961475
Median	0.152657696	0.123516754	0.037117825	0.0491195	0.162873091	0.023624863	0.0636765	0.0302395	0.04544824	0.015332548	0.021811072	0.022161	0.025760592
Q_3	0.167168271	0.162357	0.07745525	0.080712895	0.291456149	0.075713	0.09535275	0.10488475	0.10036175	0.03140125	0.03445975	0.033860866	0.03737725
Max	0.376292	0.407468207	0.099987	0.140502	0.532508	0.147440073	0.110735	0.372825	0.137222	0.051745928	0.060685	0.078928	0.060685
IQR	0.041826521	0.123114	0.05501475	0.054595395	0.203466149	0.05935575	0.078170516	0.078626599	0.069103446	0.022364	0.02461432	0.023378568	0.0277625
Upper Outliers	1	1	0	0	0	0	0	1	0	0	0	1	0
Lower Outliers	1	0	0	0	0	0	0	0	0	0	0	0	0

Data Table	Technical performance and feasibility	Reliability Availability Maintainability and Safety	Flexibility & adaptability	Technical risk assessment	Life cycle costs	Economic risk assessment	Resource utilization & material source	6Rs waste hierarchy	Environmental impact	Environmental risk assessment	Supply chain participation	Social impact	Social risk assessment
Strategic Buyer	0.167	0.131	0.044	0.100	0.236	0.147	0.013	0.013	0.029	0.052	0.019	0.027	0.022
Sr Policy Adviso	0.157	0.407	0.030	0.074	0.172	0.019	0.019	0.026	0.056	0.015	0.010	0.012	0.005
Innovation mana	0.376	0.154	0.100	0.033	0.098	0.014	0.085	0.029	0.014	0.006	0.055	0.024	0.011
Asset policy exp	0.139	0.041	0.023	0.017	0.533	0.107	0.007	0.032	0.032	0.028	0.028	0.007	0.007
Sustainable purc	0.149	0.186	0.085	0.065	0.154	0.017	0.093	0.068	0.035	0.007	0.010	0.079	0.052
Programme Man	0.039	0.116	0.008	0.019	0.458	0.065	0.103	0.026	0.094	0.010	0.025	0.007	0.029
CSR consultant	0.084	0.022	0.075	0.028	0.038	0.013	0.111	0.373	0.118	0.041	0.009	0.055	0.032
Sustainability Co	0.167	0.035	0.020	0.141	0.057	0.028	0.042	0.214	0.137	0.016	0.061	0.020	0.061

Figure 61 Decision support tool AHP output visualization: level 2 criteria box plot

AHP general demand weight distribution

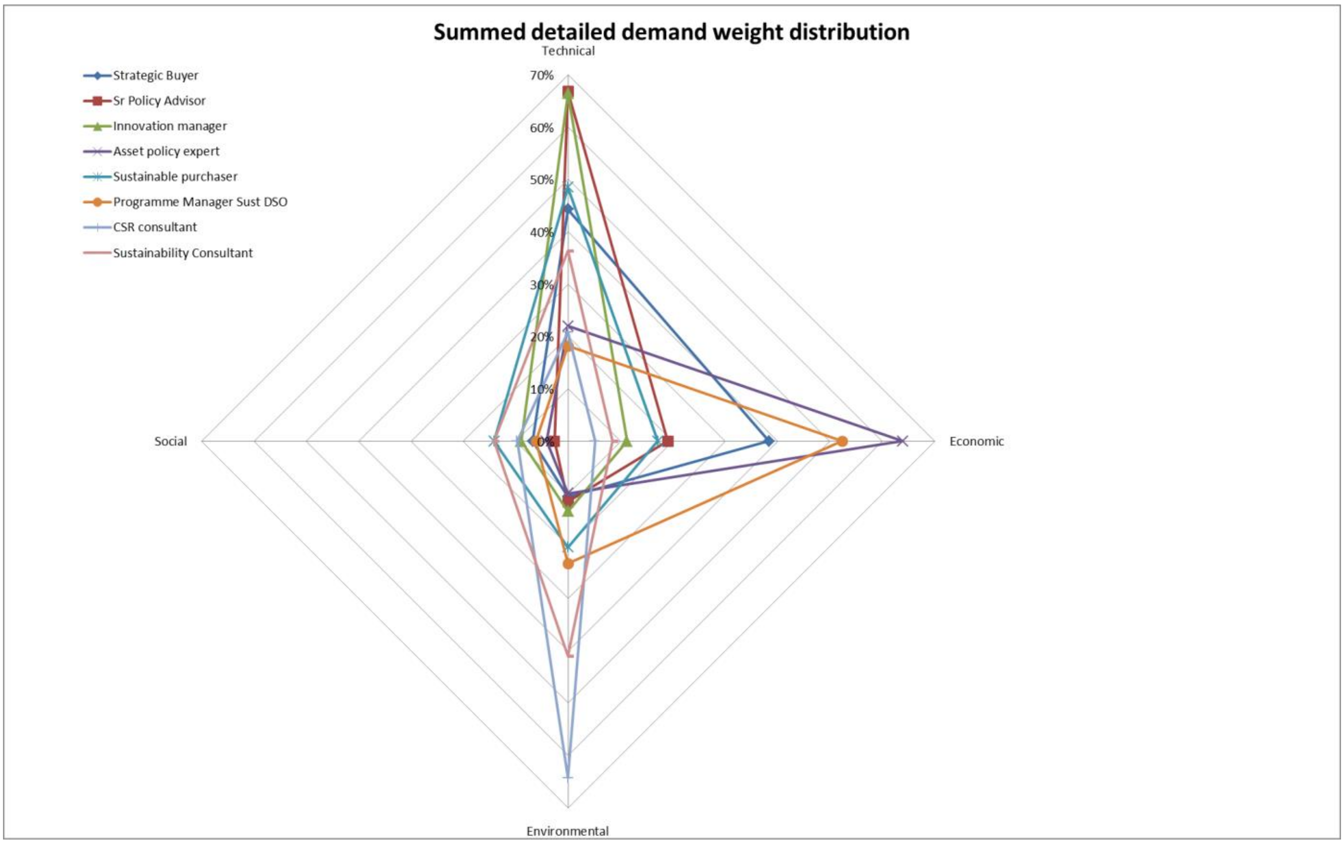
Participant	Technical	Economic	Environmental	Social	Cummulative weight
	Demand dimensions				
Strategic Buyer	0.320	0.523	0.077	0.081	1.000
Sr Policy Advisor	0.596	0.251	0.103	0.050	1.000
Innovation manager	0.664	0.113	0.134	0.090	1.000
Asset policy expert	0.220	0.639	0.099	0.041	1.000
Sustainable purchaser	0.485	0.171	0.203	0.141	1.000
Programme Manager Sust DSO	0.181632	0.523598	0.233483	0.0613	1.000
CSR consultant	0.20873	0.051226	0.642811	0.0972	
Sustainability Consultant	0.363285	0.08495	0.410166	0.1416	
Maximum score	1	1	1	1	

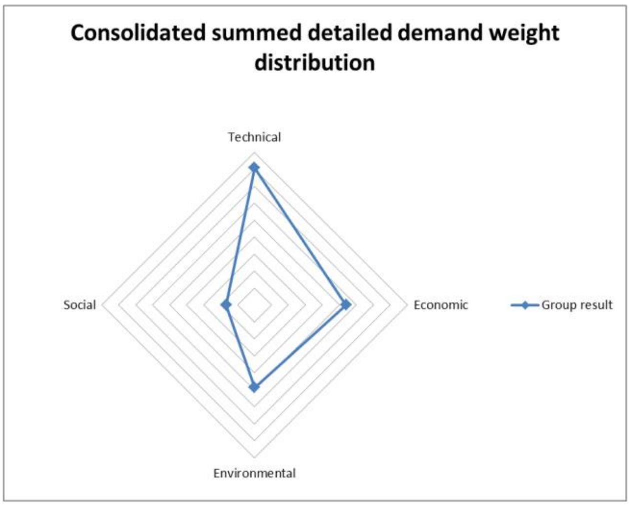
	Technical	Economic	Environmental	Social	Cummulative weight
Group result	0.380	0.295	0.238	0.080	0.993

Summed detailed demand weight distribution

Participant	Technical	Economic	Environmental	Social	Cummulative weight
	Demand dimensions				
Strategic Buyer	44%	38%	11%	7%	1.000
Sr Policy Advisor	67%	19%	12%	3%	1.000
Innovation manager	66%	11%	13%	9%	1.000
Asset policy expert	22%	64%	10%	4%	1.000
Sustainable purchaser	48%	17%	20%	14%	1.000
Programme Manager Sust DS	18%	52%	23%	6%	1.000
CSR consultant	21%	5%	64%	10%	
Sustainability Consultant	36%	8%	41%	14%	1.000
Maximum score	100%	100%	100%	100%	

	Technical	Economic	Environmental	Social	Cummulative weight
Group result	40%	27%	24%	8%	100%





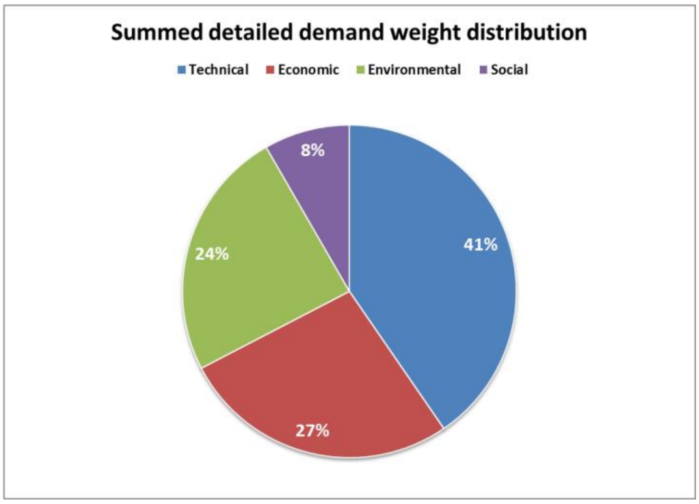
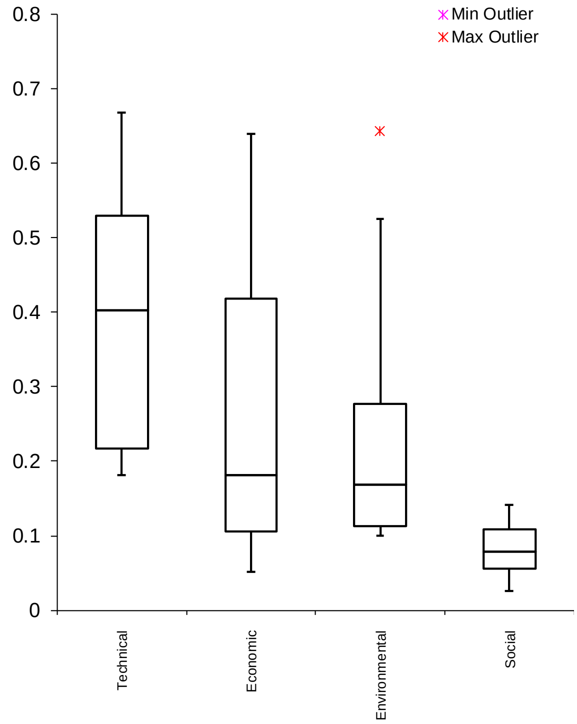


Figure 62 Decision support tool AHP output visualization: level 1 criteria radar plots

Box Plot Template



Labels	Technical	Economic	Environmental	Social
Min	0.181632	0.051227	0.099397	0.02607732
Q_1	0.21737	0.1056165	0.1129883	0.0563005
Median	0.403133807	0.180900454	0.168292	0.078651407
Q_3	0.52967425	0.418398703	0.27765375	0.108224
Max	0.668077806	0.63901	0.642812	0.141598
IQR	0.31230425	0.312782203	0.16466545	0.0519235
Upper Outliers	0	0	1	0
Lower Outliers	0	0	0	0

Data Table	Technical	Economic	Environmental	Social
	0.443	0.383	0.106	0.068
	0.668	0.191	0.115	0.026
	0.664	0.113	0.134	0.090
	0.220	0.639	0.099	0.041
	0.485	0.171	0.203	0.141
	0.182	0.524	0.233	0.061
	0.209	0.051	0.643	0.097
	0.363	0.085	0.410	0.142

Figure 63 Decision support tool AHP output visualization: level 1 criteria box plot

Appendix V   Fair Meter case study details

The following experts have participated in the Fair Meter case study workshop and are consulted to evaluate the procurement policy: W. Janssen van Doorn (strategic purchaser Alliander), H. Van Zantvoort (sustainable purchaser Alliander).

Note: In the Fair Meter case, both environmental and social objectives are defined. Based on the proposed terminology in §2.2.2, the wording of *fair* would refer to social and economic objectives. For clear communication purposes with participants in the Fair Meter case study, *fair* is a temporary substitute for *sustainable*. Hereby, fair also incorporates environmental objectives.

Fair Meter project introduction

The fair smart meter project started in 2013. The consortium of Liander and Stedin Netbeheer, a large co-DSO, together with stakeholders from the Dutch government and knowledge institutes, set out to develop the Fair Meter. The objective of the Fair Meter project was to develop a new generation of electricity and gas meters for public household usage that are both *smart* and *fair.* The Fair Meter is an electronic device that measures electricity and gas consumption. The Fair Meter project has four project goals (Liander NV & Stedin Netbeheer BV, 2016):

1. "Provide at least 80% of all small-scale households with a Smart meter before 1 January 2021;
2. Maximising customer satisfaction;
3. Minimising the total cost of ownership of the entire Smart Meter Supply Chain and Smart metering process;
4. In cooperation with Smart Meters Supply Chain the Tenderer has to improve its performance by implementing measures according to the Fair Meter principles."

The shared ambition of stakeholders was to take a leading role regarding sustainability principles and hereby inspire and incentivise others in the DSO and similar industries to integrate sustainability in their operation. Four issues were addressed: forced labour, conflict materials, material scarcity and E-waste. These four issues are translated in the commitment to achieve the following seven Fair Meter principles (FairSmartMeter, 2004):

Table 43 Fair Meter principles

No.	Fair Meter principles
1	Energy and CO_2 neutral supply chain
2	Meters that are complying with the circular principles
3	No use of conflict metals, hazardous substances or virgin materials
4	Responsible working conditions throughout the supply chain
5	Gaining and maintaining a transparent status quo of value chain sustainability performance
6	Keep the meter energy neutral in use
7	Make extra services of the meter available to end users

Prior to the applying the sustainable procurement policy to the Fair Meter case, more insights in the project are obtained to understand the course of action throughout the procurement process. Table X summarizes the positive and negative lessons learned.

Table 44 Lessons learned Fair Meter procurement process

Topic	Positive lessons learned	Negative lessons learned
Process & communication	The general procurement approach of an open and dialogue-centered process positively contributed to the end result.	Conflicts of interest among internal actors due to a limited level of transparency.
	Active communication via multiple websites (e.g. www.fairsmartmeter.com) and industry magazines contributes to external stakeholder support.	Dealing with both hard agreements and soft innovation freedom.
		Integrating the results of the supplier innovation process as a variable throughout the procurement process.
		Difficulties in defining the procurement process without a realistic estimate/ assessments of potential final alternative outcomes.
Criteria & weighting	Utilizing the *best value procurement* method to execute the alternative evaluation.	Difficulties faced during the formulation of best value criteria, including the difference between ambitions and reality.
		Defining arrangements regarding the fair ambitions on: probability of achieving results, and the consequences if results are or are not achieved.
		Evaluation of environmental and social supplier indicators tends to become subjective within the selection criteria evaluation process.
Product result	Final result was very much in line with the desired result, partly due to the similar sustainability mindset of suppliers.	Realistic milestones for results over time are required to guide the *fair* ambition performance.
	Leadership role of Liander and Stedin towards the industry was essential to keep ambitions high.	Clear and convincing expression by Liander and Stedin regarding the binding character of (fair) agreements by suppliers to guarantee long term results.

Fair Meter procurement challenges

The Fair meter pilot project faced challenges as the procurement process did not follow the prescribed procurement methodology of Alliander. Firstly, because of the collaboration with Stedin who have their own procurement methodology, secondly because there was no pre-made set of documents suitable for the socially responsible (sustainable) procurement process and lastly because Liander and Stedin aimed to take on socially rooted problems which introduced *best value procurement* (optimal price-quality balance as a guideline for tender evaluation). Deviations from the Alliander Procurement Methodology were:

- The explicit presentation of product and process wishes to the suppliers in an early stage of the procurement process
- Defining the demand partly function-based and partly specification-based: Limited freedom in interpretation on product specifications was allowed while extensive freedom in suppliers suggestions for a sustainable Fair Meter production process was allowed.
- The procurement process involved a pre-selection of suppliers which made it a non-public process. The dominant criteria for this selection was the mind-set of suppliers: A strong intrinsic motivation to collectively develop a fair product was desirable.

The supplier selection was based on Fair Performance. The Fair Meter project can be considered the first large scale procurement process with environmental and social demands. The set of requirements and the weighted selection criteria were established by a multi-functional team of Liander and approved by the steering committee of managerial individuals from multiple internal departments. Drafting the requirements and criteria was based on inputs from market consultation analysis, without direct communication with supplier stakeholders.

To understand the actor perceptions and interests in the sustainability goals and their prominent place in this procurement process, the attitude, power and interest of six actors is briefly analysed (see Table X).

Table 45 Actor analysis Fair Meter procurement process

Stakeholder	Attitude	Power	Interest
CSR Liander & Stedin	Very positive and eager to excel	Low	High
Purchasing	Positive and eager to excel	Medium-High	Low
Asset management	Neutral and passive: resistance to change	Medium	High
Operation	Neutral and passive: resistance to change	Medium	Medium
Stedin business	Slightly negative: resistance to higher costs	High	Medium
Top management	Slightly positive and distant: resistance to risk increases, no resistance to higher costs. Willingness to invest via green bonds and propagating positive image.	High	Medium

Fair Meter sustainable procurement policy validation

The procurement policy methodology is applied in subsequent subparagraphs. The steps in each stage are followed and activities relevant to the case study are undertaken.

Initiation stage

In the initiation stage, the following activities are relevant in the case study context:

- Formulate views on sustainability
- Define and motivate binding requirements
- Define and motivate distinctive criteria
- Explore business models & contracting types

The corporate view on sustainability is described to point out the ambitious aim of the Fair Meter pilot. Both the UN SDGs and the Doughnut economics model illustrate the selected sustainability targets. The fair (sustainability) principles of Table 27 are the foundation of the procurement requirements (see §2.2.10.1 on sustainable decision principles). Sustainable development in the Fair meter project focusses on stimulating two social foundations (energy and jobs) while reducing the impact on three environmental ceilings (land use change, climate change and chemical pollution). Figure 45 shows these five focus areas. Translating these focus areas to SDGs, seven out of seventeen align with the sustainable development focus areas and fair meter principles. Table 28 lists the relevant SDGs.

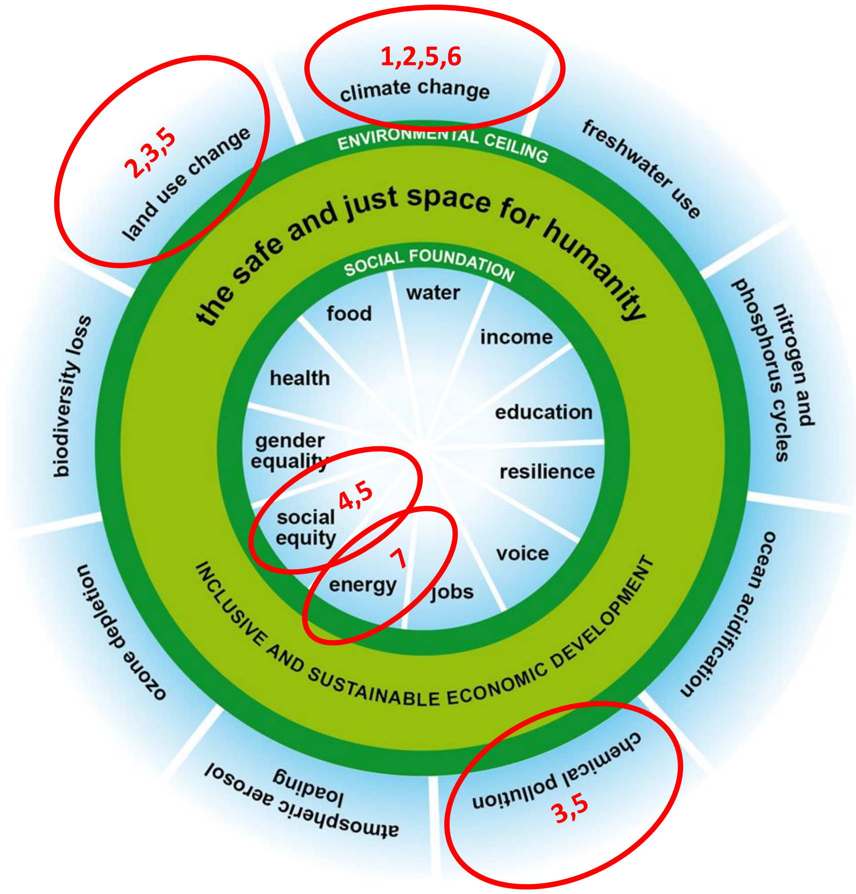


Figure 64 Fair Meter sustainability principles aligned with Doughnut economics model

Table 46 Sustainable Development Goals related to Fair Meter project

SDG	Description
Goal 3	Ensure healthy lives and promote well-being for all at all ages
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12	Ensure sustainable consumption and production patterns
Goal 13	Take urgent action to combat climate change and its impacts

From the five sustainable development focus areas, seven SDGs, fair meter principles, product and process demands (see Table XX-XX), an aggregated overview of fair meter demands is developed using the demand matrix (see Table 29). Two types of demands are distinguished: product and process demands (in **bolt**) and fair demands (in *italic*).

Table 47 Selection criteria weights Fair Meter procurement (adapted from Liander NV & Stedin Netbeheer BV, 2016)

Selection criteria weights: Appendix A.3	
General (17%)	
	Financial and economic capacity 2%
	Experience 10%
	CSR and Fair 5%
E-meters (49.8%)	
	Roadmap 3%
	CSR and Fair 6%
	Maturity of supply chain and quality management 17.4%
	Maturity of the product development process 14.8%
	Maturity of the support process 5.4%
	Maturity of the risk management process 4.2%
G-meters (33.2%)	
	Roadmap 2%
	CSR and Fair 4%
	Maturity of supply chain and quality management 11.6%
	Maturity of the product development process 9.2%
	Maturity of the support process 3.6%
	Maturity of the risk management process 2.8%

Table 48 Set of requirements Fair Meter procurement (adapted from Liander NV, Stedin Netbeheer BV, & DELTA Netwerkbedrijf BV, 2016)

Set of requirements: A.02	
2 PRODUCT	
Normative compliance:	NEN, NPR, IEC, MID, DSMR, CDMA, Welmec
Meeting requirements:	General requirements
	E-meter requirements
	G-meter requirements
	Requirements derived from AMvB, NTA, P4
	Power quality requirements
	Installation and maintenance requirements
	Wide Area Network (WAN) requirements
	Testing and defect analysis requirements
3 PRIVACY & SECURITY	
Normative compliance:	Dutch privacy & security requirements 2.0
Meeting requirements:	Privacy and security requirements
4 DEVELOPMENT AND TESTING	
Normative compliance:	none
Meeting requirements:	Development and testing requirements
5 SUPPLY CHAIN MANAGEMENT	
Normative compliance:	none
Meeting requirements:	Supply chain management requirements
6 QUALITY ASSURANCE	
Normative compliance:	none
Meeting requirements	Quality assurance requirements
7 FAIR METER PRINCIPLES	
Normative compliance:	Code of Conducts, Due diligence guidance, UN principles, Directives, Regulation
Meeting requirements	Fair meter pilot requirements

Table 49 Fair ambitions Fair Meter procurement (adapted from Liander NV et al., 2016)

The Contracting Entity applies at least the following ambitions with regard to the concept of 'Fair':

Components	Description	Ambition of Contracting Entity
Process		
Energy & Emission	Chain emissions and energy consumption over the entire chain.	Full energy and CO_2 neutral meter chain.
Resources & Raw materials	Responsible use of raw materials, minimising waste flows, approaching the chain as a circular process.	Entirely circular meter. In other words, the meter is constructed of secondary raw materials and is fully recyclable.
Fair Materials	Use of conflict-free metals and raw materials.	The meter is produced without the use of conflict metals or raw materials. Materials whose origin cannot be determined with certainty are also avoided in the production process.
Labour	Responsible working conditions for employees in the entire chain.	All chain parties ensure responsible working conditions for their employees and can demonstrate this. Insofar as possible, these are assessed against international labour Conventions.
Transparency	Refers to the degree of transparency with regard to the status quo of each Fair component.	For each component, the status quo is made entirely clear by the relevant party.
Product		
Energy use	Relates to the energy consumption of the meter during its life expectancy.	The Fair Meter is energy neutral in use.
Resources / raw materials	Relates to the use of hazardous substances (hazardous substances) in the meter	Hazardous substances are not used in the production of the meter. This concerns both the composition of parts of the product, and additives in production. Where this cannot be avoided, these materials are obtained from a secondary source.
Software & Data	Concerns the extent to which the end user has insight into the software, its functionality and the use (by third parties) of (personal) data that is communicated by the meter.	All extra services on the meter are opt-in for the end user. The end user fully understands the extent and type of data that is communicated.

The asset life cycle phases from the requirement matrix are also used to discuss sustainable business models that align with the fair meter project. From the generalized sustainable business model typologies, four out of five are of potential interest to the fair meter project. Alternatives can focus on one or multiple of the business models to distinguish themselves from competitors. Each of these four model types has a different sustainability potential: Component and material reduction (dematerialization) can reduce resource use and simplify the product, optimizing the functionality of the product may yield increased user satisfaction and 'smarter' meter use by the DSO, use circular economy principles and non-virgin materials (circularity and material loops) can bring down the negative impact of the product on the environment, and maximizing the useful life of the product

Table 50 Fair Meter asset material life cycle demand matrix

	Design	Raw material	Production	Transportation	Installation	Use	End of use
	Conceptual design, preliminary design, detail design	Virgin and recyclate	Development, production	Transport	Construction, commission	Utilisation and support: operate, maintain, performance and modify, upgrade	Retirement and disposal: decommission, waste management, integration in other chains
Technical		**Supply chain management requirements**	**Product requirements**	**Supply chain management requirements**	**Product requirements**	**Product requirements**	
		Quality assurance requirements	**Development and testing requirements**	**Quality assurance requirements**	**Quality assurance requirements**	*Software & data*	
			Supply chain management requirements			**Privacy & security requirements**	
			Quality assurance requirements			**Supply chain management requirements**	
			Fair Meter Pilot			**Quality assurance requirements**	
Economic	Design costs	Material costs	Production costs	Transport costs	Installation costs	O&M costs	End of use costs
						User costs	
Environmental		*Chain emission & energy consumption*	*Chain emission & energy consumption*	*Chain emission & energy consumption*	*Chain emission & energy consumption*	*Chain emission & energy consumption/energy use*	*Chain emission & energy consumption*
		Resources & Raw Materials	*Transparency status quo*				*Recyclable*
		Fair materials	*Hazardous substances*				*Quality assurance requirements (Bill of Materials, traceability, transparency)*
		Transparency status quo	*Quality assurance requirements (Bill of Materials)*				
		Hazardous substances	**Fair Meter Pilot**				
		Quality assurance requirements (Bill of Materials)					
Social		*Labour conditions*	*Labour conditions*	*Labour conditions*	*Labour conditions*	*Labour conditions*	*Labour conditions*
		Fair materials	*Transparency status quo*			*Software & data*	
		Transparency status quo	*Hazardous substances*			**Privacy & security requirements**	
		Hazardous substances	**Fair Meter Pilot**				

from multiple life limiting dimensions (prolong lifetime) may reduce the replacement frequency of the product, reducing its economic, environmental and social footprint.

Table 51 Fair Meter sustainable business models

Design	Raw material	Production	Transportation	Installation	Use	End of use
Conceptual design, preliminary design, detail design	Virgin and recyclate	Development, production	Transport	Construction, commission	Utilisation and support: operate, maintain, performance and modify, upgrade	Retirement and disposal: decommission, waste management, integration in other chains
Dematerialization	Circularity and material loops	Dematerialization			Dispossession	Circularity and material loops
Optimize functionality		Circularity and material loops			Prolong lifetime	
					Optimize functionality	

The fair meter suppliers both have a different focus in their alternative. Landis+Gyr offer an improved and more fairly produced meter (focussing on dematerialization, optimization of functionality and recycled content) and Floniskra focusses on a high level of supply chain transparency and a specific aim on data collection, analytics and visualization (which translates into optimize functionality, circularity and material loops and prolong lifetime). Both suppliers thus offer a different focus in their fair meter project proposal that are assessed based on one single set of demands.

Sourcing stage

In the sourcing stage, the following activities are relevant in the case study context:

- Define supplier selection and alternative assessment demands
- Develop criteria weights and indicators
- Assess alternatives

The set of demands in Table 29 is aggregated to five criteria over each of the four dimensions. The criteria are *project capability submittal* (i.e. performance and characteristics of the proposed product), *feasibility study* (i.e. how desirable and realistic is the alternative), *risk assessment* (i.e. identify, analyse and mitigate risks) and *value added* (i.e. the increased positive impact of the product), and *impact* (i.e. the (potential) negative consequences of the product). The technical, economic, environmental and social dimension is considered for the criteria (table 31). The hierarchical visualization of the criteria is shown in Table 32.

Table 52 Fair Meter criteria hierarchy

Technical criteira	Economic criteira	Environmental criteira	Social criteria
Project capability submittal	Project capability submittal	Project capability submittal	Project capability submittal
Feasibility study	Feasibility study	Feasibility study	Feasibility study
Risk Assessment	Risk Assessment	Risk Assessment	Risk Assessmemt
Value added submittal	Value added submittal	Value added submittal	Value added submittal
	Tender Price (economic impact)	Environmental impact	Social impact

Weighting the criteria in the criteria hierarchy using the AHP software tool of Groepel (2017) in collaboration with two Liander experts resulted in a consolidated weight distribution (the global priorities in Table 32). The Liander experts (one strategic purchaser, one sustainable purchaser) reached a high level of consensus on weight distributions in general as shown in Table XX. Figure XX and XX show the individual weight distribution of the experts. The consolidated result is not adjusted after the dialogue following the weighting process of the criteria.

Table 53 Group consensus criteria weight distribution Fair Meter case study

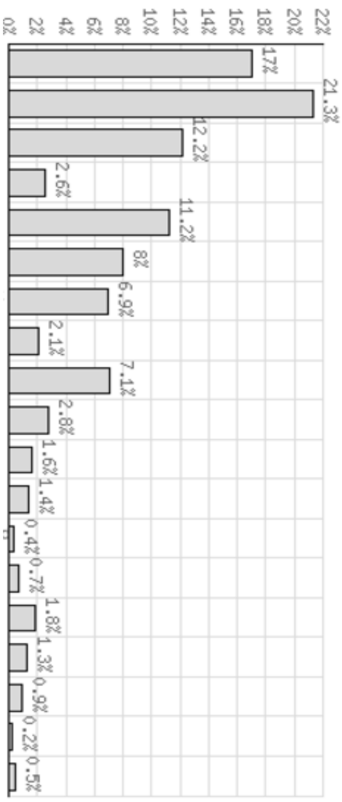
Criteria dimension	Level of group consensus	
Weight distribution among TEES dimensions	90.7%	Very high
Weight distribution technical	90.9%	Very high
Weight distribution economic	20.9%	Very low
Weight distribution environmental	66.0%	Moderate
Weight distribution social	68.6%	Moderate
General prioritization	77.1%	High

Table 54 Fair Meter consolidated criteria weights

Decision Hierarchy

Level 0	Level 1		Level 2		Global Priorities
Fair Meter Case v1	Technical	0.5313	? Capability T	0.3208	17.0 %
			Technical feasibility	0.4006	21.3 %
			Technical risk assessment	0.2294	12.2 %
			Technical value added	0.0492	2.6 %
	Economic	0.352	? Capability Ec	0.3176	11.2 %
			Economic feasibility	0.2259	8.0 %
			Economic risk assessment	0.1948	6.9 %
			Economic added value	0.0589	2.1 %
			economic impact/tender price	0.2028	7.1 %
	Environmental	0.0684	? Capability Env	0.4038	2.8 %
			Environmental feasibility	0.2301	1.6 %
			Environmental risk assessment	0.2098	1.4 %
			Environmental value added	0.0529	0.4 %
			Environmental impact	0.1033	0.7 %
	Social	0.0482	? Capability S	0.38	1.8 %
			Social feasibility	0.2744	1.3 %
			Social risk assessment	0.1964	0.9 %
			Social value added	0.0518	0.2 %
			Social impact	0.0974	0.5 %
					1.0

Criteria weight



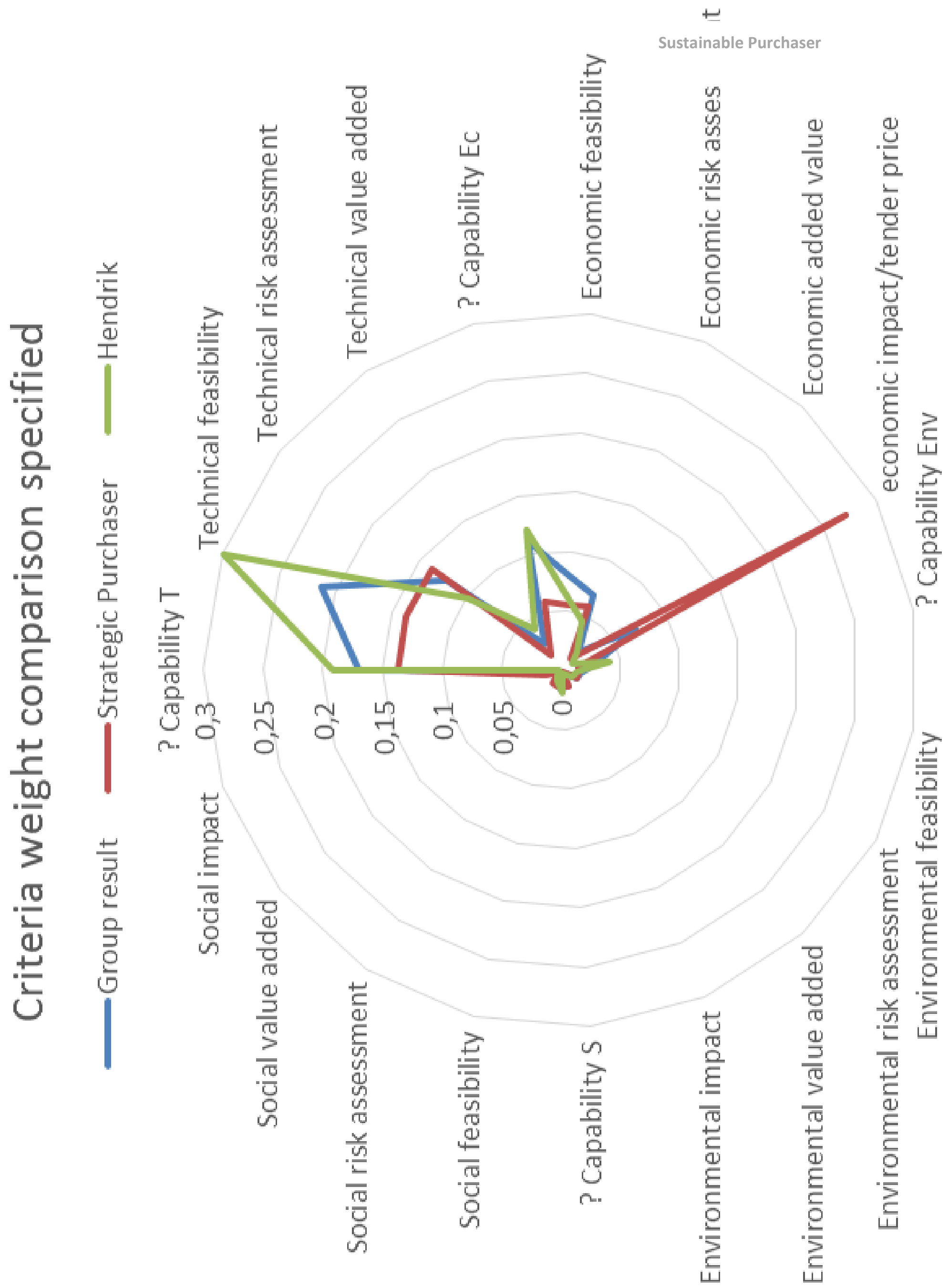


Figure 65 Fair Meter criteria weights radar plot

Weight distribution strategic purchaser

Decision Hierarchy

Level 0	Level 1		Level 2		Global Priorities
Fair Meter Case v1	Technical	0.4266	? Capability T	0.3214	13.7 %
			Technical feasibility	0.3214	13.7 %
			Technical risk assessment	0.3214	13.7 %
			Technical value added	0.0357	1.5 %
	Economic	0.4552	? Capability Ec	0.1299	5.9 %
			Economic feasibility	0.1201	5.5 %
			Economic risk assessment	0.1264	5.8 %
			Economic added value	0.0264	1.2 %
			economic impact/tender price	0.5972	27.2 %
	Environmental	0.0609	? Capability Env	0.2424	1.5 %
			Environmental feasibility	0.2424	1.5 %
			Environmental risk assessment	0.2424	1.5 %
			Environmental value added	0.0303	0.2 %
			Environmental impact	0.2424	1.5 %
	Social	0.0573	? Capability S	0.2424	1.4 %
			Social feasibility	0.2424	1.4 %
			Social risk assessment	0.2424	1.4 %
			Social value added	0.0303	0.2 %
			Social impact	0.2424	1.4 %
					1.0

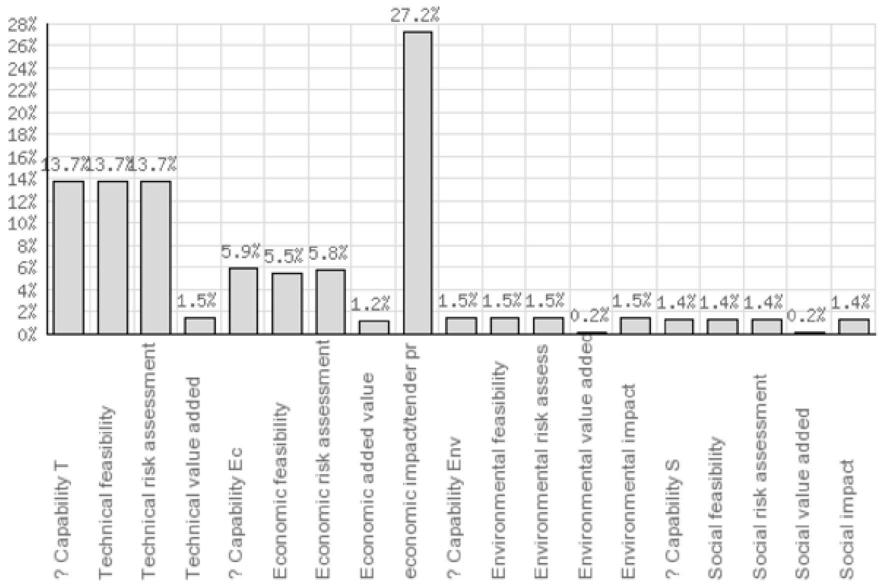


Figure 66 Fair Meter AHP-OS criteria distribution results strategic purchaser

Weight distribution sustainable purchaser

Decision Hierarchy

Level 0	Level 1	Level 2	Global Priorities
Fair Meter Case v1	Technical 0.6296	? Capability T 0.3038	19.1 %
		Technical feasibility 0.4755	29.9 %
		Technical risk assessment 0.1562	9.8 %
		Technical value added 0.0645	4.1 %
	Economic 0.2578	? Capability Ec 0.4693	12.1 %
		Economic feasibility 0.2414	6.2 %
		Economic risk assessment 0.1719	4.4 %
		Economic added value 0.0783	2.0 %
		economic impact/tender price 0.0391	1.0 %
	Environmental 0.0735	? Capability Env 0.5594	4.1 %
		Environmental feasibility 0.1782	1.3 %
		Environmental risk assessment 0.1507	1.1 %
		Environmental value added 0.0752	0.6 %
		Environmental impact 0.0366	0.3 %
	Social 0.039	? Capability S 0.5009	2.0 %
		Social feasibility 0.2578	1.0 %
		Social risk assessment 0.1338	0.5 %
		Social value added 0.0744	0.3 %
		Social impact 0.0331	0.1 %
			1.0

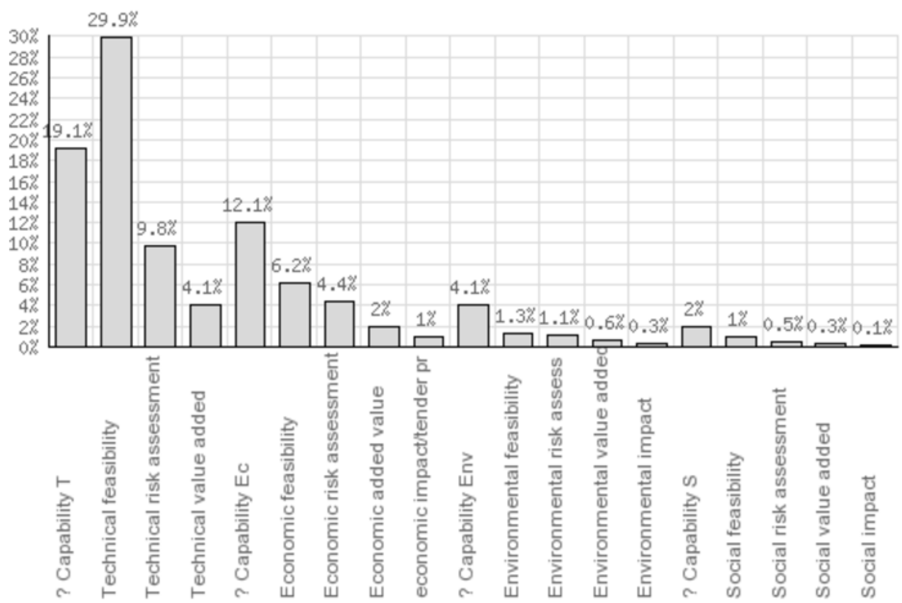


Figure 67 Fair Meter AHP-OS criteria distribution results sustainable purchaser

The global priorities are used to calculate the relative scores of the alternatives of Landys+Gyr and Floniskra by both the Liander experts individually. The aggregated assessment result shows a moderate preference of 63% for the alternative of Landys+Gyer (see Figure 47). The detailed individual assessments of both experts in Figure 46 clearly show the lack of strong consensus (74,5% based on the AHP software tool).

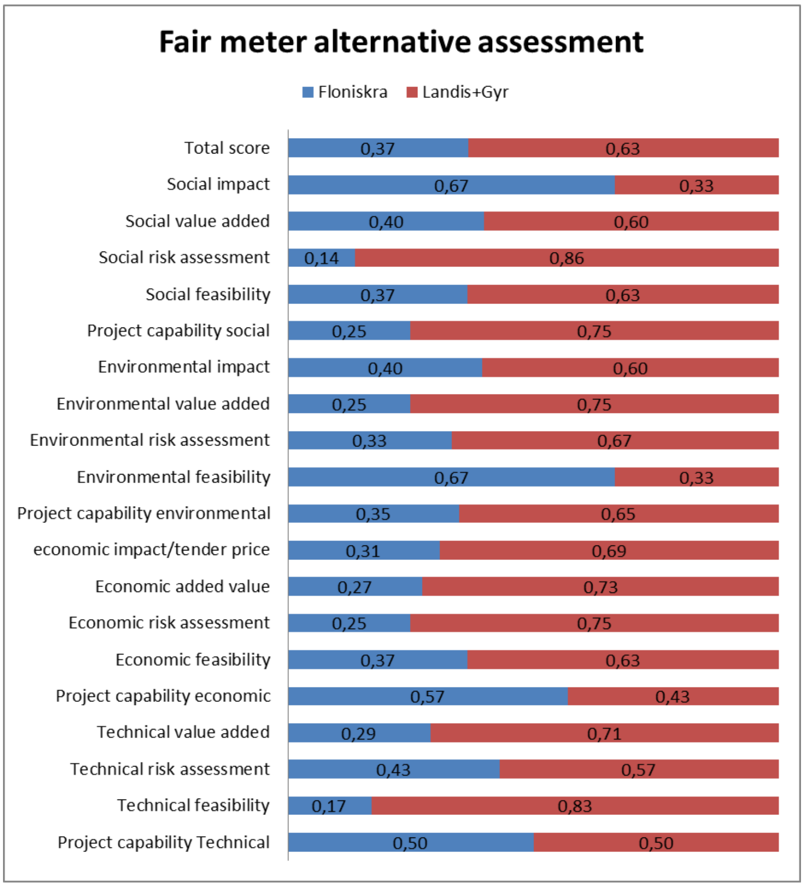


Figure 68 Fair Meter alternative assessment results

Alternative comparison
Strategic purchaser

Global Priorities	Floniskra	Landys & Gyr
17.0 %	0.0213	0.1492
21.3 %	0.1824	0.0304
12.2 %	0.0244	0.0975
2.6 %	0.0131	0.0131
11.2 %	0.014	0.0978
8.0 %	0.0398	0.0398
6.9 %	0.0514	0.0171
2.1 %	0.0104	0.0104
7.1 %	0.0357	0.0357
2.8 %	0.0092	0.0184
1.6 %	0.0017	0.014
1.4 %	0.0048	0.0096
0.4 %	0.0018	0.0018
0.7 %	0.0018	0.0053
1.8 %	0.0092	0.0092
1.3 %	0.0066	0.0066
0.9 %	0.0084	0.0011
0.2 %	0.0012	0.0012
0.5 %	0.0023	0.0023
1.0	**44.0 %**	**56.0 %**

Alternative comparison
Sustainable purchaser

Global Priorities	Floniskra	Landys & Gyr
17.0 %	0.1492	0.0213
21.3 %	0.1703	0.0426
12.2 %	0.1067	0.0152
2.6 %	0.0224	0.0037
11.2 %	0.0894	0.0224
8.0 %	0.0596	0.0199
6.9 %	0.0514	0.0171
2.1 %	0.0182	0.0026
7.1 %	0.0595	0.0119
2.8 %	0.0242	0.0035
1.6 %	0.0105	0.0052
1.4 %	0.0128	0.0016
0.4 %	0.0032	0.0004
0.7 %	0.0062	0.0009
1.8 %	0.0165	0.0018
1.3 %	0.0099	0.0033
0.9 %	0.0079	0.0016
0.2 %	0.0017	0.0008
0.5 %	0.0031	0.0016
1.0	**82.3 %**	**17.7 %**

Figure 69 Fair Meter alternative assessment result comparison strategic purchaser and sustainable purchaser

Completion phase

In the completion phase, the no activities are undertaken in the case study context

Quality assurance and quality control

The quality assurance and control activities are evaluated in the policy evaluation.

Appendix W Circular cable case study details

In contrast to the Fair Meter project, the circular cable procurement process is not completed. The procurement is within the strategic sourcing step of the Alliander procurement methodology. Similar to the previous case study, the available information of the procurement process are inputs. Expert consultation is facilitated in two workshop sessions to discuss the feasibility of the sustainable procurement process. The expert consultation workshops involved six internal experts from Liander, and two external experts from ENEXIS, a large Dutch co-DSO: B. Smallenbroek (strategic purchaser), J. Van Slogteren (Senior Consultant Asset management), P. Soepboer (Senior policy expert assets), T. Broersma (Innovator asset management), H. Van Zantvoort (Sustainable purchaser), C. den Hartog (Innovation manager asset management), D. Hermans (CSR consultant), and H. De Vries (Sustainability consultant).

In addition to the general introduction of the circular cable procurement project, the attitude, power and interest of eleven actors that are involved in the Circular Cable procurement process is briefly analysed (see Table X). This actor analysis provides insights in the process currently going on at Alliander.

Table 55 Actor analysis Circular Cable procurement

Stakeholder	Attitude	Power	Interest
Asset management	Critical attitude but intrinsic motivation to integrate sustainability in asset management. Quality, safety and reliability are top priorities. Innovation is welcome, as long as standards are complied with. Need to be practical in operation: no large amounts of different cable types in the system.	High	High
Purchasing	Department welcomes sustainable procurement, also due to experience with Fair Meter. Positive but reluctant as price should not increase drastically. Willingness to pay depends on corporate management permission.	Low	Medium
CSR	Eager and ambitious to implement sustainable practices throughout the organization.	Low	High
Operations	Open for innovations as long as the new product simplifies the work rather than complicates the activities. Also skeptical towards multiple different product types at the same time due to unpractical operation and maintenance work. Focus on reliability and simplicity rather than sustainability.	Medium	Low
Corporate management	Stimulating sustainable development and steering towards KPI targets of circular procurement kilograms. Electrical cables have a high KPI impact potential due to weights. Strategic and long term economic feasibility is crucial.	High	High
Suppliers	Current suppliers are open, but in need of guaranteed business cases in order to invest and innovate. Reluctant due to large amount of goals and criteria. Aiming for minimal effort and maximal result. Public market suppliers have ambitious PR, no specific proof. No “practice what you preach” results yet.	Medium	Medium

Stakeholder	Attitude	Power	Interest
Waste processors	Profitable developments due to increasing demand for recycled and upcycled material. 'Waste=food' leads to new businesses and dependability of supply chain on waste processors, therefore eager to participate in current developments.	Low	Medium
Customers	The average household client does not care about a circular network developments. Large scale industrial clients have a divided attitude: costs should remain minimal, but potential positive PR in case of lower CO_2 emissions related to their electricity use.	Low	Low
Government	As circular DSO assets contribute to a more sustainable Dutch electricity grid, and circular procurement contributes to the national sustainable procurement targets, the government is in favour of the initiative. Passive actor who is not involved in the process.	High	High
Regulatory authorities	Passive attitude, responding to the possible need for new or revised standards. Innovations have to meet existing standards.	High	Low
Shareholders	The benchmarked price of the service offered may increase due to higher life cycle costs of assets. Higher investments imply a lower dividend and therefore a lower share in profits for shareholders. Attitude of municipalities largely dependent on intrinsic motivation: sustainability-minded are positive.	High	Low-medium

Initiation stage

The corporate sustainability view of Liander in the specific circular cable situation focusses on the reduction of negative impact on land use change (virgin material extraction) and climate change (emissions) while providing energy to Dutch clients. Translating these three focal points of sustainability into SDGs, the procurement of the circular cable can contribute to SDG 7, 9 and 12 considering the function of the cable and the sustainable business models conventional cable, and to SDG 13 due to the circular principles that aim to reduce the contribution to climate change in combination with minimal cable losses and a long product lifetime.

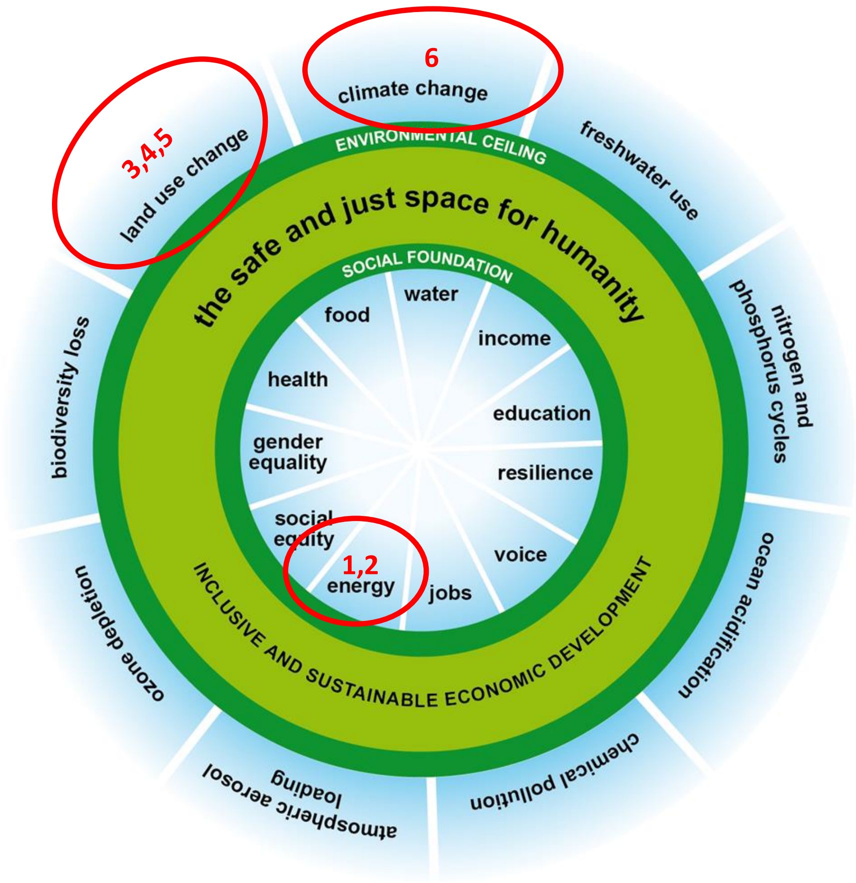


Figure 70 Circular Cable sustainability principles aligned with Doughnut economics model (adapted from (Raworth, 2017, p. 44)

Table 56 Preliminary set of demands Circular Cable

Sustainability dimensions	No.	Preliminary set of demands
Technical	1	Comparable or higher asset reliability and performance
Economic	2	Low life cycle costs with a minor (2% on TCO) willingness to pay for circular asset innovation
Environmental	3 4 5 6	High recycled material content High recyclability of material used Less material used for cable isolation Low CO_2 equivalent life cycle emissions
Social	-	No social demands set in the current stage of the procurement process

From the generalized sustainable business model typologies, two out of five are of potential interest to the circular cable project: less material used and component reduction (dematerialization) and the use of recycled material in the product as well as the possible decomposition and recycling of the product at the end of its useful lifetime (circularity & material loops).

Sourcing stage

The aggregated criteria categories in Table 38 are used in the cable case study as these criteria are able represent the preliminary set of demands. The general criteria apply to different life cycle phases. By aggregating the criteria form different phases to one criteria category, the criteria can be weighted more effectively using the AHP decision-making tool. The Circular Cable case studies of Liander and ENEXIS use slightly different criteria hierarchies. The Liander case has three additional criteria: Willingness to pay, sustainable business model and acceptance of stakeholders. To be able to combine results of the Liander and ENEXIS case, the criteria hierarchy of the ENEXIS case is used and the consolidated weight distribution of the Liander experts is revised based on relative importance of its criteria.

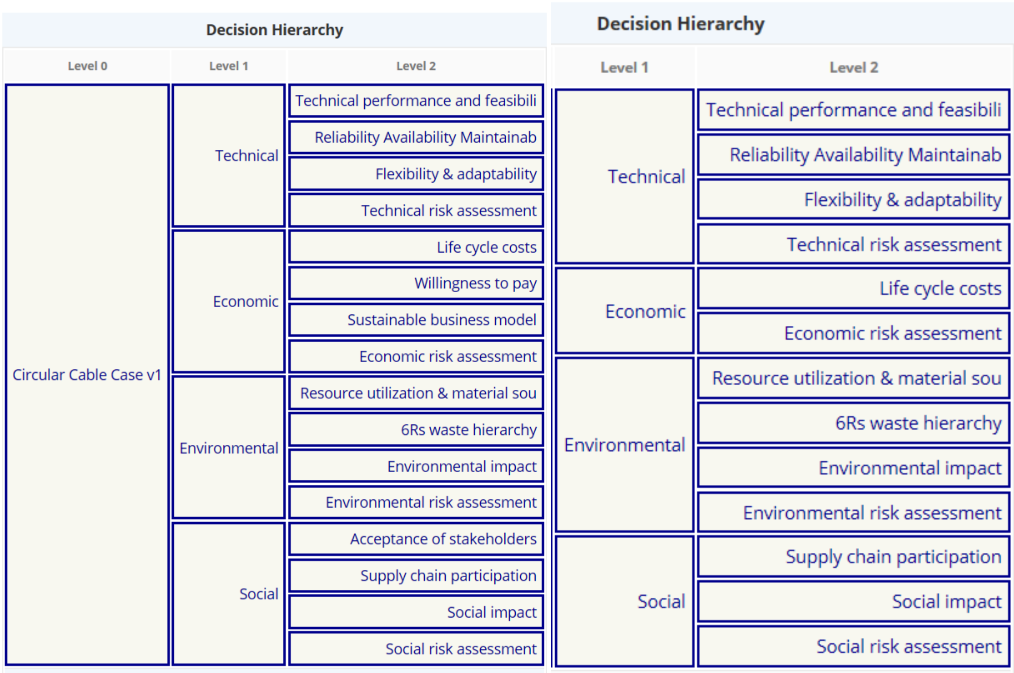


Figure 71 Criteria hierarchies Circular Cable (right iterated from left)

Weighting the criteria in the criteria hierarchy using the AHP software tool of Groepel (2017) in collaboration with two Liander experts (one strategic buyer and one senior policy advisor) and thereafter in collaboration with two ENEXIS experts (one asset policy expert and one innovation manager) resulted in a misaligned weight distribution (see the radar plot in Figure 49).

From the radar plot, a consensus on low weights for environmental and social criteria can be observed while the weights for technical and economic criteria differ substantially. The boxplot in figure X provides the details that confirm this observation. Detailed weight distributions of the four lowest consistency are illustrated in Figure 50. Based on the first round of criteria weighting, the criteria *technical performance and feasibility, RAMS* and *life cycle costs* are criteria in need of consensus building via dialogue between the actors involved. Despite the inclusion of a more environmental focus of the procurement process, the current weighting results do not reflect the shift in prioritization towards more sustainable added value recognition.

Table 57 Circular Cable asset material life cycle demand matrix and sustainable business models

	Design	Raw material	Production	Transportation	Installation	Use	End of use
	Conceptual design, preliminary design, detail design	Virgin and recyclate	Development, production	Transport	Construction, commission	Utilisation and support: operate, maintain, performance and modify, upgrade	Retirement and disposal: decommission, waste management, integration in other chains
Technical			Technical performance and feasibility			Technical performance and feasibility	
						RAMS	
				Flexibility & adaptability	Flexibility & adaptability	Flexibility & adaptability	Flexibility & adaptability
			Technical risk assessment	Technical risk assessment	Technical risk assessment	Technical risk assessment	Technical risk assessment
Economic		Life cycle costs	Life cycle costs	Life cycle costs	Life cycle costs	Life cycle costs	Life cycle costs
				Economic risk assessment	Economic risk assessment	Economic risk assessment	Economic risk assessment
Environmental		Resource utilization & material source	Resource utilization & material source				Resource utilization & material source
		6Rs waste hierarchy	6Rs waste hierarchy				6Rs waste hierarchy
		Environmental impact	Environmental impact	Environmental impact	Environmental impact	Environmental impact	Environmental impact
		Environmental risk assessment					Environmental risk assessment
Social		Supply chain participation	Supply chain participation				Supply chain participation
		Social impact	Social impact				Social impact
		Social risk assessment	Social risk assessment	Social risk assessment	Social risk assessment	Social risk assessment	Social risk assessment
	Dematerialization	Circularity and material loops	Dematerialization			Dispossession	Circularity and material loops
	Optimize functionality		Circularity and material loops			Prolong lifetime	
						Optimize functionality	

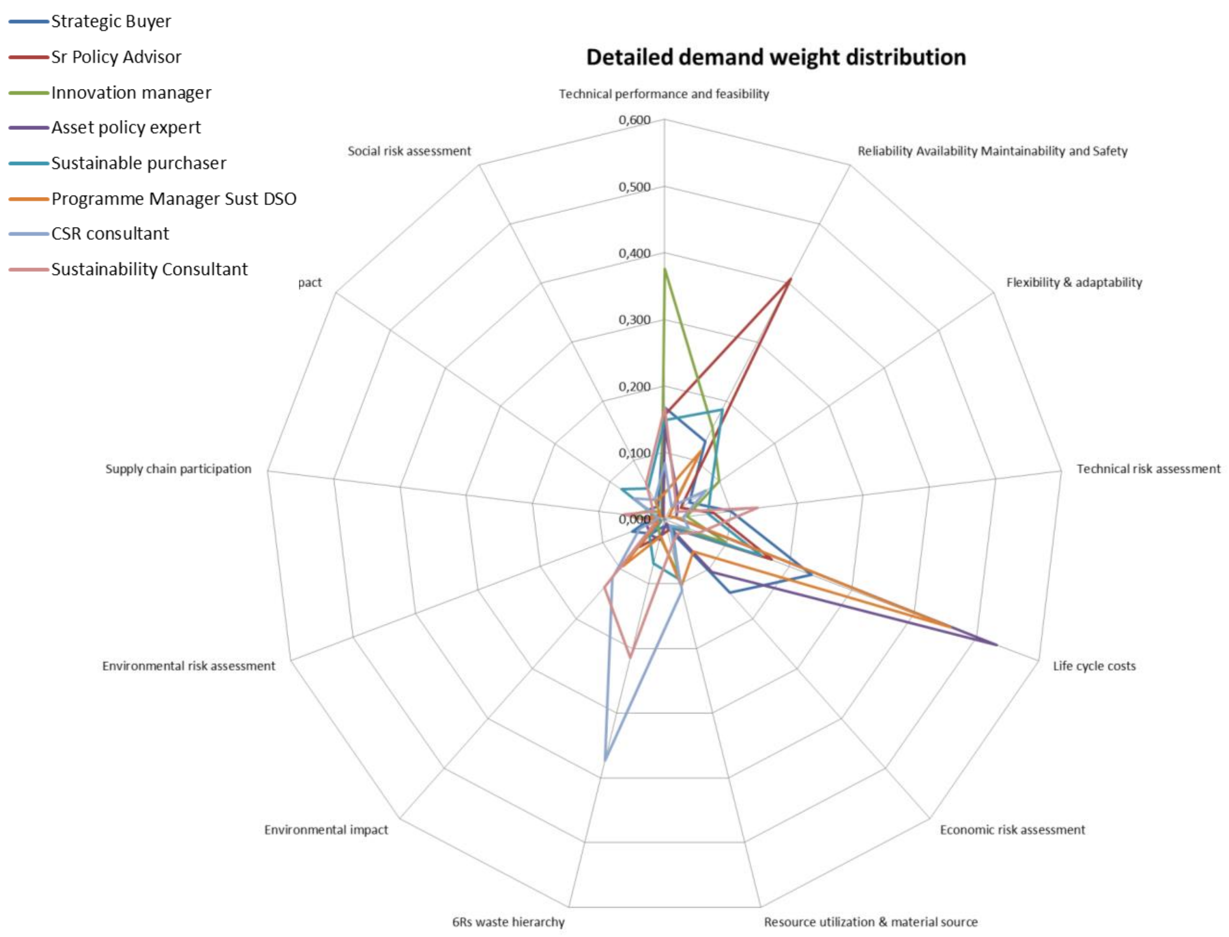


Figure 72 Circular Cable level 2 criteria weight radar plot

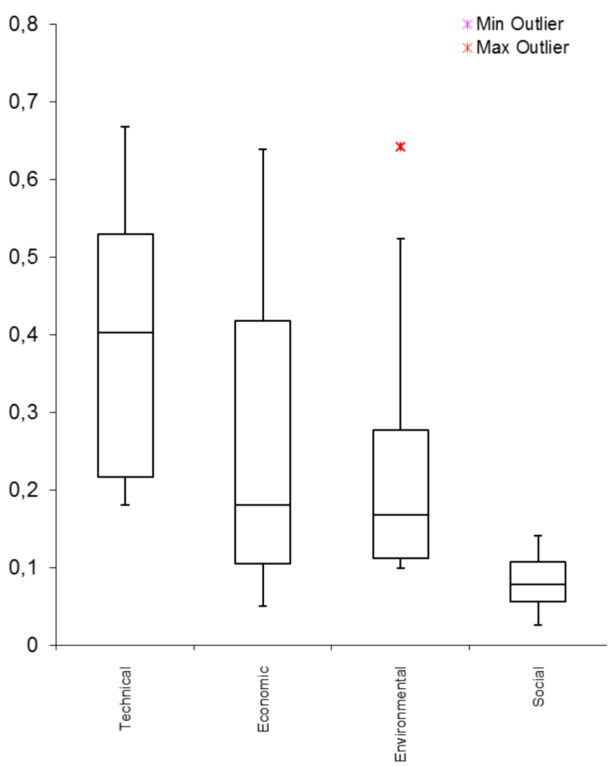


Figure 73 Circular Cable level 1 criteira weight box plot

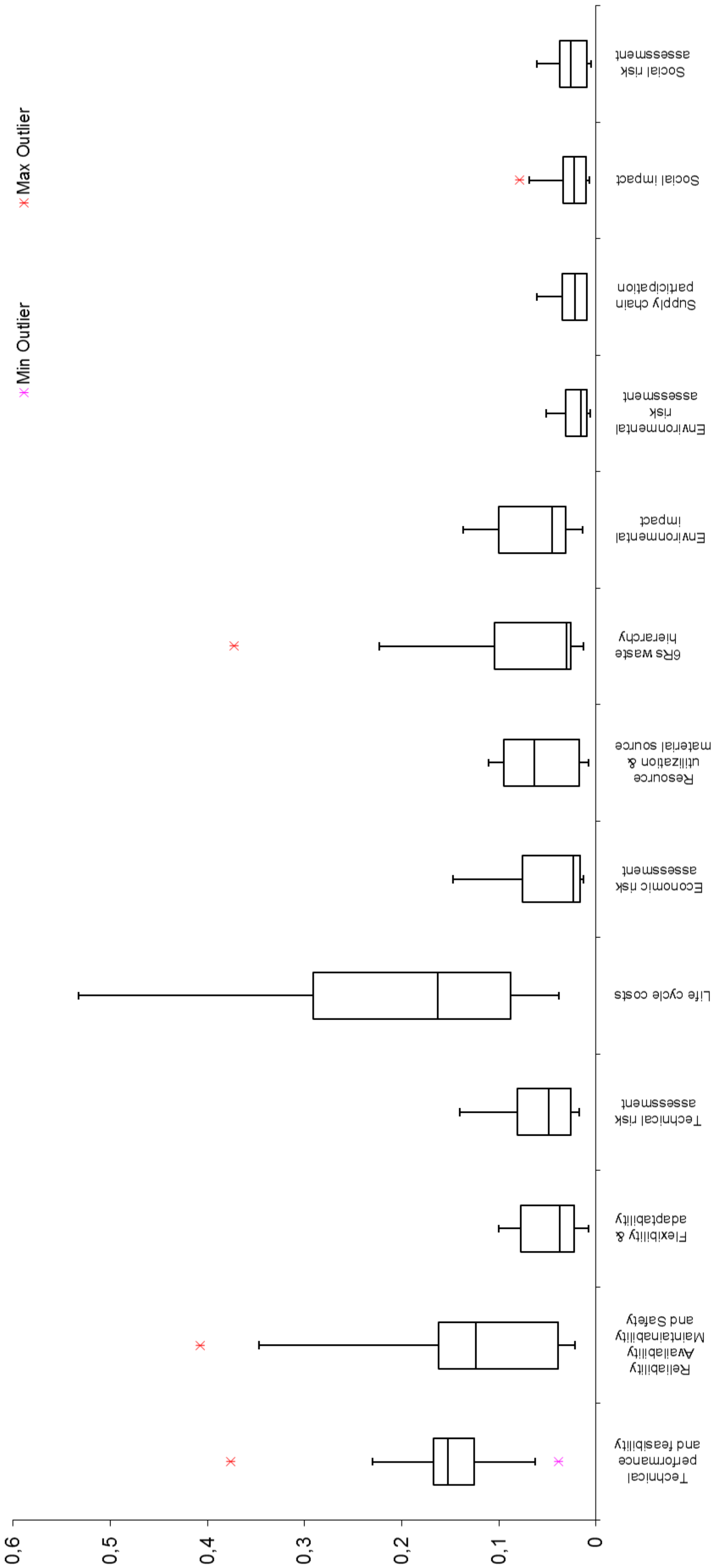


Figure 74 Fair Meter level 2 criteria weights box plot

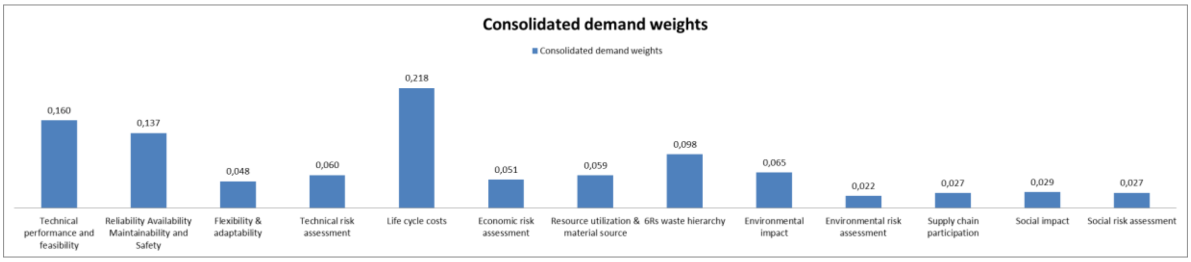


Figure 75 Circular Cable consolidated criteria weights

The first criteria weighting round resulted in the consolidated weight distribution shown in figure 51. The expert consensus based on individual weighting results is moderate.

Table 58 Group consensus criteria weight distribution Circular Cable case study

Criteria dimension	**Level of group consensus**	
Weight distribution among TEES dimensions	62.4%	Low
Weight distribution technical	70.6%	Moderate
Weight distribution economic	96.1%	Very low
Weight distribution environmental	67.3%	Moderate
Weight distribution social	69.3%	Moderate
General prioritization	68.6%	Moderate

This weight distribution is used in the alternative assessment of two tendering cable suppliers. From the alternative assessment it can be observed that Alternative B, despite its high score on the low weighted environmental criterion *resource utilization & material source*, does not compensate the lower score on nine other criteria, including the high weighted life cycle costs and the three other environmental criteria.

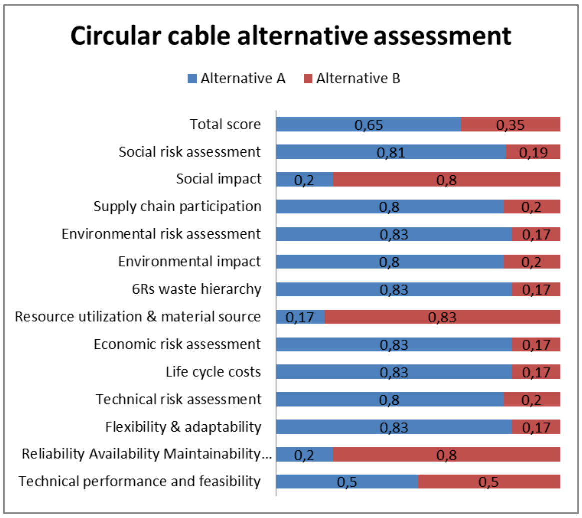


Figure 76 Circular Cable alternative assessment results

Completion phase

In the sourcing stage, no activities are undertaken in the case study context.

Quality assurance and quality control

The quality assurance and control activities are evaluated in the policy evaluation.