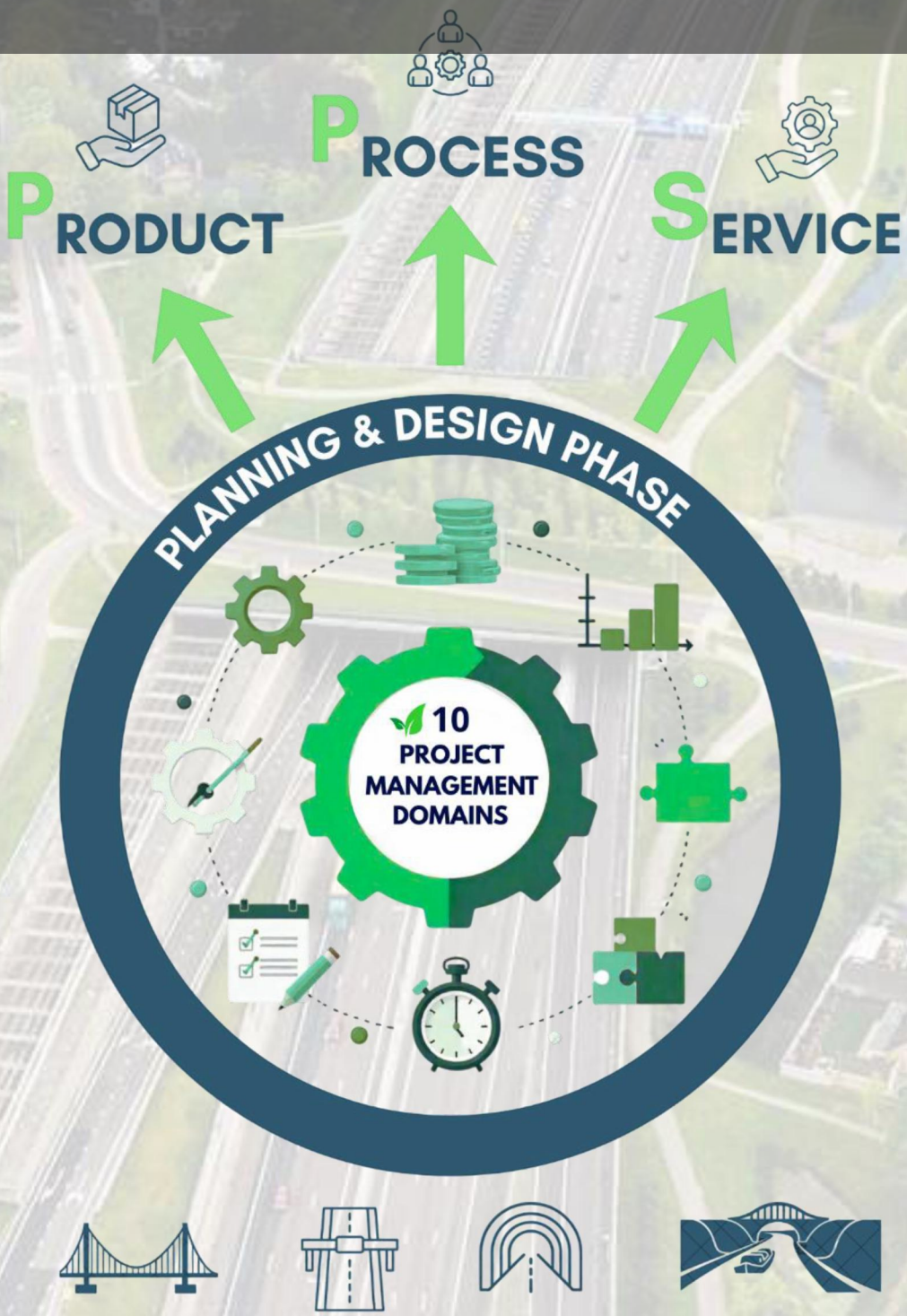
Research

Developing a method for integrating sustainability in infrastructure projects

Master thesis - CME5100 & CME5200

S. Omary (5359015)



Delft University of Technology

TU Delft

Integrating sustainability metrics to improve project analysis and decision-making in infrastructure development

Developing a framework for sustainability integration and quantifying impact assessment on infrastructure projects

by

S. Omary

Student Name	Student Number
S. Omary	5359015

Chair:	Dr. M. (Martijn) Leijten
First TU supervisor:	Houwing, E.J. (Erik-Jan)
Second TU supervisor:	Dr. M. (Ming) Yang
Company supervisor 1:	Ir. C. Reit
Company supervisor 2:	Ir. M. Uzun
Faculty:	Faculty of Civil Engineering and Geosciences
Department:	Construction Management and Engineering
Date:	Sunday 2nd August, 2026

TU Delft

Witteveen+Bos

Preface and acknowledgment

Completing this Master's thesis marks the end of an important academic journey at Delft University of Technology. Over the past years, I have had the opportunity to deepen my knowledge in Construction Management and Engineering (CME), while also developing a better and broader understanding of how infrastructure project project are shaped not only by technical choices, but also by management decisions, organizational structures and the position of sustainability.

My interest in sustainability originated during my role as a junior structural engineer after completing my Bachelor, where I aimed to redesign structures in a more optimal way to reduce material use while maintaining structural integrity. After successfully completing the bridging programme and starting this master's study, I realized that sustainability plays a much larger role during project development, rather than at the level of individual operations (i.e., a structural task or my role as a structural engineer). This realization caught my attention and increased my interest in sustainability on a broader project level, particularly within infrastructural projects. Despite sustainability being widely recognized as important, it remains a challenge for engineers and managers to keep track of its actual input, process and output. Many existing tools can assess or calculate sustainability performance, but the real challenge lies in translating sustainability ambitions into measurable, decision-relevant and actionable project requirements during the planning and design phase. This insight motivated me to investigate how sustainability can be integrated at the level of products, processes and services (PPSs) within project management domains and how such integration can support improved decision-making in Dutch infrastructure projects.

In particular, I would like to express my appreciation to the organizations and people who supported me during this research. I am grateful to Witteveen+Bos (W+B) for giving me the opportunity to carry out this research within their organization and for providing access to valuable practical knowledge. I would also like to thank Colin Reit and Mehmet Uzun for their supervision, guidance and valuable feedback throughout the process. Their internal and practical perspective helped me to critically reflect on the relevance and applicability of my work. In addition, I would like to extend my appreciation to the 18 internal participants at W+B who contributed to the interviews and validation sessions. Their willingness, experience and critical feedback were essential in understanding the current state of sustainability integration in practice at W+B and formed an important empirical foundation for this research.

Furthermore, I would like to thank my graduation committee at Delft University of Technology. My sincere gratitude goes to Dr. Martijn Leijten for chairing this research and for providing valuable academic guidance and to Erik-Jan Houwing and Dr. Ming Yang for their supervision, detailed feedback and continuous support throughout the thesis process, whereas their critical perspective and input, helped me to further sharpen the scientific quality of this research.

Beyond the academic and professional world, I would also like to thank my family, friends and especially my wife (Hila) for their continuous support, patience and encouragement during this period. Writing this thesis made me realize that that this is not only an academic process, but also a personal one, with peaks and downfalls of progress, uncertainty and reflection. Their support helped me to stay focused and motivated until the end.

Finally, I hope that all my effort resulted into this thesis, provides useful insights for researchers, project managers, sustainability advisors and infrastructure professionals who aim to move sustainability from ambition to implementation. My hope is that this research contributes even in a minor way, to a future in which sustainability is not only recognized in infrastructure projects, but structurally embedded in the decisions that shape them.



Enjoy the read!

S. Omary (5359015)
Delft, August 2026

List of Abbreviations

+CD Tool +Circular Design Tool. 21, 26, 45, 70, 71, 97

BPKV Beste Prijs-Kwaliteitverhouding. 19

CAPEX Capital Expenditure. 21, 30, 57, 70

CBA Cost-Benefit Analysis. 32, 70

CCB Change Control Board. 26, 27, 43, 70

CE Circular Economy. 14, 15, 20

CROW Centre for Regulation and Research in Civil Engineering, Hydraulic Engineering, Road Construction and Traffic Engineering, Dutch = Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek. 18

DOP Sustainable Design Principles, Dutch = Duurzaam Ontwerp. 16, 73

DOPs Duurzame Ontwerp Principes - Sustainable Design Principles. 50, 55, 57, 59

DSRM Design Science Research Methdology. 8, 9, 12, 102, 106

DuboCalc Duurzaam Bouwen Calculator = Sustainable Building Calculator. 97

ECI Environmental Cost Indicator. 1

EEFs Enterprise Environmental Factors. 23, 56, 87

EIA Environmental Impact Assessment. 91

EMVI Economisch Meest Voordelige Inschrijving. 19

ESG Envrionmental, Social and Governance. 1, 8

EU European Union. 8

EVM Earned Value Management. 31, 32, 70

FEDP Front-End Development Phase. 1, 17, 18, 26, 60, 74, 102, 104

GROTIK Money, Risk, Organization, Time, Information and Quality, in Dutch = Geld, Risico, Organisatie, Tijd, Informatie en Kwaliteit. 50, 54, 58, 72

GWW Grond-, Weg- en Waterbouw (= Civil Engineering). 1, 20, 89

HWBP Hoogwaterbeschermingsprogramma. 73

IFD Industrial, Flexible and Demountable. 16, 55, 57, 73

IPM Integral Project Management, Dutch = Integraal Project Management. 23, 50, 72, 107

ITTOs Inputs, Tools and Techniques & Outputs. 23

KCI Climate-Neutral and Circular Infastructure; Dutch = Klimaatneutrale en Circulaire Infrastructuur. 15, 16, 18

KES Klant-Eis Specificaties. 27, 28, 32, 50, 55, 70, 73, 80, 96, 113

LC Life-Cycle. 1, 7, 17–19, 21, 30, 32, 49, 55, 70, 71, 94

LCA Life Cycle Assessment. 5, 21, 30

LCC Life-Cycle Costing. 14, 50

LCCA Life-Cycle Cost Analysis. 5, 21, 32, 70

MARK Meerkleurig Argumentatief ReferentieKader. 89, 99, 100, 102, 110, 112

MCDA Multi-Criteria Decision Analysis. xii, 7, 19, 44, 47, 75, 83, 102, 107, 110

MCI Material Circularity Index. 21, 28, 37, 42, 75

MEAT Most Economically Advantageous Tender. 19, 40–42, 67, 73, 87

MIRT Multi-Year Programme Infrastructure, Spatial Planning and Transport, Dutch = Meerjarenprogramma Infrastructuur, Ruimte en Transport. 18

MKBA Maatschappelijke Kosten-Baten Analyse. 70

MKI Milieu Kosten Indicator. 1, 14, 16, 19, 25, 27, 28, 30, 32, 33, 37, 42, 45, 70, 71, 75, 95

MVI Maatschappelijk Verantwoord Inkopen. 18

NBS Nature-Based Solutions. 50

NPCE National Programme Circular Economy = Nationaal Programma Circulaire Economie. 16, 20

NPV Net Present Value. 67, 74

OPAs Organizational Process Assets. 23, 42, 56, 70, 87

OPEX Operational Expenditure. 21, 30, 57, 70

PI Power-Interest Matrix. 39, 43, 44, 68, 80

PM Project Management or Project Manager. x, xii, 1, 3, 4, 11, 17, 22, 23, 43, 46, 70, 75, 78, 79, 81, 83, 102

PMBoK Project Management Body of Knowledge. 3, 7, 10, 22, 51, 75, 86

PMC Product -Market Combination. 12, 23, 34, 36, 50, 54, 91, 102

PMIS Project Management Information Systems. 26, 33, 70, 88, 113

PMP Project Management Plan. 24, 30, 70, 92, 94, 102, 112

PMs Project Managers. 1, 5, 8, 12

PPPs Public Private Partnerships. 15

PPS Product, Process and Service. x, 11, 13, 23, 41, 46, 51, 67, 78, 102, 107

PPS-SIME Framework Product–Process–Service Sustainability Integration and Measurability Embedding Framework. 84, 86, 88–91, 99, 101, 102, 108, 110–114

PPSs Products, Processes and Services. 1, 4

PSU Project Start-Up. 65, 74

QBL Quadruple Bottom Line. 14, 17, 58, 70

R&R Replacement & Renovation or V&R in Dutch. 8, 55, 60

RACI Responsible, Accountable, Consulted, Informed-Matrix. 36, 68, 71, 74, 110

RAM Responsibility Assignment Matrix, same as RACI-Matrix. 36, 68, 71, 74, 110

RBS Resource-Breakdown Structure. 34, 36, 71

RWS Rijkswaterstaat. 1, 19, 21, 62, 89, 104, 113

SA Sustainability Assessment. 108

SCBA Social Cost-Benefit Analysis. 26, 32, 70

SDGs Sustainable Development Goals. 8, 15, 54

SEB Clean and Emission-Free Construction; Dutch = Schoon en Emissieloos Bouwen. 15, 16, 20, 40, 62

SEIS Sociaal Economisch Impact Scan. 50

SIA Social Impact Assessment. 50

SKAO The Foundation for Climate-Friendly Procurement and Business Practices; Dutch = Stichting Klimaatvriendelijk Aanbesteden en Ondernemen (SKAO). 19, 28, 32, 33, 36

SLR Systematic Literature Review. x, 10–13, 46, 51, 69, 76, 84, 102

SMC Standardized Measure Card. 84, 86, 88, 92, 99, 102, 111, 113

SMCs Standardized Measure Cards. 92

SOP Standard Operating Procedure. 4

SOPs Standard Operating Procedures. 23, 37, 88, 96, 101, 103, 106

SPM Sustainable Project Management. 3

SSIs Semi-Structured Interviews. 10, 44, 46, 48, 51, 60, 65, 69, 75, 84, 102

SSK Standaard Systematiek Kostenramingen. 55

TBL Triple Bottom Line. 14, 17, 28, 58, 70, 98, 112

TCO Total Cost of Ownership. 58

TU Technical University. 2

W+B Witteveen+Bos. 2, 18, 37, 54, 55, 57, 65, 75, 81, 90

WBS Work-Breakdown Structure. 27, 28, 70

Executive Summary

Problem and background

Sustainability is widely recognized as an important objective in Dutch infrastructure projects, but it still remains insufficiently anchored in project management processes where early decisions are made. In Dutch infrastructure sector, several sustainability tools and frameworks exists (e.g., DuboCalc, CO_2-Prestatieladder, +CD Tool, Ambitieweb and Omgevingswijzer), that help to define ambitions, determine environmental impacts and compare design alternatives. However, their existence and use does not guarantee that sustainability becomes part of project steering, management, control and decision-making. The main problem of these tools are that they are often treated as an additional assessment activity, instead of being an integrative part of Products, Processes and Services (PPSs) that shape project development during the planning and design phase, also called front-end development phase (FEDP). This is due to the core concern that sustainability ambitions are often formulated at a high level and are not consistently translated into measurable outcomes (e.g., requirements, baselines or work packages). This results into sustainability remaining vulnerable due to ambitions erosion. This means that initial sustainability ambitions gradually weaken when project teams face pressure on cost, time, scope or technical feasibility. The central problem is therefore, not simply a lack of sustainability awareness or missing any tool. It is a lack of a structure and semi-quantitative method that connect sustainability ambitions to existing project management workflows or Standard Operating Procedure (SOP). Not having this connection, means that sustainability is still dependent on individuals, intrinsic motivation and client demand only, instead of being part of project management practices.

Research purpose

The purpose of this research is to improve the measurability of sustainability efforts of PPSs within project management domains (PM-domains), in order to improve sustainability decision-making in Dutch infrastructure projects during the planning and design phase. This is done throughout the perspective of an engineering consultancy firm like Witteveen+Bos (W+B), as W+B is highly involved in early project development and project control/management. Therefore, the main research question is as follows:

> *"How can the measurability of sustainability efforts of products, processes and services within the project management domains be improved to enhance sustainable decision-making in Dutch infrastructure projects during the planning and design phase?"*

This question is answered by analyzing how sustainability can be anchored within the 10 PM-domains of the 6th edition of the *Project Management Body of Knowledge* (PMBoK) at the level of PPSs. The aim is not to develop another standalone sustainability assessment tools, but rather to design a method that strengthens existing project management structures and make sustainability more measurable, decision-relevant and reproducible.

Methodology

This thesis follows a Design Science Research Methodology (DSRM), that is structured through the Double Diamond model; Discover, Define, Develop and Deliver phase. This methodology is used in order to gradually move from problem exploration to method development and validation.

- **Discover**
  In this phase a Systematic Literature Review (SLR) was conducted to identify how sustainability can theoretically be integration into the 10 PM-domains of the PMBoK at the level of PPSs. This results into an initial (theoretical) overview of sustainability integration opportunities across all the 10 PM-domains.
- **Define**
  In this phase, empirical (practical) data is collect through 18 Semi-Structured Interviews (SSIs) with professional from W+B, including a variety of roles (e.g., project leaders, project managers, technical managers and more). This is done to understand the broad definition on sustainability integration within the company. These interviews were analyzed using an extended Gioia methodology, as this helped to identify how sustainability integration currently takes place in practice, where the main barriers (pitfalls) occur and which opportunities (gaps) are considered relevant by practitioners.
- **Develop**
  The theoretical and empirical findings were merged together as an integrated opportunity matrix/register containing a total of 305 sustainability integration opportunities. As a next step, a Multi-Criteria Decision Analysis (MCDA) is applied to this matrix/register using a total of 3 criteria; Measurability and Quantifiability (***MaQ***), Decision Leverage (***DL***) and Embeddability (***E***). These criteria are selected since this research does not only focus on whether sustainability can be measured numerically (hard or soft), but also considers whether it can influence decisions and can be anchored in existing project management structures.

- **Develop**
  In this last phase, the highest ranked opportunity from the most prominent PM-domains is translated using the PPS-SIME Framework, which stands for '*Product–Process–Service Sustainability Integration and Measurability Embedding Framework*'. This framework is applied and validated throughout a redesigned MARK-method, that results into a Standardizes Measure Card (SMC).

Key findings

A key finding within this research is that sustainability integration in Dutch infrastructure project is increasingly recognized, but remains fragmented in practice. Regardless of the fact that sustainability is visible across the 10 PM-domain and disciplines (PMC's), its application is not yet consistently standardized in project management routines and workflows. The SSIs proof that sustainability depends on individuals, intrinsic motivation, client demand, timing, project context and involvement of sustainability experts. This verifies that sustainability integration is inconsistent and vulnerable (as it is exposed to so many variables). Secondly, missing ***SMART formulated sustainability objectives during project initiation and before PMP baseline setting*** is one of the main structural gaps. Early project decisions 'lock-in' most of the sustainability potential, as they are also influenced by the cost, time and scope baselines that are defined in the Project Management Plan (PMP). If sustainability objectives are not defined before these baselines are fixed, then they will become harder to maintain, defend and steer-upon later in the project. This results in sustainability becoming secondary (additional requirement), rather than being part of the original project logic. Third, the Project Integration Management has the highest potential for sustainability integration, as this domain contain the highest overall score from the MCDA with $V(a) = 2.52$ and a Process-components score of $V(a) = 2.60$, which implies that anchoring sustainability into existing project workflows and processes has the strongest potential. Project Integration Management is therefore, the most logical starting point, as it connects all the other PM-domains and determines whether sustainability objectives are formally translated into the PMP or else. If sustainability is not integrated at this control- and layer-level, it remains difficult to make it visible in the other subsequent domains (scope, cost, time and risk). Lastly, sustainability measurability should be understood more broadly than only measure final hard environmental outcomes (e.g. MKI, CO_2 or MCI), as they are important, they do not completely capture whether sustainability has actually influenced decision-making. Some sustainability efforts do not immediately produce a measurable impact, but they can still improve decision quality (related to 'short-termism') and prevent sustainability ambitions from disappearing later in the project.

Developed method and application

The developed methodology is the PPS-SIME Framework that contributed to this research by translating sustainability integration opportunities into measurable, decision-relevant and anchored project management actions. As it link sustainability opportunities to PPS-components and prioritizes them through the defined indicators (Outcome - (***MaQ***), Decision Leverage - (***DL***) and Embeddability - (***E***)) and translates them into a practical project management instrument presented as the SMC. The framework uses three control levels: strategic, tactical and operation. Together with three layer-levels: individual, project and organizational. This structure allows one to assess not only what should be measured, but also where the opportunity should be controlled and at which level it should be anchored. By doing so, this framework prevents sustainability from remaining an abstract ambition and translates it into measurable project control and project management practices.

The framework is applied to the highest ranked opportunity within the Project Integration Management; '***Formulate SMART sustainability objectives before PMP baseline setting***. This opportunity was selected not only by the highest, score but also due to the fact that it addresses the core problem of this research. In case sustainability objectives are formulated in this document, before baselines are fixed, new proposal or suggestion become difficult to introduce as they must compete with already established project constraints. The selected opportunity therefore, focuses on updating the PMP with a dedicated sustainability section, including SMART sustainability objectives, measurable indicators, target values, verification methods, responsible roles, work packages and decision moments. The objective is not to create a separate sustainability procedure, but to anchor sustainability in a project management document that already has a central steering function.

The validation procedure of the application was performed through a redesigned MARK-method. That is subdivided into four steps; Measure, Result, Explanation and Substantiation.

- **Measure**
  This step defines what will be done.
- **Result**
  This step explains what the intervention or opportunity should deliver.
- **Explanation**
  This step clarifies why the intervention should work within project management and project control practice.
- **Substantiation**
  This step assesses why the project team can trust that the intervention or opportunity is realistic, feasible and reusable.

The validation showed that the selected opportunity is practically feasible because it builds on an existing project management document, in this case the PMP, instead of setting up a completely new and separate sustainability procedure. Additionally, it is also decision-relevant because sustainability objectives formulated before baseline setting can influence later decisions on cost, scope, time and risk (the other 4 subsequent PM-domains). Lastly, it is also reproducible as the same SMC logic can be applied to other opportunities, domains and projects.

Conclusion and discussion

In conclusion, the answer of this research is that, the measurability of sustainability efforts in Dutch infrastructure projects can be improved by shifting sustainability from a separate assessment activity to an integrated project management and project control practice. Sustainability is measurable not only when final sustainability outcomes are calculated, but especially when it influence on decisions, responsibilities of roles and project control structures are made explicit. The developed PPS-SIME Framework provides this through a structure method, as it connects sustainability ambitions to PM-domains, translates them into PPS-level opportunities, evaluates them through MCDA criteria/indicators and operationalizes them through the SMC. This output, serves as an aiding decision-support during project development, by anchoring opportunities earlier, more explicitly and more consistent in the planning and design phase (FEDP). Proving that improving sustainability integration is not necessarily a technical problem, but a project management and governance problem. The available and existing tools are useful, but disconnection with decisions, documents, roles and baselines that steer the project undermines the real impact of sustainability. Without this connection, sustainability tools remain supportive instruments instead of integrated decision-support mechanisms.

Based on these findings, a recommendation is to include mandatory sustainability aspects into project development instruments (e.g., the sustainability section in the PMP before baseline setting). By doing so, sustainability becomes measurable, held accountable and required evidence is provided for formal review or handover moments. This would ensure that sustainability is included (before the cost, time and scope baselines are fixed). Larger complex projects require a sustainability team with essential project roles (depending on the decisions structure of the company). This team is responsible for translating sustainability ambitions into practice by integrating them within existing project workflows during project development. Sustainability should not remain the responsibility of one specialist only, but should be embedded in the roles and responsibilities of the broader project team. Second, the SMC should be used as a standard project management tool for high priority sustainability opportunities. The SMC provides information on what the opportunity means in practice, what evidence is needed, how it impacts decisions and where it fits within existing workflows. Preferably, the SMC should be integrated into existing systems that are suitable for integration (e.g., PMP, WBS or else). As it is now done only from the perspective of one engineering consultancy firm, which limits direct generalization to other organizations such as contractors, public clients or asset owners. By doing so, creating a separate sustainability process and instead strengthens existing project control structures is avoided.

Third, it is valuable to extend the application of the PPS-SIME Framework beyond Project Integration Management, to see what impact the other domains have during project development at the FEDP. Meaning that sustainability should be integrated for example into LCC/LCCA, MKI comparison or risk registers. Adding to that, the validation focused on application should not be interpreted as proof that the method already leads to real sustainability outcomes in practice. In order to determine this, additional research is required using real project data to evaluate method improving actual sustainability outcomes. Last recommendation, aimed at the public sector (e.g, Rijkswaterstaat or ProRail) is to define sustainability requirements earlier and explicitly in project briefs, tenders and client specifications. If not done so, the project team have limited steering capacity and also prevents sustainability from becoming optional later at later stages of the project.

Final statement

The value of this research lies in making sustainability more traceable, assignable and reviewable within existing project management practices. Done, by applying the PPS-SIME Framework and the SMC as an output, it helps project teams to reduce ambition erosion, improve accountability and strengthens early decision-making as it also better connects sustainability ambitions to project control. The PPS-SIME Framework also support organizational learning by allowing for documentation and reuse of sustainability evidence, responsibilities and lessons learned across projects. This creates ***awareness*** of use, which is ***the outcome of training***, thus the more often it is used in practice the better the framework becomes. Regarding engineering consultancy firms, this improves the consistency and reliability of sustainability advice. Suitability of this framework to other companies is difficult due to the generalizability of this framework, which needs to re-assessed based on the organizational design of a company (EEFs and OPAs). Overall, the framework contributes to sustainable project management by embedding sustainability within project management domains, rather than assessing it only after key decisions have been made. In closing, this thesis research shows that improving sustainability integration in Dutch infrastructure projects require more than just tools or ambition-setting sessions. The key challenge is to connect sustainability to the project management structures that determine how decisions are made, documented, controlled and reviewed (related to the organizational design). The PPS-SIME Framework provides a practical semi-quantitative way to make this connection. By embedding sustainability into project management structures during the planning and design phase, project teams are better able to make sustainability measurable, decision-relevant and reproducible before long-term project outcomes are 'locked in'.

Contents

Preface and acknowledgment i

Executive Summary v

1 Introduction 1

2 Research formulation 3
- 2.1 State-of-art . . . 3
- 2.2 Research problem . . . 5
- 2.3 Research design . . . 6
  - 2.3.1 Research questions . . . 6
    - 2.3.1.1 Research phase . . . 6
    - 2.3.1.2 Development phase . . . 6
  - 2.3.2 Research objectives and aims . . . 6
  - 2.3.3 Research scope . . . 7
- 2.4 Research relevance . . . 8
  - 2.4.1 Scientific relevance . . . 8
  - 2.4.2 Practical relevance . . . 8
- 2.5 Research methodology . . . 9
- 2.6 Research design . . . 12

3 Systematic Literature Review (SLR) 13
- 3.1 What is sustainability? . . . 13
  - 3.1.1 Theoretical approaches . . . 14
    - 3.1.1.1 Triple Bottom Line (TBL) . . . 14
    - 3.1.1.2 Quadruple Bottom Line (QBL) . . . 14
  - 3.1.2 Sustainable Development Goals (SDGs) . . . 15
  - 3.1.3 The SDG-development of the Netherlands . . . 15
  - 3.1.4 Sustainability in Dutch infrastructure development . . . 16
    - 3.1.4.1 Sustainable Development . . . 17
    - 3.1.4.2 Sustainable Construction . . . 18
    - 3.1.4.3 Circular Economy (CE) . . . 20
- 3.2 PMBoK analysis for sustainability integration . . . 22
  - 3.2.1 Project Integration Management . . . 23
  - 3.2.2 Project Scope Management . . . 26
  - 3.2.3 Project Time Management . . . 28
  - 3.2.4 Project Cost Management . . . 30
  - 3.2.5 Project Quality Management . . . 32
  - 3.2.6 Project Resource Management . . . 34
  - 3.2.7 Project Communication Management . . . 36
  - 3.2.8 Project Risk Management . . . 38
  - 3.2.9 Project Procurement Management . . . 40
  - 3.2.10 Project Stakeholder Management . . . 42

4 Exploratory research and data collection 46
- 4.1 Semi-Structured Interviews set-up and participants . . . 46
  - 4.1.1 Project Leader (PL) . . . 48
  - 4.1.2 Environmental Manager (OM) . . . 48
  - 4.1.3 Technical Manager (TM) . . . 48
  - 4.1.4 Sustainability Advisor (DA) . . . 48
  - 4.1.5 Contract Manager (CM) . . . 48
  - 4.1.6 Project Advisor (PA) . . . 48
  - 4.1.7 Cost Engineer (CE) . . . 49
  - 4.1.8 Project Control Manager (MPB) . . . 49
  - 4.1.9 Project Manager (PM) . . . 49
  - 4.1.10 Designer (BIM) . . . 49
- 4.2 Data analysis in ATLAS.ti . . . 51
  - 4.2.1 Extended Gioia methodology . . . 51
    - 4.2.1.1 1st-Order Concepts . . . 51
    - 4.2.1.2 2nd-Order Themes . . . 51

4.2.1.3 3rd-Order Aggregate Dimensions . . . 51
4.2.1.4 4th-Order Fitted Dimensions . . . 51
4.2.2 Findings and results . . . 54
4.2.2.1 SSIs-Q1 - Roles and project context . . . 54
4.2.2.2 SSIs-Q2 - Current contribution to sustainability integration . . . 57
4.2.2.3 SSIs-Q3 - Sustainability integration opportunities . . . 60
4.2.2.4 SSIs-Q4 - Evaluation PPS-components . . . 65
4.2.3 Opportunity matrix . . . 69

5 Framework and conceptual model **75**
5.1 Multi-Criteria Decision Analysis (MCDA) . . . 75
5.1.1 Definition of alternatives . . . 75
5.1.2 Evaluation criteria . . . 76
5.1.3 Criteria weighting . . . 76
5.1.4 Scoring and ranking . . . 76
5.1.5 Weighted Sum Model . . . 77
5.2 Ranking and analysis of results . . . 77
5.2.1 Distribution of $V(a)$ scores . . . 77
5.2.2 Average $V(a)$ per PM-domain and PPS-component . . . 78
5.2.3 Average overall $V(a)$ score per PM-domain . . . 79
5.3 Overview of all top PPS-components . . . 82
5.4 PPS-SIME Framework . . . 84
5.4.1 Indicator type . . . 86
5.4.2 Control level . . . 87
5.4.3 Layer level . . . 88
5.4.4 Standardized Measure Card (SMC) . . . 88

6 Analysis and validation **89**
6.1 Application of the PPS-SIME Framework . . . 89
6.1.1 Redesigned MARK-method . . . 89
6.1.2 Top opportunity implementation and validation . . . 90
6.1.2.1 Measure - what are we going to do? . . . 92
6.1.2.2 Result - what does it deliver? . . . 93
6.1.2.3 Explanation - why does it work? . . . 95
6.1.2.4 Substantiation - why should we trust that it will work in practice? . . . 96
6.1.2.5 Standardized Measure Card (SMC) for the selected top opportunity . . . 97
6.1.2.6 Validation procedure and outcome . . . 97

7 Discussion and limitations **102**
7.1 Discussion . . . 102
7.1.1 Overview of main findings . . . 102
7.1.2 Interpretation of results . . . 102
7.1.3 Positioning with existing literature . . . 103
7.1.4 Implications . . . 103
7.2 Limitations . . . 104
7.2.1 Single organization context and limited transferability . . . 104
7.2.2 Subjectivity of the MCDA scoring . . . 104
7.2.3 Scope restriction to planning and design phase . . . 104
7.2.4 Application-focused validation approach . . . 104
7.2.5 Generalizability of the framework . . . 105

8 Conclusion **106**

9 Recommendation and future research **112**
9.1 Recommendations for practice . . . 112
9.2 Recommendations for public sector . . . 113
9.3 Recommendations for future research . . . 114

References **115**

A Literature review **125**

B Interview protocol **167**

C ATLAS.ti **171**

D Multi-Criteria Decisions Analysis (MCDA) **214**

References for Appendices **232**

List of Figures

2.1 All 10 project management domains (Shokouhi & Senisel Bachari, 2025) . . . 3
2.2 Double Diamond concept of this research (source: Author) . . . 9
2.3 Systematic Literature Review (SLR) approach (source: Author) . . . 10
2.4 Research Design (source: Author) . . . 12

3.1 The three sustainability concepts (Purvis et al., 2019). . . . 13
3.2 The SDG Wedding Cake (Stockholm Resilience Centre, 2016) . . . 15
3.3 Steps for sustainability integration of project in the Netherlands within the MIRT phase ((CROW / Kennisplatform Aanpak Duurzaam GWW, 2025)) . . . 19
3.4 Example of using DuboCalc for several cases and material use (Duurzaam GWW CROW, 2016) . . . 20
3.5 Timeline for the Dutch transition to a circular economy between 2016 - 2050 (Government of the Netherlands, 2025). . . . 20
3.6 Transition between linear economy and circular economy (Pereira et al., 2019) . . . 21
3.7 Project stages of an infrastructural project (Bragança et al, 2014) . . . 22
3.8 Revision to The Standard for Project Management and Migration from the Sixth Edition to the Seventh Edition of the PMBoK Guide and the PMIstandards+ Digital Content Platform (Project Management Institute, 2021) . . . 22
3.9 Project influences regarding EEFs and OPAs (Project Management Institute, 2017) . . . 23

4.1 Overview of participant roles represented in the informal meetings (source: Author). . . . 47
4.2 Distribution of interview participants according to years of professional experience (source: Author). . . . 48
4.3 Flowchart of aggregation procedure in ATLAS.ti (source: Author) . . . 52
4.4 Influence region of design decision expressed LC-impact and costs (Bragança et al, 2014) . . . 56
4.5 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q3 (source: Author) . . . 60
4.6 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q3 (source: Author) . . . 61
4.7 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q3 (source: Author) . . . 62
4.8 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q3 (source: Author) . . . 63
4.9 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q3 (source: Author) . . . 64
4.10 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q4 (source: Author) . . . 65
4.11 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q4 (source: Author) . . . 66
4.12 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q4 (source: Author) . . . 67
4.13 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q4 (source: Author) . . . 68
4.14 Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q4 (source: Author) . . . 69

5.1 Score distribution of $V(a)$ scores for all opportunities across the 10 PM-domains and corresponding PPS-components (source: Author) . . . 77
5.2 The average $V(a)$ score per PM-domain and PPS-component (source: Author) . . . 78
5.3 The average overall $V(a)$ score per PM-domain (source: Author) . . . 79

6.1 Sustainability in team composition within W+B (source: Author) . . . 91

List of Tables

2.1 4-level structure of the extended Gioia methodology, using the Gioia Methodology as a base (source: Author) 11

3.1 Comparison of sustainability concepts (source: Author) . . . 14
3.2 Comparison of sustainability rating systems (source: Author) . . . 17
3.3 CO_2 ambition levels and corresponding award advantage ((Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a)) . . . 19
3.4 Project Integration Management Process Groups and it elaboration (Project Management Institute, 2017) 24
3.5 Project Management Plans and Project Documents (Project Management Institute, 2017) . . . 24
3.6 Sustainability integration opportunities across PPS-components within Project Integration Management (source: Author) . . . 26
3.7 Resources Project Integration Management sustainability integration opportunities . . . 26
3.8 Project Scope Management Processes and their elaboration (Project Management Institute, 2017) . . . 26
3.9 Sustainability integration opportunities across PPS-components within Project Scope Management (source: Author) . . . 28
3.10 Resources Project Scope Management sustainability integration opportunities . . . 28
3.11 Project Time Management Processes and their elaboration (Project Management Institute, 2017) . . . 29
3.12 Sustainability integration opportunities across PPS-components within Project Time Management (source: Author) . . . 30
3.13 Resources Project Time Management sustainability integration opportunities . . . 30
3.14 Project Cost Management Processes and their elaboration (Project Management Institute, 2017) . . . 30
3.15 Sustainability integration opportunities across PPS-components within Project Cost Management (source: Author) . . . 32
3.16 Resources Project Cost Management sustainability integration opportunities . . . 32
3.17 Project Quality Management Processes and their elaboration (Project Management Institute, 2017) . . . 32
3.18 Sustainability integration opportunities across PPS-components within Project Quality Management (source: Author) . . . 33
3.19 Resources Project Quality Management sustainability integration opportunities . . . 34
3.20 Project Resource Management Processes and their elaboration (Project Management Institute, 2017) . . . 34
3.21 Sustainability integration opportunities across PPS-components within Project Resource Management (source: Author) . . . 36
3.22 Resources Project Resource Management sustainability integration opportunities . . . 36
3.23 Project Communications Management Processes and their elaboration (Project Management Institute, 2017) . . . 36
3.24 Sustainability integration opportunities across PPS-components within Project Communications Management (source: Author) . . . 37
3.25 Resources Project Communications Management sustainability integration opportunities . . . 38
3.26 Project Risk Management Processes and their elaboration (Project Management Institute, 2017) . . . 38
3.27 Sustainability integration opportunities across PPS-components within Project Risk Management (source: Author using (Project Management Institute, 2017)) . . . 40
3.28 Resources Project Risk Management sustainability integration opportunities . . . 40
3.29 Project Procurement Management Processes and their elaboration (Project Management Institute, 2017) 41
3.30 Sustainability integration opportunities across PPS-components within Project Procurement Management (source: Author using (Project Management Institute, 2017)) . . . 42
3.31 Resources Project Procurement Management sustainability integration opportunities . . . 42
3.32 Project Stakeholder Management Processes and their elaboration (Project Management Institute, 2017) . 43
3.33 Sustainability integration opportunities across PPS-components within Project Stakeholder Management (source: Author using (Project Management Institute, 2017)) . . . 44
3.34 Resources Project Stakeholder Management sustainability integration opportunities . . . 44
3.35 Overview of sustainability integration opportunities across PM-domains and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017) . . . 45

4.1 Overview of interview participants and anonymization (source: Author) . . . 47
4.2 Overview of the involved participant roles, responsibilities and sustainability-related tasks within infrastructure projects (source: Author). . . . 50
4.3 Overview of the Fitted Dimensions (FD) across the four interview questions (source: Author). . . . 52
4.4 The heatmap visualizes relative intensity of coded associations rather than statistical correlation coefficients, with darker shading indicating higher frequencies of co-occurrences between participants and questions with related themes in ATLAS.ti (source: Author, see Appendix C for more elaboration) . . . 53

4.5 Overview of the Fitted Dimensions (FD) related to SSIs-Q1 (source: Author). . . . 57
4.6 Overview of the Fitted Dimensions (FD) related to SSIs-Q2 (source: Author). . . . 60
4.7 Overview of the Fitted Dimensions (FD) related to SSIs-Q3 (source: Author). . . . 65
4.8 Overview of the Fitted Dimensions (FD) related to SSIs-Q4 (source: Author). . . . 69
4.9 Overview of sustainability integration opportunities across PM-domains 1 to 5 and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017). These new items are identified opportunities from the SSIs interviews. . . . 70
4.10 Overview of sustainability integration opportunities across PM-domains 6 to 10 and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017). These new items are identified opportunities from the SSIs interviews. . . . 71

5.1 Number of identified sustainability integration opportunities across the 10 PM-domains and corresponding division into PPS-components (source: Author) . . . 75
5.2 Evaluation criteria and weights . . . 76
5.3 Scoring criteria used for evaluating sustainability integration opportunities (source: Author). . . . 76
5.4 Overview of the highest scoring sustainability integration opportunities across the examined PM-domains based on the MCDA analysis (source: Author). . . . 83
5.5 Indicator types used within the PPS-SIME Framework, including their purpose, examples and corresponding evidence (source: Author). . . . 86
5.6 Control levels and their application across the three layers in the PPS-SIME Framework (source: Author). 87
5.7 Layer definitions in the PPS-SIME Framework (source: Author). . . . 88
5.8 Structure of the Standardized Measure Card (SMC) in the PPS-SIME Framework (source: Author). . . . 88

6.1 Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Integration Management based on the MCDA analysis (source: Author). . . . 89
6.2 Redesigned MARK-method for validating sustainability integration opportunities within the PPS-SIME Framework . . . 90
6.3 Example of a SMART sustainability objective for integrating the Carbon Cost Calculator (C3) into project cost estimation (source: Author). . . . 93
6.4 Assigned responsibilities and sequential work packages for implementing the SMART sustainability objective related to the Carbon Cost Calculator (C3) within the sustainability team (source: Author). . . . 94
6.5 Standardized Measure Card (SMC) for integrating SMART sustainability objectives before PMP baseline setting. . . . 97

1

Introduction

The term 'sustainability' is often used as an umbrella term, with wide-ranging and variable meanings in Dutch infrastructure projects and construction industry. The most widely accepted definition is 'seeking to meet the needs of the present without compromising the abilities of future generations' (World Commission on Environment and Development, 1987). This definition emphasizes that sustainability is not a fixed state but a continuous process that is affected by technological advances, resource availability and changing social structures (Pardo-Bosch & Aguado, 2016). Infrastructure projects are critical for economic, social and environmental development (sustainability integration), but face significant challenges like the Betuwroute (Toni Aschwanden, 2007) (economic factor, cost overrun of approximately €4.7 billion) or Amelisweerd A27 highway (van Lieshout, 2019) (social factor, societal opposition) being proof of the consequence of poor sustainability handling and integration until realization, which is too little, too late. Depending on the size and complexity of the project, predictability in managing sustainability and traditional project drivers; cost, time and scope, also known as the Iron Triangle (Atkinson, 1999). This challenges project manager (PMs) to implement effective strategies to oversee these aspects and beyond.

Both real-life project results, are not caused by sustainability alone, but of a broader project management challenges. Rokio et al (2024) states that the planning and design phase (also called the front-end development phase (FEDP)) is where the greatest value potential lies for sustainability integration, because key-decisions made in this phase 'lock-in' much of the project its final sustainability performance. This indicates that predefined sustainability (ambitions) must be translated into concrete project management requirements, responsibilities, decision criteria and project control mechanisms during the FEDP. Reflecting the level of Products, Processes and Services (PPSs). If not done properly and decisions are final, room for change on (sustainability) choices, becomes more limited. This brings a risk of sustainability to become fragmented and poorly quantified despite its broad recognition and importance (Procura+ / ICLEI Europe, 2025), which is one of the causes of "*ambition erosion*", defined as the gradual loss or weakening of sustainability ambitions throughout project development processes (Veen, 2023). Therefore, literature verifies that sustainability is not consistently considered or actively managed and steered upon throughout the entire life-cycle (LC) of which the FEDP is part of. The PPS-level serves as a leverage point to integrate sustainability during project development, as other research verified the potential of this level by Teigiserova and Schraven (2024) that developed a PSS-framework (Product-Service System) to improve customer-contractor communication that serves as a decision-support framework. G. Silvius (2015) states that sustainability (integration) requires change of business models, products, processes and services (PPSs) and resources. Finally, Montelisciani et al. (2015) imply that products (in this context artifacts like infrastructure projects) constitute an integrated system of PPSs. Hence, this research contribute to the delivery of a method or framework in a manner that fosters sustainable project development at PPS-level as earlier research verifies its importance and relevance. In order to do so, the 10 project management domains (PM-domains) are critical to consider as they are all involved during the realization of a project (Project Management Institute, 2017), also during the FEDP. Identifying the potential of sustainability integration within the PPSs in each PM-domain enables improvement of project development and a balanced decision-making that supports project value within the Dutch construction industry. This underscores the need to assign sustainability a crucial and early role in the project development.

Along with conventional project management and project control PPSs within PM-domains, there are existing methods (e.g. Envision and IS-Rating) to integrate sustainability in infrastructure projects. They evaluate sustainability impact across the project life-cycle (LC) founded in environmental, social and governance (ESG) aspects as a starting point. Despite this, the methods are used as a static checklist with a certification level that is assigned to the project with a label to that degree. Although many infrastructure project apply these methods during the FEDP, but a few integrate them into core decision-making processes (Bueno Cadena et al., 2015). This is due to the maturity and adoption of these tools that requires trust in the method and higher use-intensity of the method (Griffiths et al., 2015). In Dutch context, the DuboCalc tool that is developed by Rijkswaterstaat (RWS), allows for comparison of sustainability and environmental cost through the Environmental Cost Indicator (ECI) or MKI in Dutch (Rijkswaterstaat, 2020) and Sustainability Guidelines for Civil Engineering (Leidraad Duurzaamheid in de GWW) offers the Omgevingswijzer and Ambitieweb to asses sustainability potential and define sustainability ambitions of a project (Ambitieweb, 2024; Omgevingswijzer, 2023). Although these tools and guidelines provide guidance for sustainability assessment (focused on quantifiable outcomes and insufficiently

capture intangible or semi-quantitative sustainability aspects), they offer limited support for identifying integration opportunities at PPS-level to support decision-making of project teams. According to RWS, only 40% of Dutch infrastructure projects currently apply sustainability assessments and just 15% of the tools in use are adapted to local contexts (Rijkswaterstaat, 2020). This highlights a broader challenge in effectively embedding sustainability during the FEDP at PPS-level.

The choice a method depends on multiple variable like project type, location and whether the choice is regionally or internationally applicable. Even though these methods help to assess or identify sustainability impact, they mostly act as verification after the FEDP of a project relying on qualitative data and lack of semi-quantified data. This creates a research gap, because of this gap project manager and engineer within a project team, often struggle to turn high-level sustainability goals into practical and measurable outcomes. In order to do so, it requires sufficient semi-quantitative data with a suitable framework or method to translate sustainability ambitions into actions that can be included in both a layer-level (individual, project organizational) and control-level (strategic, tactical and operational) (Kitsios et al., 2020). This can be addressed when the PPS-components are identified during the FEDP, that offer leverage points for integrating sustainability in order to steer the process on sustainability and prevent sustainability fragmentation and ambition erosion. Integrating sustainability into project management during the FEDP is crucial for informed decision-making, despite the absence of a widely accepted integration method. Failure to address ESG-factors can result in regulatory non-compliance, inefficiencies, reputational damage, higher costs and reduced competitiveness (Deloitte Southeast Asia Ltd, 2019). Therefore, this research investigates sustainability integration potential at PPS-level within PM-domains, targeting the root causes of sustainability challenges early in project development.

In cooperation with Technical University (TU) Delft and Witteveen+Bos (W+B) this research has been set-up. TU-Delft is an acknowledged and the W+B is a leading engineering consultancy headquartered in the Netherlands but active all around the world. The (sub)topics that will be addressed in this research include the current status of sustainability effects in the construction industry, the obstacles and challenges of semi-quantification of sustainability and eventually a proposal of an approach on PPS-level for the semi-quantification and integration of sustainability within a PM-domain during the FEDP of a project. In short, this report proposes a framework for semi-quantifying sustainability in the planning and design phase that facilitates the early and systematic integration of sustainability into the project management domain(s).

2

Research formulation

2.1. State-of-art

Sustainability integration in infrastructure projects is influenced by challenges that arise from decision-making practices during the FEDP. The real-life project examples from Chapter 1, are proof for neglecting sustainability and its corresponding consequences due to uninformed or unaware decisions-making. This is due to the fact that infrastructure projects are often big, complex, unique and specific, which makes it challenging in achieving consistent and practical integration of sustainability. Literature confirms that the link between project management and sustainability is relatively new (Achman, 2013), whereas Sustainable Project Management (SPM) has emerged throughout the years that goes beyond traditional project drivers (cost, time and scope) prioritizing ESG indicators (Ivandic Vidovic et al., 2025). Traditional project management and project control practices are mainly focused on the Iron Triangle leaving environmental, social and economic impacts underexplored (Olawumi & Chan, 2018; A. G. Silvius & Schipper, 2014), which is an outdated and limited perspective, as well as a restricted view of successful project management (Frefer et al., 2018; Moreno-Monsalve et al., 2023). Sustainability integration is widely acknowledged for long-term project success, but the practical guidance on how to do this with actual results, remains underdeveloped during the FEDP (Kibert, 2016). According to A. G. Silvius and Schipper (2014), integration of sustainability concepts into project management processes is currently a developing area. Therefore (depending on the type and size of the project), the tangibility of sustainability is hard to shape due to inconsistency, unpredictability and iterative character of a projects as they are unique. As a result of this, sustainability ambitions are often not translated in the same way as is done for traditional project drivers into manageable project elements at PPS-level. Recognizing sustainability as part of project success does still not explain how sustainability is embedded into PPSs, through which infrastructure projects are managed and controlled during the FEDP. This research is a contribution to that developing area, on how sustainability principles can be integrated into products, processes and services PPSs during the planning and design phases, which can provide multidimensional value when the principles are applied properly (A. G. Silvius & Schipper, 2014; Williams et al., 2019) (**Gap 1**). According to the 6th edition of the *Project Management Body of Knowledge* (PMBoK), project management is considered the simultaneous coverage of multiple managerial areas of knowledge, in this research called PM-domains (see Figure 2.1). Each PPS is a component related to (at least) one of these PM-domains (Project Management Institute, 2021).

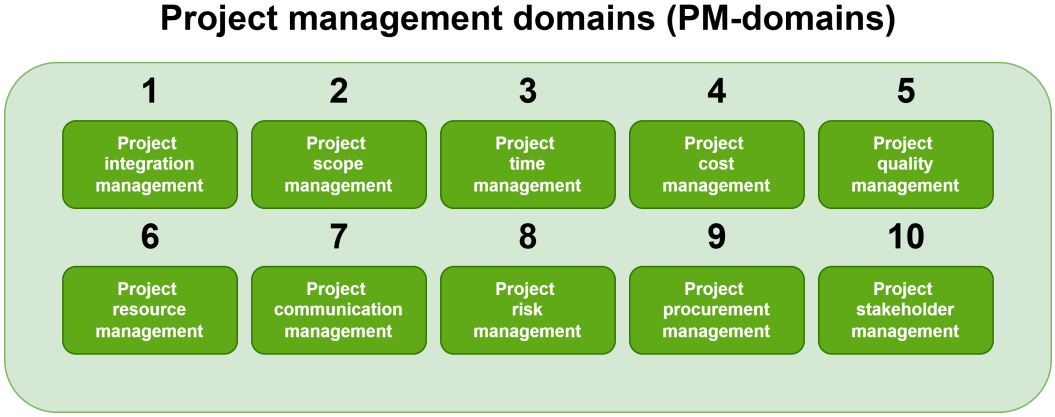


Figure 2.1: All 10 project management domains (Shokouhi & Senisel Bachari, 2025)

The planning an design phase (FEDP) include a structured set of PPSs related to the 10 PM-domains, that can serve as levers for embedding/anchoring sustainability properly when aligned and used. In order to understand the concept of each component it is good to understand what each component means:

- **Product (P)**
  In project management, a deliverable or also referred to as product, is any tangible or intangible good or outcome that is produced as a result of a task or project within the PM-domain. It serves as proof of evidence that work has been done and functions as a building block that can carry or embed sustainability. An example is '*include sustainability category within the lessons learned repository*'.
- **Process (P)**
  In project management, a process is an *ongoing* structured and repeatable sequence of activities of methods that is designed to achieve a specific tasks or project (sub)goal within the PM-domain. In the analysis of the PM-domains there are 'Process Groups' which are main processes within that specific domain, read Appendix A. This is something that is done, but not something that is produced. An example is '*consider sustainability concepts during project charter development*'.
- **Services (S)**
  In project management, a service is the delivery of intangible value to a person, process or product, basically acting as a supporting function. This is something that enables, but does not execute. An example is '*organize Ambitieweb sessions as facilitator during project charter development*'.

The existing sustainability methods, briefly mentioned in Chapter 1, use a multi-criteria scoring based on categories. However, they are applied during or after development and serve mainly as a certification system rather than as an active decision-support tool for project teams on PPS-level sustainability integration. The Dutch existing tools and methods (e.g. Omgevingswijzer (Omgevingswijzer, 2023) and Ambitieweb (Ambitieweb, 2024)), offer domain-specific support but are rarely integrated into operational PM-domains. Meaning that their output do not directly become part of the PM-domain mechanisms through which decisions are controlled and made. This is an identified gap and distinction between assessing sustainability and embedding/anchoring sustainability in project decision-making (**Gap 3**). This is relevant, as the FEDP is where the greatest potential for value creation through integration lies, where final key decisions determine a significant part of the project its eventual sustainability performance (Rokio et al, 2024). The FEDP does not contain a suitable framework for integrating sustainability at PPS-level, whereas defined and present sustainability ambitions should be translated into the same project management structures that determine how other project objectives are planned, controlled and reviewed. John Wiley & Sons (2020) verifies that it is critical for sustainability integration to integrate sustainability into project management activities as early as possible and that it must become a fundamental part of project management through steering committees (on PPS-level) (**Gap 3**). Even though sustainability is seen as a key factor by practitioners, there are disagreement about where the issue sits and how sustainability principle should be integrated into projects (Ebbesen & Hope, 2013) (**Gap 1**). Practical application of sustainability remains fragmented due to factors such as cost considerations, lack of expertise and inadequate regulatory framework (Bhatti et al., 2026).

Therefore, this research aims to address the gap between the growing importance of sustainability in the construction sector and the limitations of traditional project decision-making at PPS-level during the planning and design phase (FEDP). While there are sustainability tools available across the infrastructure landscape, their use is not consistent nor sufficiently integrated within decision frameworks and project components (products, processes and services) during this phase, proving a need for a more standardized framework or approach (Bueno et al., 2015). Liu et al. (2018) verified this, emphasizing that sustainability rating systems must be integrated in the design process, implying current insufficient integration (**Gap 3**). This misalignment creates a gap between sustainability principles (on PPS-level) and the actual integration, often resulting in reactive (after decisions) rather than proactive (before decisions) project management on sustainability integration. Once identified, these principles can be incorporated in the standard operating procedure (SOP) of the engineering consultancy firm once they are established. Sustainability will therefore no longer be seen as a separate issue that needs to be explicitly addressed, but rather as a logical and integral part of the regular project process. The literature suggests a potential disconnect between sustainability assessment and project management workflows or SOPs. This research further investigates whether and how this disconnect appears in the context of an engineering consultancy firm. During infrastructure project development, conventional project objectives are managed through structured PPSs (e.g., scope is translated into requirements and work packages, cost into estimates and budgets, time into schedules and risks into risk registers). Sustainability ambitions, however, are often not embedded with the same level of procedural clarity. As a result, they may remain dependent on individual commitment (Dessi et al., 2026), client demand (Peenstra & Silvius, 2018) or late assessment, rather than becoming part of the regular project management routine (also called, SOPs). Therefore, this research, investigates the development of a semi-quantitative method/approach within a project management domain to support the early and systematic integration of sustainability considerations on PPS-level, this research seeks to make sustainability more actionable and measurable within the project management domains and across the design and planning phase of infrastructure project development.

2.2. Research problem

As sustainability is widely recognized and highlighted as important for infrastructure projects, its systematic integration and approach at the FEDP through PPSs remains fragmented and poorly quantified (Olawumi & Chan, 2018) (**Gap 1 and 2**). Existing methods are often treated as an afterthought, functioning mainly as a static checklist (Shen et al., 2007) or certification tool rather than as dynamic inputs for decisions on scope, cost, risk or other relevant PM-domain decisions (**Gap 3**). In the systematic review by Alaloul, Altaf, Musarat, Javed, and Mosavi (2021) 1251 publications were screened but only 55 explicitly mentioned Life-Cycle Analysis (LCA) or Life-Cycle Costing Analysis (LCCA) in infrastructure projects, which indicates the limited use of such assessments in actual practice (**Gap 2**). Besides the fact that there exists a disconnect between sustainability (assessment) and project management workflows as mentioned earlier, critical PM tasks (e.g. cost estimation, risk prioritization and planning) usually do not include sustainability metrics at an early stage to influence decision-making, which leads to sustainability being overlooked or seen as an add-on rather than being seen as a strategic value driver (UNEP, 2011) (**Gap 3**). Products do not always include measurable sustainability indicators allowing for multidimensional trade-off analysis (Ahn et al., 2013), whereas services tend to prioritize cost of long-term environmental or social return (Bauer, 2014; Zuo & Zhao, 2014) (**Gap 2**). In short, various topics are considered throughout project LC via the PPSs to ensure the project its final success, whereas sustainability is just secondary and tags along as an afterthought. This emphasizes the need for sustainability to be fully integrated from the beginning, but there are no clear processes, guidelines or agreements in place for that yet to do so. As a result of this, sustainability ends up depending on individuals and client demand for example (**Gap 3**).

Due to this, project managers lack practical and semi-quantitative methods/tools to make a compelling case for sustainability. Due to missing indicators or metrics, it is hard to collect evidence in order to gain internal commitment or stakeholder support (**Gap 2**). This is related to the phenomenon 'ambition erosion', which is the gradual loss or weakening of sustainability ambitions throughout a process. Meaning that initial, strong commitment to sustainability goals set, diminishes or gets diluted as the project moves through phases (Veen, 2023). Therefore, the primary need is not necessarily to persuade stakeholders directly, but to equip PMs with methods that translate sustainability ambitions into tangible project value. Bragança et al (2014) state that instead of forcing sustainability into existing systems, products should be designed and produced from the outset to align with sustainable development principles. This statement coincides with the approach of this research, whereas a sustainable method or framework is developed based on the potential of sustainability implications of PPSs within the planning and design phase (FEDP) of an infrastructure project from an engineering consultancy firm perspective, in this case W+B. Since the current existing tools:

- Are not built to support real-time decision making (limits usability and promote sustainability, read Appendix A)
- Are not built to adapt to changing conditions (limits usability and promote sustainability, read Appendix A)
- Lack capability to assess system level effects (e.g. (G. Silvius & Schipper, 2014)
- Depend on data and (skilled) personal to influence outcomes and increase tool adoption (EPA, 2025)
- Depend on matching decision points in project LC (if not done properly, risk of abandonment of tool by 25%) (GIH, 2021)

In summary, **current existing tools are often introduced too late, when key-decisions are already taken or used later to justify past decisions** (Suprayoga et al., 2020). The central research problem is the lack of a semi-quantitative and integrated framework to guide to sustainability integration into infrastructure projects at the level of PPSs. In the absence of such a method, sustainability ambitions remain vague, implementation becomes inconsistent and stakeholder alignment weakens, resulting in missed opportunities and suboptimal project outcomes. Due to lack of empirical evidence there is no such standardized method (yet) to verify and prove its impact on infrastructural project and therefore is unrecognized as a contribution to sustainability. Based on this, the following gaps are identified:

Gap 1

No clear overview of potential PPS-components related to PM-domains for sustainability integration

"There is no structured overview of which products, processes and services (PPSs) are most relevant for integrating sustainability into key project management domains during early planning and design. Without clarity on where and how sustainability should be embedded, it remains fragmented and disconnected from early decision-making."

Gap 2

Missing structured and measurable sustainability criteria across PPS-components

"Sustainability within PPS-components often lacks clear and measurable criteria, making it difficult to evaluate, compare or justify decisions. Without well-defined indicators or decision-focused metrics, sustainability stays qualitative, secondary and hard to operationalize in practice. This absence of measurable criteria makes it difficult to weigh sustainability alongside traditional project drivers such as cost, time and scope."

Gap 3

Absence of a standardized and integrated method for sustainability integration and decision-support within PM-domain(s)

"There is no integrated method that links sustainability directly to project management workflows and decision-making. Existing approaches are either too late, too static or disconnected from actual project processes and tasks which limits their impact on early planning and design decisions."

2.3. Research design

2.3.1. Research questions

In order to comply with the objective of the research, the main research question must be answered. This answer will follow by answering the next sub-questions. The main research question that needs to be answered is as:

Main research question

How can the measurability of sustainability efforts of products, processes and services (PPSs) within the PM-domain(s) be improved to enhance sustainable decision-making in Dutch infrastructure projects during the planning and design phase?

Subsequently, this research is guided and structured by the following sub-questions in terms of the research phase (1) and the development phase (2):

Research phase

SRQ1 - Discover (diverge)

What is the current state of sustainability integration within the PM-domains at the PPS-level during the planning and design phase of a Dutch infrastructure project?

SRQ2 - Define (converge)

What is the highest PPS-based project management domain(s) and component(s) that offer highest potential for semi–quantitative sustainability integration, considering the effort required within existing workflows and the reproducibility of the method across different Dutch projects?

Development phase

SRQ3 - Develop (diverge)

How can a (semi-)quantitative decision-support method or framework be designed from the selected PM-domain(s) in order to evaluate the effort and outcome of sustainability integration during the planning and design of Dutch infrastructure projects?

SRQ4 - Deliver (converge)

How does the developed method (or potential framework) perform in a real-life infrastructural project and which lessons learned enable reproducibility of the approach for other PM-domain processes and organizations?

2.3.2. Research objectives and aims

This research aims to develop and validate a (semi-)quantitative method that integrates sustainability considerations into the PPSs within PM-domains of Dutch infrastructure projects, enabling practitioners to systematically evaluate and enhance sustainability performance during the early planning and design phases. To achieve this overarching objective, the research will pursue the following specific sub-objectives:

1. **Identify and evaluate the key sustainability PPS-components and their current level of integration within the PM-domains**
   To identify and evaluate the key sustainability PPS-components within each project management PM-domain and to assess their relevance and current level of integration in Dutch infrastructure projects during the planning and design phase (FEDP), in order to understand how sustainability is currently addressed and how it can be more effectively embedded within existing project management practices.
2. **Develop a semi-quantitative method for sustainability integration**
   Develop a practical approach that translates high-level sustainability goals into measurable outcomes at PPS-level. The method will incorporate semi-quantitative evaluations to capture both tangible and intangible sustainability aspects, thereby enabling their integration into essential PM processes such as scope definition, cost modeling and risk prioritization.

3. **Create a standardized decision-support method**
   Formalize the developed approach into a transferable and user-friendly decision-support method to be applied within W+B. This aims to reduce 'ambition erosion', which is the decline of sustainability objectives during project development, by ensuring knowledge transfer, consistent application and embedding.
4. **Validate and apply the method in real-world projects**
   Test and refine the method using a Multi-Criteria Decision Analysis (MCDA) based validation approach on an ongoing Dutch infrastructure project (base case) using a focus-group session. This will assess its effectiveness in improving sustainability-related decision-making and produce lessons learned and best practices to support future adoption.

This research aims to improve decision-making processes and provide long-term value by integrating sustainability considerations into PM-domains at PPS-level. The resulting method aspires to bridge the gap between academic insights on sustainability assessment and the practical needs of project managers, thereby supporting the transition toward more sustainable infrastructure development.

2.3.3. Research scope

To ensure a focused and manageable research, the scope of this research is carefully defined. The following aspects outline the specific boundaries of the research, clarifying the project phase, sustainability dimensions, types of infrastructure projects, geographical context and PPS-level integration (within 10 key PM-domains). In doing so, this research can explore the selected domains in depth and offer valuable insight into integrating sustainability into infrastructure project development:

- **Project phase focus**
  This research focuses on the planning and design phase of infrastructure projects. This is the phase where critical decisions are made (and 'lock-in') that greatly affect the long-term sustainability outcomes of the project.
- **Sustainability dimensions**
  This research incorporates environmental, social and economic indicators (related to sustainable theoretical approaches) to ensure a balanced assessment of sustainability. The framework or approach developed will consider all three dimensions to provide a holistic evaluation.
- **Infrastructural projects**
  This research will primarily focus on specific types of big and complex infrastructural projects relevant to the Dutch construction industry. This can be for example transportation (e.g., roads, railways), energy (e.g., renewable energy installations) and urban development projects. The specific types of projects used for base-case(s) or validation will be clearly defined.
- **Geographical context**
  Real project case(s) and validation efforts (using a workshop) will be conducted on projects within the Netherlands. This allows for consideration of regional specificities, such as Dutch regulations, environmental conditions and stakeholder expectations.
- **PPS-level**
  This research is specifically scope to the PPSs within the 10 key project management PM-domains (see Figure 2.1) during the planning and design phase. This research does not cover the entire project life-cycle (LC).
- **Project Management Book of Knowledge (PMBoK)**
  This research is focused on the well known and practical guideline *A Guide to the Project Management Body Of Knowledge* (PMBoK) related to the 10 PM-domains (Project Management Institute, 2017).
- **Engineering consultancy firms**
  The focus of this research is primarily on the perspective of an engineering consultancy during the planning and design phase of an infrastructure project, in this case W+B.

While this research focuses on the development of an approach of sustainability integration within one of the PM-domains on PPS-level during the planning and design phase, it is important to acknowledge that sustainability do not exist in isolation. They engage with broader project factors, such as integral design processes and iterative feedback loops, which influence decision-making throughout the project LC. Although some of these aspects fall beyond the direct scope of this research, recognizing their role helps to place the research within the larger context of project dynamics.

2.4. Research relevance

2.4.1. Scientific relevance

This research is scientifically relevant because it develops and validates an integrated method to embed sustainability metrics into project management PM-domains, addressing a current gap in sustainable infrastructure development theory and practice.

As in practice a wide range of sustainability assessment tools and frameworks exist (e.g. Envisions or IS-Rating), these typically operate in parallel with core project management processes. This research contributes to the scientific discourse on sustainable infrastructure by systematically embedding environmental, social and economic sustainability indicators into project management domains focused on the level of PPSs during the early planning and design phase (FEDP). By this approach, the engineering consultancy firms, in this case W+B, are able to integrate sustainability 'automatically' by adjusting their standard day-to-day workflows and use their corresponding PPSs in such a way to optimize sustainability (integration). By applying a MCDA, this research employs a method to identify the best 'perfect-fit' sustainability integration approach within the scope of this research. The validation of the developed method or framework, takes place on a real-world infrastructure case, which provides empirical insights on practical relevance and applicability, which addresses the need for more tangible sustainability assessments as discussed earlier in Chapter 1. The approach used for this research is based on the Design Science Research Methodology (DSRM), applied through the lens of a Double Diamond, explained in Section 2.5. Making the methodology grounded and adaptable to future challenges with the aim to go beyond assessing sustainability to actively integrating it into the project its DNA from the outset (Onat et al., 2017).

2.4.2. Practical relevance

This research is practically relevant because it provides practitioners with a structured method to integrate sustainability into early-stage project decisions, improving performance, reducing risks and aligning with emerging sustainability requirements.

The method developed during this research aims to support practitioners and PMs (e.g. from W+B) by providing a structured and accessible way to handle and evaluate sustainability impacts. By embedding environmental, social and economic dimensions into project management processes, this method helps teams anticipate long-term challenges such as regulatory compliance, stakeholder acceptance and environmental performance. This proactive approach can reduce project delays, lower unforeseen costs and support alignment with ESG requirements and European sustainability directives such as the Sustainable Development Goals (SDGs) and the European Union (EU) Green Deal. This is particularly relevant for Renovation and Replacement (R&R) projects, where high uncertainty makes it difficult to promise specific sustainability outcomes early on. As designs progress and client decisions are made, the potential for sustainability outcomes becomes clearer, yet outcomes cannot be guaranteed. Instead of promising fixed outcomes, this research emphasizes offering an approach that ensures sustainability is continuously considered and integrated throughout decision-making. This aligns with the concept of 'capability' and helps ensure sustainability is treated not as an external constraint but as a core component of project development, supporting both the feasibility and resilience of infrastructure projects.

2.5. Research methodology

This research follows a Design Science Research Methodology (DSRM) structured through the lens of the Double Diamond model, which is commonly used in design and innovation disciplines for its iterative and problem-solving approach. The model breaks down this research into four key phases; Discover, Define, Develop and Deliver each aligning with the sub-questions and research activities of this study, see Figure 2.2. This structured yet flexible approach ensures both theoretical depth and practical relevance in the development of a sustainability integration tool for infrastructure projects. The Double Diamond method is used within this research methodology to maintain a balance between divergent thinking (exploring issues and possibilities) and convergent thinking (refining and delivering actionable solutions) such that each phase logically flows from the previous in a way that is both academically rigorous and practically grounded. The result is a tool that bridges the gap between high-level sustainability ambitions and everyday infrastructure project decision-making.

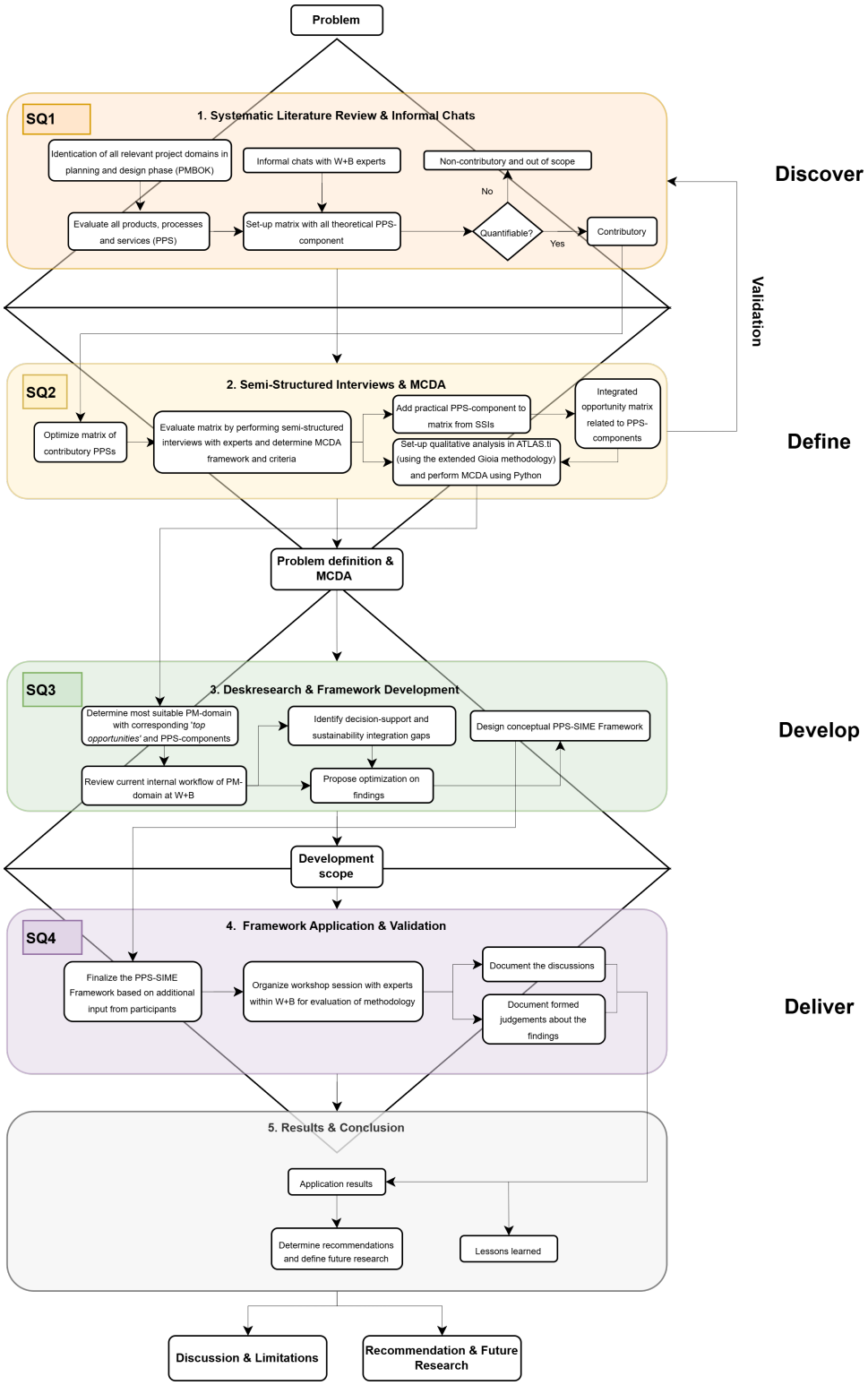


Figure 2.2: Double Diamond concept of this research (source: Author)

Discover phase (SRQ1 – Systematic Literature Review & Informal Chats)

This initial phase explores the problem by gathering both theoretical and practical insights. A main distinction to emphasize here, is that this is not related to the 'Grounded Theory' methodology since this requires more preparation in terms of literature study. This phase consists of:

- **Systematic Literature Review (SLR)**
  A thorough review of literature identifies the relevant project management domains in the planning and design phases (as per PMBoK) and their associated PPSs. It evaluates existing (inter)national tools and frameworks, particularly those relevant for Dutch infrastructure (e.g., DuboCalc, Ambitieweb), to identify their strength, limitations and gaps in early-phase sustainability integration. To ensure that relevant existing literature with connections to the research topic is identified, a systematic approach is developed. This approach involves a literature review method in which targeted keyword and time-period searches are conducted across various academic article databases (e.g Scopus, JSTOR and Google Scholar). This strategy entails progressively narrowing down collections of relevant publications by applying multiple keyword combinations. Once a manageable number of articles is obtained, a quick scan is performed based on their introductions, abstracts and conclusions, see Figure 2.3.
- **Informal Chats**
  Informal consultations with experts at W+B supports understanding what the company structure means on individual, project and organizational level. Besides this, it provided insight on who to recruit for the Semi-Structure Interviews (SSIs), in collaboration with the committee members from W+B. By doing so, it helps to accelerate the interview procedure and gather relevant data from the SSIs.

Outcome

A structured list of contributory PPS-components with initial sustainability related factors serving as the foundation for further validation.

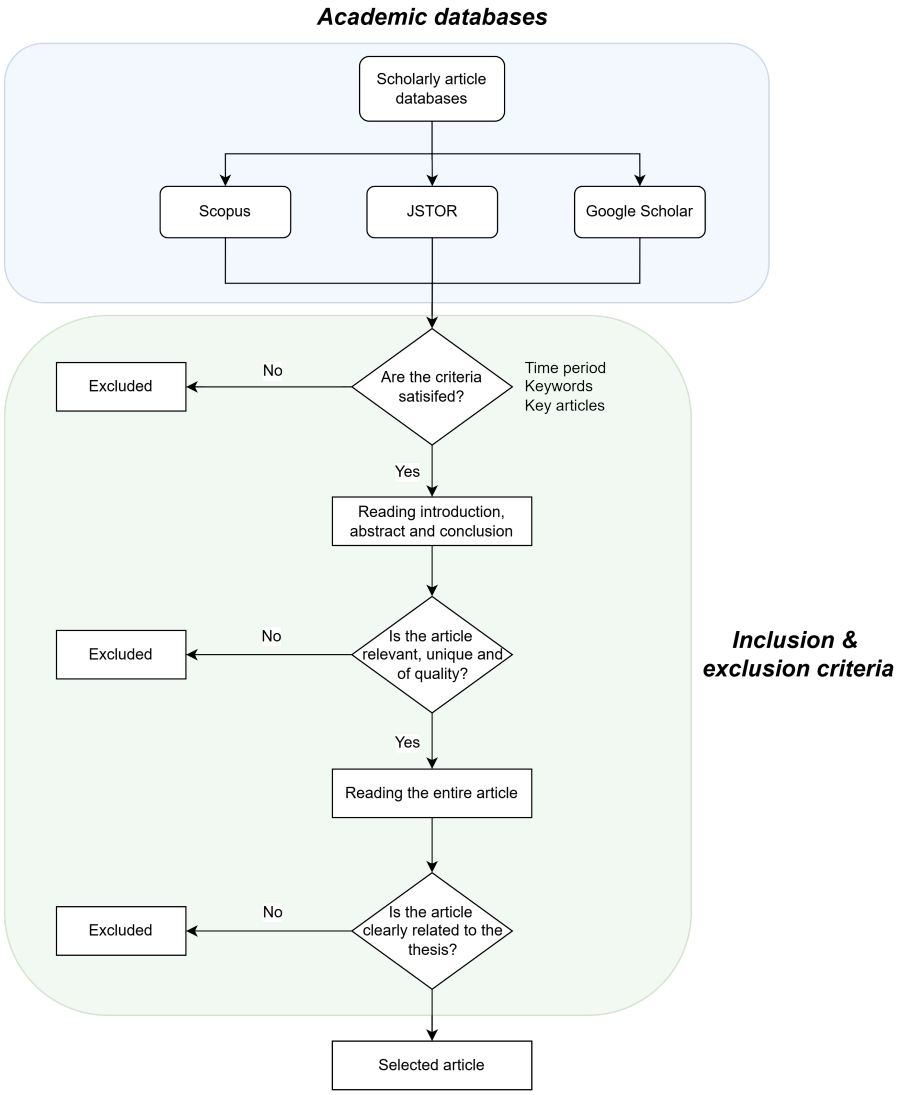


Figure 2.3: Systematic Literature Review (SLR) approach (source: Author)

Define phase (SRQ2 – Semi-Structured Interviews & MCDA)

In this phase, the collected data and preliminary factors are validated and prioritized based on the criteria and weighting factors determined in collaboration with the experts. This phase consists of:

- **Semi-Structured Interviews**
  Semi-Structured Interviews are conducted with participants at W+B with different backgrounds and roles (e.g. project manager and sustainability advisor), with a minimum of 12 interviewees according to Adler and Adler (2012), in order to validate the identified PPS-components. This number is suggested as it gives the researcher experience of planning and structuring interviews, conducting and partially transcribing these and generating quotes for the papers. More than this seems to be impractical within the customary time constraint. These interviews also determine the most relevant criteria for sustainability integration and identify their practical measurability. The qualitative data from these interviews will be analyzed using thematic coding in ATLAS.ti following the structured steps of the *Gioia methodology* as a basis, enabling systematic identification of first-order concepts, second-order themes and aggregate dimensions as mentioned in Table 2.1, referred to as the *extended Gioia methodology*. This method helps to move from raw qualitative data to well-structured theoretical concepts, using a multi-step coding process. It ensures that the final findings are grounded in the participants' own words while still allowing to build abstract concepts and theory (Frank, 2025). However, an extra dimension is added, which is about the fitting within the research context (also stated as generalization). More information about this can be found in Appendix A.

Table 2.1: 4-level structure of the extended Gioia methodology, using the Gioia Methodology as a base (source: Author)

Level	Description	Purpose
1st-Order Concepts	Labels (codes) that stay close to the participants' own words. Often lots of codes.	Captures terms and perspectives of informants
2nd-Order Themes	Researcher groups related 1st-Order concepts into more abstract categories.	Adds interpretation and meaning
3rd- Order Aggregate Dimensions	The highest-level categories capturing broad theoretical constructs.	Builds the conceptual framework
4th-Order Fitting	Extension of the Gioia methodology, which entails the overall fitting of the 3rd-Order Aggregate Dimension into the research context	Fits the conceptual framework within the research context, in terms of theoretical background (SLR and interviews)

- **MCDA-framework and criteria setup**
  A MCDA framework is prepared by using Python to collect results. This is intended to optimize and rank contributory factors. Literature findings are cross-checked with the interview outcomes to ensure the 'fit-for-purpose' PPS-components selection within the corresponding PM-domain. Eventually it is validated based on the measurability and quantifiability, decision leverage and embedding.

Outcome

The outcome of the *extended Gioia-method* is shown in a "Gioia data structure" diagram, which is a 4-level flowchart showing how raw data links to themes and (fitted) dimensions. As last, a finalized, validated list of sustainable quantifiable PPS-components and a prioritized decision-support structure (represented as a framework) is obtained.

Define phase (SQ3 – Deskresearch & Framework Development)

Using the findings and collected data from the previous phases, now the focus is upon the design of the new sustainability integration methodology or framework. This phase consists of:

- **Identify most suitable PM-domain**
  Based on evaluated PPS-components (on expert judgment), the PM-domain with the highest sustainability potential is selected.
- **Gap analysis and workflow optimization**
  Desk research analyzes existing workflows in the selected PM-domain(s) and identifies existing decision-support gaps and opportunities for sustainability integration.
- **Framework development**
  A new semi-quantitative sustainability integration framework is drafted and reviewed with internal experts to ensure practical alignment.

Outcome

A conceptual methodology/framework for integrating sustainable PPS-components into (existing) PM workflows of the most promising PM-domain, tailored to the Dutch infrastructure context.

Define phase (SRQ4 – Framework Application & Validation)

This final phase is used to test and evaluate the developed methodology within the chosen PM-domain(s). This phase consists of:

- **Workshop session**
  Focus groups with W+B experts, PMs and engineers in order to evaluate the methodology for usability, practicality and added value. This is done during a collaborative day with the disciplines (also called PMC's at W+B) of Construction Management and Sustainability ('Circular Net Zero Solutions').
- **Framework testing**
  The framework is applied to a real infrastructure project or idea that has been developed internally, taking into account the organizational (decision-)structure focused within that specific PM-domain.
- **Discussions, judgments and lessons learned**
  The results of the validation session are derived from the discussions and judgments made during this session. This helps to clarify the results of the framework and hleps to assess its efficiency and reproducibility

Outcome

A validated PM-domain sustainability integration method on PPS-level, with practical recommendations for improving decision-making in early project phases.

2.6. Research design

As mentioned earlier this research adopts a structured Design Science Research Methodology (DSRM) through the iterative Double Diamond model to develop a practical method for integrating sustainability in Dutch infrastructure projects. The design (see Figure 2.4) is systematically divided into four phases: Discover, Define, Develop and Deliver.

- The Discover phase answers **SRQ1** by applying a SLR to identify initial PPS-components relevant to sustainability integration.
- These findings are used to inform the Define phase (SRQ2), where SSIs (analyzed using the extended Gioia methodology) and a MCDA framework to validate and prioritize these factors, resulting in a structured data diagram and a validated and integrated list of quantifiable PPS-components and corresponding opportunities.
- Next, the Develop phase (**SRQ3**) is directed towards the design of a draft semi-quantitative methodology, including gap analysis and workflow optimization, for a suitable PM-domain and fitting to the requirements of the Dutch context.
- In the final step of the Deliver phase (**SRQ4**), this draft methodology will be carefully evaluated through expert focus groups and tested in a real Dutch infrastructure project, resulting in a validated sustainability integration method and practical recommendations to improve decision-making at the early stages.

The outputs of the different phases are interconnected and provide a logical flow from problem exploration to a practically tested solution.

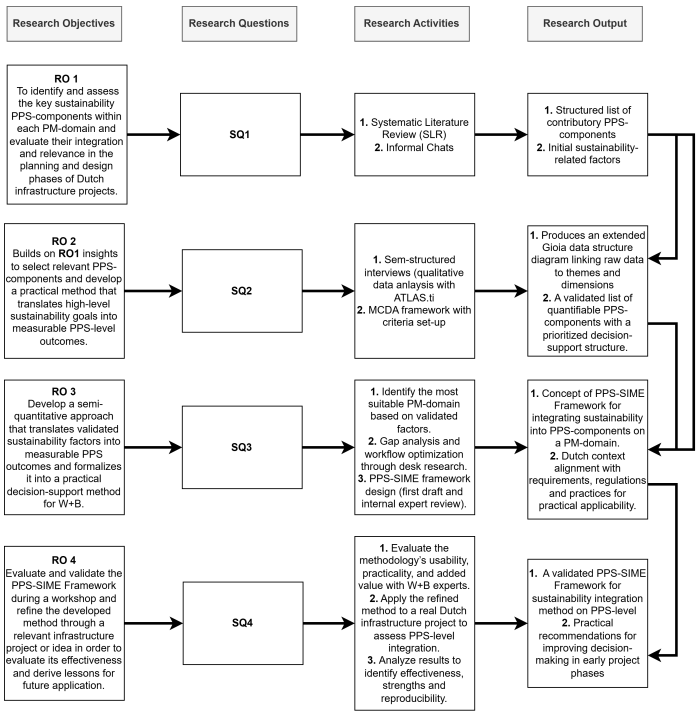


Figure 2.4: Research Design (source: Author)

3

Systematic Literature Review (SLR)

This chapter presents a Systematic Literature Review (SLR) which provides the theoretical, contextual and practical basis for this research. The SLR follows a funnel logic (zoom-out to zoom-in), gradually narrowing the scope from broad conceptual and policy perspectives on sustainability to the operational and organizational dimensions relevant to Dutch infrastructure projects on PPS-level. This approach enables a structured understanding of how sustainability is currently perceived, operationalized and measured. Representing the common thread of this report.

3.1. What is sustainability?

The first step is to understand what sustainability really means. As stated before in Chapter 1, the most framed definition is that of the Brundtland Commission (World Commission on Environment and Development, 1987). This definition couples intergenerational equity with economic and social development, representing the global touchstone for policy, research and practice. The main elements of sustainability are shown in Figure 3.1.

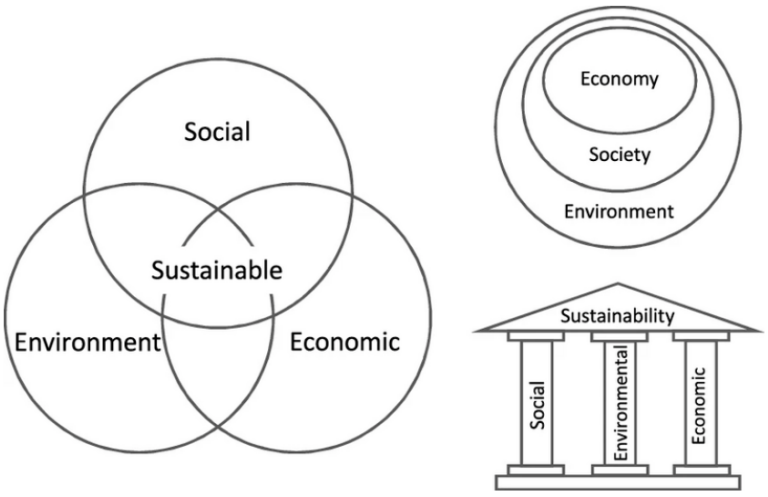


Figure 3.1: The three sustainability concepts (Purvis et al., 2019).

1. **The environment - environmental**
   Whereas natural resources and ecosystems are conserved by reducing pollution, managing waste, protecting biodiversity and using renewable energy to stay within the Earth's ability to produce.
2. **The society - social**
   Whereas well-being and quality of life for all people is fundamental, including equitable access to services like heal and education, social justice, fair labor practices and strong inclusive communities.
3. **The economy - economical**
   Whereas long-term economic viability and growth that is inclusive does not deplete the natural or social resources it depends on.

In general these sustainability core components are mainly used differently in research, dependent on how they are interpreted and how they portray the relationships and hierarchy between them. Often terms like "spheres," "pillars," and "circles" are metaphors used to visualize different models of sustainability. In Table 3.1 is explained what the analogy between these 3 different sustainability concepts are.

Table 3.1: Comparison of sustainability concepts (source: Author)

Sustainability concept	Visual metaphor	Philosophy
3 Pillars	Pillars supporting a structure	This concept emphasizes that sustainability is the balance point where all three components meet and work in harmony (the 'Triple Bottom Line' (TBL) of People, Planet, Profit). Components are equally important and exist in a state of balance, trade-offs are managed to find a "sweet spot" in order to maintain its stability.
3 Circles	Overlapping circles (Venn diagram)	This concept emphasizes that sustainability refers to two main visualizations, namely the Pillars model and the nested Spheres model represented by the concentric circles. The overlapping model suggests a balance between the economy, society and the environment. In contrast, the nested model shows a clear hierarchy: the economy exists within society and society exists within the environment. The environment is therefore the fundamental foundation for all human activities.
3 Spheres	Spheres (often nested or interlinked)	This concept emphasizes that sustainability exists only in harmony if the outer sphere (environment) is strong and stable in order to act as a shield toward the other two dimensions (society and economy) for development as is already explained in the 3 Circles concept above.

The terms 'spheres', 'circles' and 'pillars' are often used interchangeably to describe different dimensions of sustainability. This approach is a derivative of Brundtland's concept and was developed throughout the years by Elkington et al. (1997) representing the theoretical Triple Bottom Line (TBL). However, some models go beyond the traditional three dimensions. For example, the Circles of Sustainability approach also includes additional components such as politics and culture (Purpose). The relationship depends on the specific model used, but generally describes distinct areas of influence or transformation (e.g., personal, political, practical spheres of transformation) representing the Quadruple Bottom Line (QBL).

3.1.1. Theoretical approaches

Triple Bottom Line (TBL)

As mentioned earlier, the TBL is a sustainability framework developed by John Elkington, it challenges the old-fashioned profit-centric view of organization performance by proposing an approach that long-term value creation must be assessed through the dimensions of:

- Economic (Profit / Prosperity)
- Environmental (Planet)
- Social (People)

The TBL framework states that sustainable development is achieved only when these three dimensions are balanced and support each other, rather than being treated as trade-offs.

The economic dimension is implicitly underlining the fact that it goes beyond short-term profitability, because the economical development is inherent to time. This proofs and shows that in the Dutch construction industry this dimension is related to aspects such as Life-Cycle Costing (LCC), circular business models (e.g. material use and leasing concepts) and cost optimization though low-maintenance and energy-efficient projects. **The environmental dimension** focuses on minimizing negative ecological impact and improving environmental contribution or at least maintaining it. Within the Dutch construction industry this dimension is strongly embedded within criteria and tools like the CO_2-Prestatieladder, MKI-calculations and the target to reach a full Circular Economy (CE) by 2050 which is elaborated on in Subsubsection 3.1.4.3. **The social dimension** addresses the impact of organization activities on people and communities. In the Dutch construction industry this dimension gained significant traction due to working shortages and aging workforce within the employment market, increased attention to occupational health and safety and community participant in projects.

Quadruple Bottom Line (QBL)

Due to some limitations in practice such as treating sustainability dimensions as separable rather than systemic (1), allowing organization to prioritize certain pillars while symbolically addressing others (2) and lacking standardized performance metrics (3) the development of expansion of the TBL has originated, resulting in the Quadruple Bottom Line (QBL). Other studies emphasized that expanding the TBL into the QBL adds a more corporate spirituality as a fourth pillar (Mohd Zawawi & Abd Wahab, 2019; Salihu et al., 2025). Therefore, the QBL is often conceptualized as the Purpose-driven value, additionally to the Planet, People and Profit, resulting in:

- Economic (Profit / Prosperity)

- Environmental (Planet)
- Social (People)
- Governance (Purpose)

The purpose dimension is often recognized as governance and institutional responsibility focusing on decision-making quality, transparency and long-term societal alignment with all parties involved. In the Dutch construction industry governance is particularly relevant because of strong Public Private Partnerships (PPPs), complex tendering and procurement procedures with all parties and stakeholders and increasing ESG reporting mandates due to Dutch and/or European rules and regulations. Governance acts as an enabling mechanism that integrates economic, environmental and social goals into unified strategies rather than separate initiatives.

3.1.2. Sustainable Development Goals (SDGs)

Based on the concepts and systems outlined earlier in Table 3.1, related to the TBL and QBL analogy, the United Nations introduced a universal call to action aimed at creating a more sustainable and equitable world. This agenda consists of 17 Sustainable Development Goals (SDGs), designed to end poverty, protect the planet and ensure that all people can live in peace and prosperity by 2030 (UN Global Compact Network Netherlands, 2026). Together, the 17 SDGs are supported by 169 specific targets that define the concrete objectives associated with each goal. Achieving the ambitions of the United Nations Agenda 2030 requires collective effort. Governments, organizations, companies like W+B and individuals all have a vital role to play role in driving these goals and helping to create a more sustainable future. During the years, these concepts developed in different opinions and approaches on how to visualize the coherence and understanding of the SDGs altogether. In 2016, the Stockholm Resilience presented a new visualization, which was the so called SDG 'Wedding Cake', this is a visual representation, see Figure 3.2, that represents a tiered cake, with each layer representing a different earth system (Stockholm Resilience Centre, 2016).

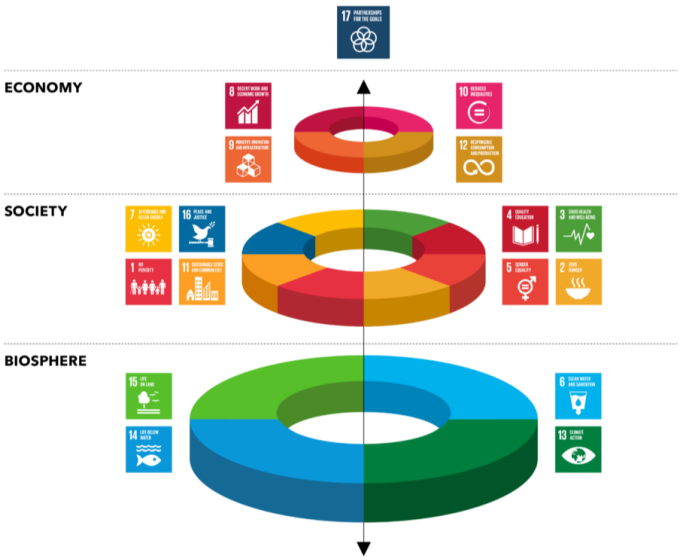


Figure 3.2: The SDG Wedding Cake (Stockholm Resilience Centre, 2016)

Stockholm Resilience Centre (2016) states that it describes how economies and societies should be seen as embedded parts of the biosphere. This vision is a move away from the current sectorial approach where social, economic and ecological development are seen as separate parts. Meaning that the focus shifts from the environmental externality to the biosphere as precondition for social justice, economic development and sustainability (Folke et al., 2016). This is emphasized by participant [P6] of the SSIs from Table 4.1 in Chapter 4, who stated that the world and humanity can continue without an economy, but the economy cannot exist without society and nature. If you damage the biosphere, society and the economy will collapse as well. The moral of the story is that the system of earth are important and interconnected to each other. The ecology, society and economy are the three systems that are represented and each is nested (or embedded) within the other emphasizing their impact and interconnection. Additionally, the nesting demonstrates the significance of individual systems in accomplishing the SDGs. To conclude, societal and environmental systems are critical and fundamental for an economic system and its functioning (Cisar, 2023).

3.1.3. The SDG-development of the Netherlands

The Netherlands has developed a comprehensive policy and institutional context for sustainability, especially for infrastructure, energy transition and circular economy (CE), extensively elaborated in Subsubsection 3.1.4.3. These developments are mainly relevant for SDGs 9, 11, 12 and 13. These goals are represented in Dutch infrastructural policy through ambitions for climate neutral construction (e.g. SEB), circular material use (e.g. KCI), sustainability procurement (e.g. 'Duurzaam inkopen') and flexible infrastructure systems. However, in this research, the relevance of the SDGs is not that they provide a complete project level method for sustainability application or integration. The relevance of the SDGs

lies in that they represent the performance and baseline for sustainability development in the Netherlands in which Dutch infrastructure projects are developed. The challenge in practice is that the abstract and upfront ambitions are translated into project decisions during the FEDP (the planning and design phase). Since, this is the phase where sustainability ambitions are formulated, interpreted, weakened or locked into project scope, cost, risk and procurement management and design decisions. Thus, the Dutch SDGs context is only used in this research as a strategic background, not as analytical core. The analytical core of this research is about the integration of sustainability into project management domains on PPS-components level in Dutch infrastructure projects. In short, the SDGs explain why sustainability matters, but these goals do not explain how sustainability should be anchored or embedded into day-to-day project management processes of engineering consultancy firms like W+B. Extensive information on Dutch SDGs development are documented in Appendix A.

3.1.4. Sustainability in Dutch infrastructure development

The Netherlands is making progress in the context of sustainability (integration) in infrastructure projects since (inter)national policies, CE ambitions, procurement practices and sector specific assessment tools have increasingly translated sustainability ambitions into project requirements. The Dutch infrastructure development is mainly connected to SDG 9 (industry, innovation and infrastructure), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production) and SDG 13 (climate action). These goals alone do not result in integrated decision making on sustainability at project level, they mainly function as a strategic policy direction. The practical challenge is therefore not the absence of sustainability ambitions, but the translation of these ambitions into concrete decisions during the planning and design phase (FEDP) of infrastructure projects. In the Dutch infrastructure sector, sustainability is nowadays strongly shaped through national climate targets based on:

- Het Klimaatakkoord (Paris Agreement) (Rijksoverheid / Ministerie van Economische Zaken en Klimaat, 2019)
- CE ambitions based on the Nationaal Programme Circular Economy (NPCE) (Ministerie van Infrastructuur en Waterstaat, 2023) and Climate and Circular Infrastructure (KCI) (Duurzaam GWW, 2026)
- Procurement requirements based on Clean and Emission-Free Construction programme (SEB) (CROW Kennisplatform, 2026)
- Assessment tools in practice like Ambitieweb (Ambitieweb, 2024) and Omgevingswijzer (Omgevingswijzer, 2023) being part of 'Aanpak Duurzaam GWW' (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025))

These developments have led to several initiatives that aim to reduce emissions and in parallel, increase material (re)use and encourage more sustainable design choices (e.g. IFD and DOP principles). Altogether these initiatives proof that sustainability in the Dutch construction industry is not only a technical design ambition, but also a policy- and procurement-driven transition.

The SEB programme is relevant for construction execution because it is mainly focused on reducing emissions from construction equipment, vehicles and machinery. The programme encourages (with 'push' and 'pull') measures using regulatory pressure, that mandates and requests the use of cleaner construction methods. The SEB programme has a bounded scope of application and mainly addresses construction related emissions and does not provide a full framework by itself for integrating sustainability across all project management domains or across the entire project LC on PPS-components level. Because of this, SEB is important as part of the Dutch sustainability environment but it is not applicable and sufficient as a project management method for sustainability integration. The 'Aanpak Duurzaam GWW' (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025; Duurzaam GWW CROW, 2016), standing for 'Sustainable Approach for Civil Engineering', is more directly connected to infrastructure project development. The approach supports clients and the market by incorporating sustainability in civil engineering projects (of which infrastructure projects are part of) by motivating early ambition setting, project specific prioritization, innovation and assessments. This approach includes instruments such as the Omgevingswijzer for a broad analysis of a project's effects on its surroundings (Omgevingswijzer, 2023), Ambitieweb helps to define and document sustainability ambitions across several themes (Ambitieweb, 2024), CO_2-Prestatieladder for criteria use during tenders or compare alternatives for carbon reduction (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b) and DuboCalc for MKI extraction of a variant or product to determine environmental performance (Rijkswaterstaat DuboCalc, 2025). All these instruments help project teams to keep track of sustainability within their projects, since they provide values or insights on a project. This will be elaborated more in detail later in this report.

These instruments are valuable, but also show a limitation that is central to the context of this research, since they can make sustainability visible, comparable and measurable, but they do not automatically embed sustainability into everyday project management or project control processes where planning, scope, cost, risk, procurement and design trade-offs are made. Hence, in this research the challenge lies in identification of PPSs that contribute to sustainability integration within current standard workflows across different PM-domains and see if they are fit to quantify and measure. In short, they help to answer the question of how sustainable a project or alternative is, but they provide less guidance on how sustainability should actively reshape project management decisions during the FEDP. This is an important distinction worth mentioning, since sustainability ambitions can weaken or erode (due to ambition erosion as was highlighted by Veen (2023)) during project development when they are not translated into responsibilities, deliverables, monitoring

mechanisms and decision criteria. Finally, the existing Dutch policies and tools show that sustainability is already institutionalized in the construction sector, however there still exists a gap in operation integration. Meaning that sustainability must be anchored in project management domains and PPS-components during the FEDP, rather than being treated as a separate or additional assessment activity or as an ambition setting exercise only. More information about this is provided in Appendix A.

Sustainable Development

Sustainable development is subjective concept everyone is for, but there are deep disagreement about how to improve it or understand it (Jacobs & Stott, 1992). Literature, again, provide different definitions of the term sustainable development (as sustainable or sustainability is included here), but is often used in projects involving construction. Another resource refers to this as 'society's commitment to achieving interconnected objectives of economic development (including ending poverty), social inclusion, environmental sustainability and good governance with personal security' based on a developed framework (Network, 2012). However, just like the 'Wedding Cake' in Figure 3.2, World Commission on Environment and Development (1987) refers to a system where 'development and environment need to be in a 'balancing system'. Finding the 'sweet spot' within supply (development) and demand (environment). This indicates that sustainability (development) is interpreted and defined differently and can be only realized when impacting variables are altogether in harmony. In practice, (inter)national rating systems have tried to represent and reproduce these definitions as a tool that can be used, within the field of engineering such as Envision (ISI, 2023), the IS Rating Scheme (Infrastructure Sustainability Council (ISC), 2021, 2025; Infrastructure Sustainability Council of Australia, 2025), CEEQUAL (CEEQUAL Ltd., 2018; Royal College of Pathologists and Crossrail Learning Legacy, 2018) and BREEAM-NL (Building Research Establishment, 1990; Dutch Green Building Council (DGBC), 2025) as shown in Table 3.2. They are strong in making sustainability visible and comparable, but are weak at embedding it inside day-to-day project management and control. This is because of the focus on evaluating a project across TBL criteria throughout the entire project LC, besides the fact that they offer a 'common national language for evaluating sustainability in infrastructure development'. That is the reason why they can be useful for sustainability integration , but are not fully 'anchored' in traditional project control and project management practices. These rating systems contain a scoring mechanism, which eventually awards the project after a design review for example. This indicates that the tools mainly serve as as a certification system rather than as an active decision support tool for sustainability integration (on PPS-level). In addition, these tools are often applied during or after design development, meaning that planning is not completely taken into account and that is where project control comes into play as well. The rating systems lack real time decision making and early integration into cost estimation, risk management and scheduling for example.

Sustainability rating system	Geographical application and scope	Methodology	Characteristics	Fit for PM sustainability integraiton
Envision	Applied internationally, mainly focused on civil infrastructures	It works with a TBL credit-based LC assessment, with verification after design review	The rating system contains a file which covers social, environmental and economic criteria across the LC and functions as a tool to guide decision-making and recognize high sustainability levels	The rating system works strong as a sustainability benchmark, but it shows that it is still mainly verification-led rather than being suitable for integration into day-to-day project control
IS Rating Scheme	Applied in Australia and New Zealand, mainly focused on infrastructure programs, projects, networks and assets	It works with a QBL based rating framework across project phases with separate tools for each stage	The rating system is broader than focusing on a single phase and contains a file noting that planning, design, procurement and construction require different modules, making it more phase-sensitive than a simple checklist	The rating system might be useful for LC sustainability thinking, but is not completely anchored within the FEDP project control or project management
CEEQUAL	Applied in the UK and Ireland plus an international manual, mainly focused on civil engineering, infrastructure, landscaping and public realm	It works with an evidence-based question set, scored through manuals and external (third-party) verification and awarded via a percentage scoring mechanism	The rating system distinguishes itself due to its adaptability to local context, whereas the international version requires local weighting, with separate project/contract routes and a whole-team award option	The rating system encourages early sustainability considerations, as documented evidence and question sets support strategy and design-phase thinking, but it still mainly functions as an assessment and award system
BREEAM-NL	Dutch adaptation of BREEAM, mainly focused on the built environment and buildings	It works with certification across the whole building LC	The rating system is adapted to the Dutch context and used by building owners, project teams and facility managers to benchmark or certify buildings; more building-focused than infrastructure-focused	The rating system is the least central to this research scope, as it is treated as a building-industry tool rather than a mechanism for embedding sustainability into infrastructure project control

Table 3.2: Comparison of sustainability rating systems (source: Author)

In summary, these sustainability rating systems add value to sustainability integration by giving projects criteria, benchmarks and verification routes, but they are not operationalizing inside the PM-domains where decisions are actually controlled and managed during infrastructural projects. The sustainability rating systems rather answer 'how sustainable is this project?' instead of 'how should sustainability reshape the next planning, cost, risk or procurement decision?' which is exactly the gap this research identifies for the planning and design phase. Thus, the sustainability rating systems are valuable in assessment and certification framework, but they are not sufficient as embedded project control and management mechanisms, so a specific PM oriented approach still needs to translate sustainability from a rating

outcome into a FEDP decision logic. Regardless of the inapplicability of these rating systems in practice there are some Dutch initiatives that has been designed for the construction industry originated from governmental strategies to strengthen sustainability (integration). The approach of these sustainability rating systems are elaborated extensively in Appendix A.

Sustainable Construction
Sustainable construction in the Dutch infrastructure sector is formed by climate targets as mentioned earlier. The performance of the Netherlands on innovation and infrastructure is strong (Sustainable Development Solutions Network (SDSN), 2025a, 2025b), the main challenge is not the formulation of sustainability ambitions, but the translation into measurable project decisions during the early project stages. This is relevant to this research, because the FEDP largely determines which sustainability outcomes are later locked into project PPSs. The government aims for a target of reducing CO_2 emissions by 49% by 2030 related to the 2050 ambitions discussed in Subsubsection 3.1.4.3. The concept of 'sustainable procurement' (e.g. MVI) contributes to this, instead of focusing only on price and quality (e.g. glsBPKV also 'best price-quality ratio'). The MVI approach is used in procurement processes to include environmental, social and circular criteria into infrastructural projects and aligns with the governmental purchasing strategy ('inkopen met impact'). This strategy requires contracting parties to systematically embed sustainability throughout the entire procurement stage (PIANOo / Expertisecentrum Aanbesteden, 2026; PIANOo & Rijksoverheid, 2021).

The policies in the Netherlands, are used as frameworks and show that sustainability in the Dutch construction sector is not only a treated design ambition, but increases as a more procurement- and transition driven topic on the agenda, however this is not within the scope of this research. The SEB designed a Roadmap that addresses operational emissions during the construction and excludes emissions for material production operational decarbonization during construction and excludes emissions from material production, other industrial processes and asset use (Programma Schoon en Emissieloos Bouwen, 2024). So, the SEB supports operational decarbonization during the execution phase, but it does not by itself provide a framework for integrating sustainability across the full project LC. More elaboration on the SEB can be found in Appendix A.

On project level sustainability integration, the CROW (Centre for Regulation and Research in Civil Engineering, Hydraulic Engineering, Road Construction and Traffic Engineering) developed the 'Aanpak Duurzaam GWW' that was mentioned earlier. This approach supports public and private actors in translating the KCI strategy into project practices and is grounded in the TBL logic. The approach is relevant to this research since it explicitly emphasizes early phase integration, prioritization, innovation and functions as a uniform assessment (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025), which consists of five main steps:

- Translate organizational sustainability objectives into concrete projects and tasks.
- Integrate sustainability as early as possible, preferably already during integrated area development, because the planning phase offers the greatest room for influence.
- Focus each project or task on the themes where the largest sustainability gains can be achieved.
- Create room for innovation by allowing parties to propose their own sustainable solutions.
- Assess sustainability in a uniform way by using shared instruments such as the Omgevingswijzer (Omgevingswijzer, 2023), Ambitieweb (Ambitieweb, 2024), the CO_2-Prestatieladder (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b) and DuboCalc (Rijkswaterstaat DuboCalc, 2025).

This approach, uses the Omgevingswijzer and Ambitieweb, which in particular are relevant during the FEDP, since it helps project teams move from broad sustainability ambitions to project specific priorities. The Omgevingswijzer helps to scan the environmental of the project location on social, ecological and economic across 12 themes and visualizes the effects of on its surroundings (Duurzaam GWW CROW, 2016). Performing this collaboratively during a session with internal and external stakeholders helps with identifying where sustainability impacts and opportunities are located. Finally, this instrument can also be used to compare project alternatives (if the assessment is tailored to the project context of course). The Ambitieweb adds value to this by recording and maintaining sustainability ambitions throughout the project LC, across 12 sustainability themes. Doing so during the concept, planning and design phases are more effective for sustainability integration, because these are phases where ambition setting can still influence later project decisions or choices. This can be done on a (generic) organizational level, project level and for evaluation on sustainability integration or development within projects. On a project level for infrastructure projects, the value lies more in the graphic itself, by identifying opportunities, negative impacts, alignment of stakeholders and agreeing ambition levels which are documented in a shared ambition profile. The quality of this profile or outcome is dependent on project knowledge, stakeholder composition and facilitation of these sessions. More elaboration on this can be found in Appendix A.

At W+B, these tools and instruments are applied within a funnel-based approach in the MIRT phase as shown in Figure 3.3, which covers the exploration, plan development and contract preparation phase, where each step is considered as a gradual understanding of the project from broad ambitions to concrete (sustainable) outcomes. The funnel shape means shows that the process starts wide, meaning that a lot of possibilities and ideas are identified and becomes progressively narrow whereas specific choices are made and decision are finalized. The exploration phase ('verkenningsfase'), is about understanding the project context and defining sustainability ambitions. This starts off with analyzing

project questions and ambitions together with involved stakeholders, using the Omgevingswijzer and Ambitieweb (once done during the high level initial exploration phase and a second time during transition to the plan development phase). During the plan development phase ('plantuitwerking') the defined ambitions are translated into specified designs with technical specifications. Meaning that sustainability goals are incorporated into the project through design choices, requirements and performance criteria. After having a few design options, the alternatives are assessed and evaluated against relevant criteria by using the MCDA method to support decision making. This phase is more oriented on determining what is achievable and how can it be implemented, instead of what is desirable. Finally, in the contract preparation phase ('contractvoorbereiding'), the selected solutions and (design) decisions are documented, to be a foundation and justification of the decisions made, particularly in terms of sustainability performance. This will function as an input for the contract documents and procurement procedures, so that sustainability ambitions are secured. Some accountability measures like handover documents and application of instruments (e.g. CO_2-Prestatieladder defining the CO_2 emissions and DuboCalc defining the MKI) are included as well.

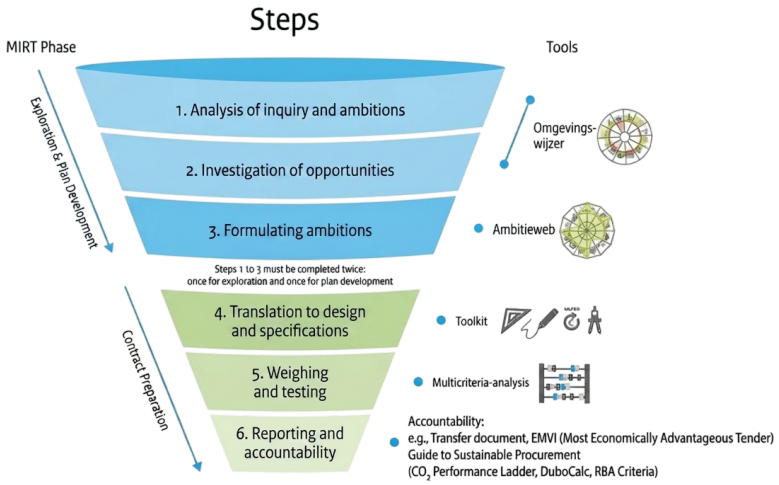


Figure 3.3: Steps for sustainability integration of project in the Netherlands within the MIRT phase ((CROW / Kennisplatform Aanpak Duurzaam GWW, 2025))

The CO_2-Prestatieladder is a Dutch sustainability instrument, that is developed by ProRail and managed by the SKAO since 2011. The system consists of 3 ambition levels. It is applied to reduce CO_2 emissions within organizations across the entire value chain and collaboration with supply chain companies. Regarding projects, it is often utilized during the the procurement phase, whereas it functions as a practical method for translating carbon ambitions into tender incentives that can potentially lead to a fictive discount on the final bidding. The instrument can be used as a BPKV criterion for procurement, whereas a higher ambition level can result in a bigger fictive discount on the tender price and better competitive position (Rijkswaterstaat, 2026a, 2026b). Rijkswaterstaat (RWS) applies this logic within a broader EMVI (also MEAT) or BPKV framework, in which bids are evaluated on the combination of price and quality, including sustainability and risk management. The most recent model of the CO_2-Prestatieladder, which is model 4.0 as shown in Table 3.3. Compliance by bidders can be shown by submitting a so called CO_2 Awareness Certificate or by showing at project level that the tendered ambition level will be achieve, overestimating the ambition can backfire, since bad performance might lead to sanctions. More elaboration on this can be found in Appendix A.

Table 3.3: CO_2 ambition levels and corresponding award advantage ((Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a))

CO_2 ambition level	**Award advantage**
No CO_2 ambition level	0% or €0 or 0 points
CO_2 ambition level 1	5% or €37,500 or 50 points
CO_2 ambition level 2	10% or €75,000 or 100 points
CO_2 ambition level 3	15% or €112,500 or 150 points

Note: Using the absolute scoring method, the total award advantage ranges between €800,000 and €1.1 million, based on a total of 550 points.

DuboCalc, developed by Rijkswaterstaat, complements this by quantifying environmental impacts in monetary shadow costs expressed as the MKI. It is used to compare design variants and to prepare and assess BPKV/EMVI tenders in civil engineering projects (Rijkswaterstaat DuboCalc, 2025). As shown in Figure 3.4, a lower MKI indicates a lower environmental burden over the project LC, which makes DuboCalc particularly relevant for design comparison and tender

substantiation. In practice, these insights helps both clients and contractors to make environmental impacts more transparent and comparable (Duurzaam GWW CROW, 2016).

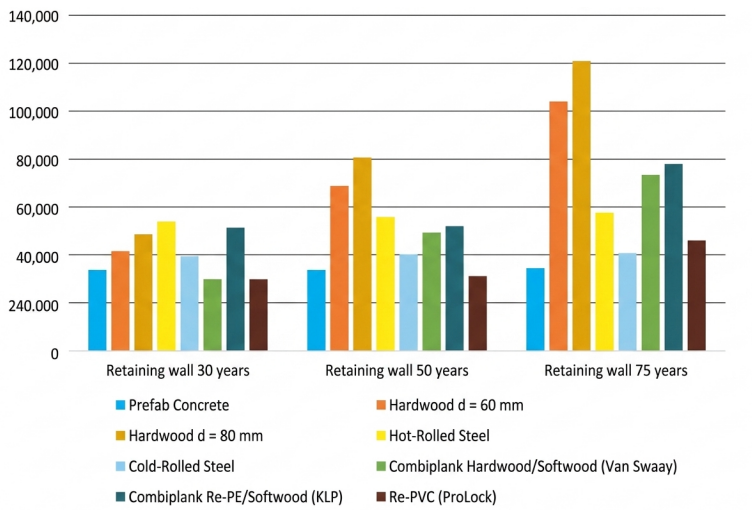


Figure 3.4: Example of using DuboCalc for several cases and material use (Duurzaam GWW CROW, 2016)

Together, SEB, the Aanpak Duurzaam GWW, the Omgevingswijzer, the Ambitieweb, the CO_2-Prestatieladder and DuboCalc show that sustainable construction in the Dutch infrastructure sector already has a relatively mature policy and instrument base. Their main added value lies in ambition setting, assessment, procurement and reporting. At the same time, they do not automatically ensure that sustainability is structurally embedded in the daily project management decisions through which project products, processes and services are shaped. That operational gap between sustainability ambition and project management integration is the core issue addressed in this research. These approaches also contribute to the broader transition toward a CE, which is elaborated further in Subsubsection 3.1.4.3.

Circular Economy (CE)

Sustainability is an important driver in the current Dutch construction industry with trends such as circularity and bio-based innovation. As a leader in this field, the Netherlands has committed to achieving a fully circular economy by 2050, guided by the National Programme Circular Economy (NPCE) from 2023 till 2030 (Ministerie van Infrastructuur en Waterstaat, 2023). In order to achieve the full CE goal this strategic plan is extended and guided by the Circular Dutch Economy ('Circulaire Nederlandse Economie') (Government of the Netherlands, 2025). The timeline is shown below in Figure 3.5.

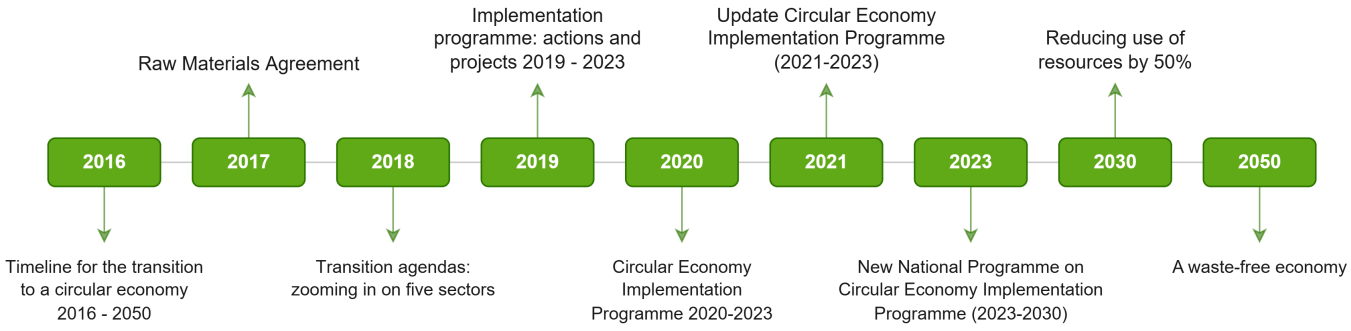


Figure 3.5: Timeline for the Dutch transition to a circular economy between 2016 - 2050 (Government of the Netherlands, 2025).

The analogy of circularity within the economy of the Netherlands can be expressed as a shift from a linear project delivery towards a collaborative, procurement driven value maintenance across the whole project LC. Not only does this in the Netherlands mean that circular construction is about recycling (e.g. using the R-ladder strategy (Rijksdienst voor Ondernemend Nederland, 2025), but also about redesigning roles, contract and information- and workflows, so materials stay valuable for a longer period of time. Besides that, reverse cycles (of closed loop systems) become feasible and project teams can work with suppliers earlier within the chain or process. As stated by (van der Voet et al., 2025), there is not an accepted definition for circular economy, but the core concept is relatively clear. A circular economy aims at keeping resources in use as long as possible. Meaning that waste generation and resource extraction should both be reduced to minimize the impact. Use of different strategies in practice that are developed within current frameworks, aiming at keeping resource as long as possible in the use phase without causing any waste or emissions.

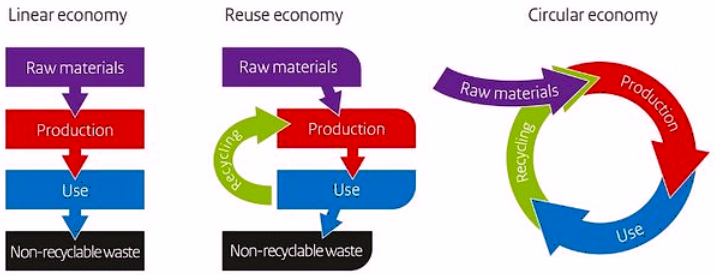


Figure 3.6: Transition between linear economy and circular economy (Pereira et al., 2019)

Therefore, the narrative of a circular economy is moreover emphasized on the principle of extracted resource in the past that are now in use for structures in projects. (van der Voet et al., 2025) refers to this as 'in-use stocks in society'. These provide services to the society, such as mobility or shelter. Indicating that these 'in-use stocks' should be kept healthy for a longer period of time and is not only about process efficiency or closing loops, but about comprehensive asset management (e.g. Asset Management 2.0 from RWS (Rijkswaterstaat, 2025). Since a circular economy can be realized by maintenance of 'in-use stocks', less input of newly extracted materials and decoupling its effect from economic development. (Pots, 2018) argues that the economic development can be positive influenced through the procurement processes that create a 'transition arena' for learning where early procurement, (functional) specifications, shared risk and cooperation between client and partner come together. In contradiction, (Prins et al., 2015) stated that the Dutch construction sector is already fragmented, overly linear and supports a more 'radical' CE interpretation that better fits the economic incentives of the sector. The approach in this does not necessarily indicate that transition will be successful, however (Coenen et al., 2023) identified three vicious cycles that form persistent barriers to increase the success rate. These barriers all relate to procedural, organizational and institutional challenges rather than technological ones. They require explicit changes in scope definition, procurement timing, risk sharing and financial responsibilities, since Dutch circular construction is being operationalized through procurement, collaboration and thinking, but the literature still treats it as a project level transition rather than an embedded routine within everyday project control. To do so, there are some current approaches (e.g. LCA and LCCA) that help analyzing circularity on project or element level, which is also done by W+B using the +CD Tool that defines the Material Circularity Index (MCI) also called the MKI in Dutch.

Life-Cycle Analysis (LCA)

The Life-Cycle Analysis (LCA) is a methodology that is standardized under the ISO-14040 and ISO-14044 certification, which is used to assess the environmental impact of products or projects across its entire LC from raw materials extraction through production, use and end of life disposal ("ISO 14040: Environmental management – Life cycle assessment – Principles and framework", 2006). In the Dutch construction industry, the LCA is more and more applied to quantify embodied CO_2 and material related pollution at project and element level. Buyle et al. (2013) argues that LCA is relevant for the built environment, as building account for a significant share of global resource consumption and emissions. Regarding a CE, LCA allows project teams to compare material strategies (e.g. reuse, recycling or replacing from the R-ladder strategy (Rijkswaterstaat, 2025)) and evaluate the environmental trade-offs across the entire project LC (Honic et al., 2019). In practice, application of LCCA still remains fragmented since it differs per situation, since it is dependent on data availability, boundary definitions and functional unit choices that changes per project. This results into a limitation of comparing and integration at FEDP procurement decisions (Buyle et al., 2013).

Life-Cycle Cost Analysis (LCCA)

The Life-Cycle Cost Analysis (LCCA) is a decision support method that evaluates the total cost of ownership of an assets or structure over its entire service life which involves initial investment, operation, maintenance and end-of-life costs (Fuller, 2016). This indicates that total cost of ownership is a summation of Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). In general, the LCCA allows clients and procurement teams to make decisions beyond 'low initial cost selection' meaning that a more value-based decision can be made, that consider the principles of a CE (Woodward, 1997). LCCA serves as a bridge between economic and environmental objectives if integrated with LCA, which allows project teams to assess both financial and ecological performance in parallel (Gluch & Baumann, 2004). In Dutch context, the LCCA is more and more included in procurement frameworks, where the total cost of ownership (CAPEX + OPEX) criteria are used to incentivize long term asset performance and circular material recycling. Nevertheless, uncertainties in future cost estimates (e.g. discount rates, maintenance cycles or residual material value and performance) still remains a barrier to the use of this method in circular construction (Gluch & Baumann, 2004).

3.2. PMBoK analysis for sustainability integration

Now that the theoretical background on sustainability, SDGs and developments in the Netherlands including the CE are covered. The next step is to delve in more detail about the project management domains and their corresponding PPS-components during the planning and design phase as this research analyzes the topic from the perspective of W+B. Meaning that only the FEDP (planning and design phase) is considered, as shown in Figure 3.7. In this research, each PM-domain from the project management guideline, the Project Management Book of Knowledge (PMBoK), is investigated, which is a leading PM-guideline that is used in practice, being a comprehensive guide of standards and best practices for applying various methodologies developed in the United States by the Project Management Institute Inc.

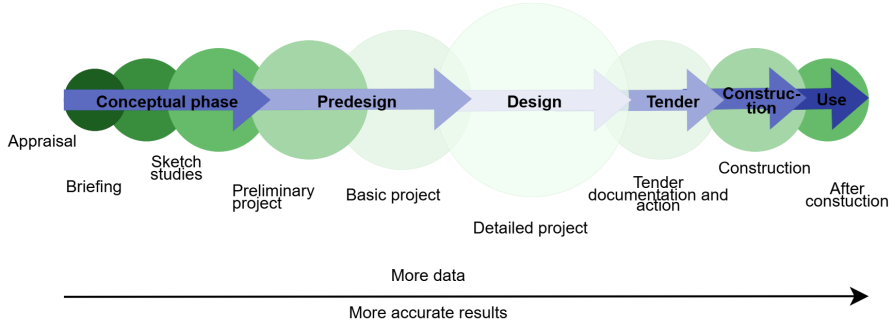


Figure 3.7: Project stages of an infrastructural project (Bragança et al, 2014)

The 7th edition of the PMBoK, that is developed by professional and the global community within this sector, shows strong alignment and confirm that the guiding principles apply across the full spectrum of project management. However, this edition is introduces a new systems oriented perspective on project management, meaning a view of value delivery within *The Standard for Project Management* and continues in the presentation of the content of PMBoK. It is basically a shift from 10 PM-domains (6th edition) to 8 project performance domains (7th edition), as shown in Figure 3.8, which represents the key interrelated management capabilities and support effective project management. The previous 6th edition of the PMBoK emphasized the importance of tailoring project management to the specific context of a project. While this approach falls more within the context of this research, this line of thought remains and is now supplemented with a broader systems view that emphasizes the interrelationships between various project elements (Project Management Institute, 2021).

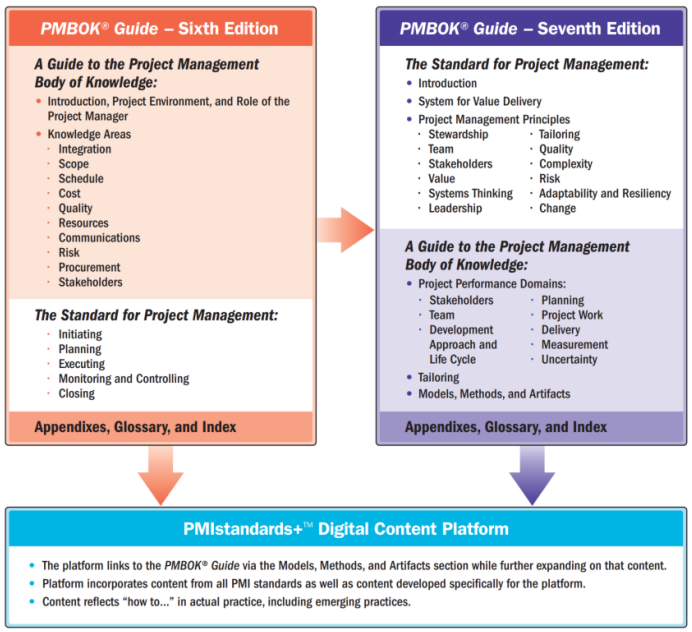


Figure 3.8: Revision to The Standard for Project Management and Migration from the Sixth Edition to the Seventh Edition of the PMBoK Guide and the PMIstandards+ Digital Content Platform (Project Management Institute, 2021)

Taking this into account, the 6th edition of the PMBoK is more applicable for use in the context of this research due to the in depth analysis of each PM-domain. Analyzing the PMBoK framework an overview is designed on how sustainability can be leveraged in each of the 10 PM-domains (knowledge areas) during the planning and design phase of Dutch infrastructure projects. Each domain lists relevant PPSs that either exists or are proposed to integrate sustainability. In order to extract this from the the resource the methodology that is introduced in the 6th edition of the PMBoK is in following order (Project Management Institute, 2017):

1. Inputs
2. Tools and techniques
3. Output

These elements are hereafter abbreviated as ITTOs in this report. Every PM-domain contains one or more 'Process Groups' that contain these ITTOs. In this research, each ITTOs was analyzed per 'Process Group' and per PM-domain, after which the most promising PPS-components were identified. Eventually resulting into to the PPS-components overview that has been validated and updated in practice related to sustainability integration in infrastructural projects during the planning and design phase, as explained in Chapter 4 for further analysis within this research. Worth mentioning related to PPS-component level sustainability integration, is the concept of Enterprise Environmental Factors (EEFs) and Organizational Process Assets (OPAs), since a project exists and operates in an environment that may have an influence on EEFs and OPAs, shown in Figure 3.9, which are:

1. EEFs
   These factors originate from the environment outside of the project and are often outside of the enterprise. They may have have an impact at the organization portfolio, program or project level. It is referred to as condition(s), not under the control of the project team, that influence, constrain or direct the project (Project Management Institute, 2017).
2. OPAs
   These processes are internal to the organization and may arise from the organization itself whether it be a portfolio, program, project or a combination. It is referred to as plans, processes, policies, procedures and knowledge bases specific to and used by the organization (Project Management Institute, 2017).

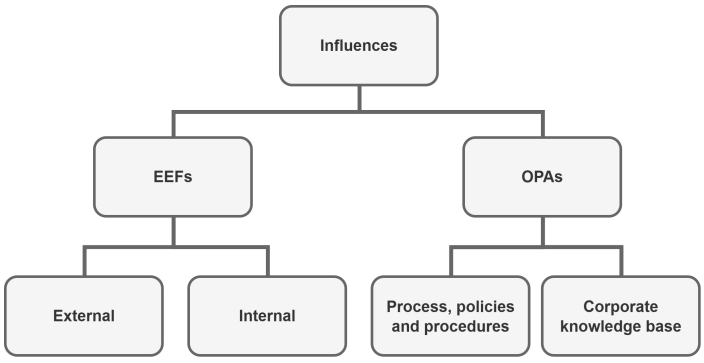


Figure 3.9: Project influences regarding EEFs and OPAs (Project Management Institute, 2017)

The EEFs and OPAs are responsible for the sustainability integration (on PPS-component level) as a company, institute or organization, since there is a dynamic interplay between them. These factors determine implicitly the demography and structure of the company (e.g. by rules an regulations or SOPs), therefore also shapes the basis on how sustainability integration can be realized. This is also identified during the interviews with the participants of W+B in Chapter 4.

3.2.1. Project Integration Management

The Project Integration Management domain, includes 'Process Groups' and activities to identify, define and coordinate various project management activities and development, as shown in Table 3.4. This is mainly handled by the project manager (PM), as shown in Table 4.2, while the other domains are (potentially) handled by other specialist (e.g. cost engineers or sustainability advisors). The action of a project manager related to this domain from the start through completing involves a systematic approach to align and connect different project processes, making trade-offs and managing conflicts along the project timeline to keep it on track from initiation to closing. This implies that accountability of project integration can not be delegated or transferred in general. The PM is responsible for integrating all other domains and has the overall view of project development, which makes this role responsible for the project as a whole. The size an complexity of a project, determines how challenging the integration might be and what level of strategy need to be set (e.g. using the IPM-model introduced by Rijkswaterstaat (2026c)). In addition to this, a project is integrative by nature, this indicates that the PM maintains the coherence of all disciplines (called PMC's at W+B) together as much as possible naturally. An important note, is that the Process Groups are presented as discrete processes with defined interfaces, however in practice this is not the case and they might overlap and interact in ways that cannot be described in details in PMBoK.

Nr.	Process	Elaboration
1.	Develop project charter	The process of developing a document that formally authorizes the existence of a project and provides the project manager with the authority to apply organizational resources to project activities
2.	Develop Project Management Plan (PMP)	The process of defining, preparing and coordinating all plan components and consolidating them into an integrated PMP
3.	Direct and manage project work	The process of leading and performing the work defined in the PMP and implementing approved changes to achieve the project's objectives
4.	Manage project knowledge	The process of using existing knowledge and creating new knowledge to achieve the project's objectives and contribute to organizational learning.
5.	Monitor and control project work	The process of tracking, reviewing and reporting overall progress to meet the performance objectives defined in the PMP
6.	Perform integrated change control	The process of reviewing all change requests, approving changes and managing changes to deliverables, organizational process assets, project documents and the project management plan and communicating the decisions
7.	Close project or phase	The process of finalizing all activities for the project, phase or contract

Table 3.4: Project Integration Management Process Groups and it elaboration (Project Management Institute, 2017)

- **Develop project charter**
  The project charter is the 'birth-certificate' of a project and reflect the initial wishes of the promoter or sponsor with regard to sustainability (e.g. statements, high level objectives, sponsor commitment or alignment workshops) (de la Cruz López et al., 2021a). Using forms and simulations for individual project phases or tasks such as the development of the project charter, helps to align all stakeholders and agreeing on the expected value of it (Orieno et al., 2024). Practically, it translates high-level objective by defining why the project exists, what the business it address, which success criteria applies and what authority the PM receives. Projects typically originate from internal needs or external drivers, often requiring a feasibility study or problem analysis. The chartering process confirms alignment between the W+B strategy and ongoing project work. More elaboration on this can be found in Appendix A, based on the Project Management Institute (2017).
- **Develop Project Management Plan (PMP)**
  The PMP must be developed in corresponding with other subsidiary plans and documents shown in Table 3.5 that contain sustainability indicators, agreements, criteria and requirements in the first place (de la Cruz López et al., 2021a). Marques et al. (2023) analyzed two methodologies that incorporates the PMP, whereas it allows for differentiation of deliverables and is an extension of the TBL including products and processes. The PMP is single document that defines how the project is executed, monitored and controlled including the management plans and baselines (cost, time and scope) (Villena et al., 2021), emphasizing incorporation of a 'Sustainable Management Plan'. In general, the PMP should be flexible, but robust enough to respond to 'changing' project circumstances, this degree of adaptability can result into more accurate information as the project progresses and finalizing the baselines as mentioned earlier. More elaboration on this can be found in Appendix A, based on the Project Management Institute (2017).

Project management plan	Project documents	
1. Scope management plan	1. Activity attributes	19. Quality control measurements
2. Requirements management plan	2. Activity list	20. Quality metrics
3. Schedule management plan	3. Assumption log	21. Quality report
4. Cost management plan	4. Basis of estimates	22. Requirements documentation
5. Quality management plan	5. Change log	23. Requirements traceability matrix
6. Resource management plan	6. Cost estimates	24. Resource Breakdown Structure (RBS)
7. Communications management plan	7. Cost forecasts	25. Resource calendars
8. Risk management plan	8. Duration estimates	26. Resource requirements
9. Procurement management plan	9. Issue log	27. Risk register
10. Stakeholder engagement plan	10. Lessons learned register	28. Risk report
11. Change management plan	11. Milestone list	29. Schedule data
12. Configuration management plan	12. Physical resource assignments	30. Schedule forecasts
13. Scope baseline	13. Project calendars	31. Stakeholder register
14. Schedule baseline	14. Project communications	32. Team charter
15. Cost baseline	15. Project schedule	33. Test and evaluation documents
16. Performance measurement baseline	16. Project schedule network diagram	
17. Project life cycle description	17. Project scope statement	
18. Development approach	18. Project team assignment	

Table 3.5: Project Management Plans and Project Documents (Project Management Institute, 2017)

- **Direct and manage project work**
  The core execution if the project is defined in this process, which involves leading and performing the work defined and explained in the PMP, including implementing approved changes (with the aim to achieve the objectives). A benefit of this process is that it is the moment where planning is translated into activity, which offers overall management of the project work and deliverables. However, effective collaboration on sustainability requires a suitable

(sustainability) strategy, perhaps with assistance of experts (de la Cruz López et al., 2021a). In addition to this, several sustainability practices exists that highlight the importance of incorporating sustainability considerations (e.g. supplier selections or improving project team's sustainability competencies), but in practice a little to no recognition is given to the benefits of implementing these practices in the beginning of a project (Soares et al., 2024). Lessons learned from these practices can be captured in a register for all challenges, problems, risks and opportunities. This register serves as both input and output that is updated throughout the project LC, at the end the project or a phase, its content will be transferred to the repository of the organization helping future teams avoid similar pitfalls and improve performance.

- **Manage project knowledge**
  The process above coincides with this one, as knowledge is collected in one environment, to achieve the project objectives and contribute to organizational learning. Projects provide valuable opportunities for continuous learning whereas the lessons learned play a critical role for improving future projects (Soares et al., 2024). This is however, depending on the project team capacity related to project experiences and competencies and knowledge that might be missing. This process can be used to key benefits, whereas prior organizational knowledge is used to produce or improve project outcomes and it is also created by the project outcomes to serve other future projects or phases. To understand what the base level on sustainability is within a project team or at W+B, it might be useful to send out an internal comprehensive questionnaire, to assist W+B in assessing their performance in terms of sustainable practices, resulting in a sustainable maturity level (Moutinho et al., 2025).
- **Monitor and control project work**
  Regarding continuous tracking, reviewing and reporting of the overall project performance against the baselines (set in the PMP). Therefore, it is essential to have sufficient qualitative and quantitative data (e.g. MKI, CO2, € or number of changed decisions) in order to establish forecasts on the achievement of the project's objectives and steer adequately (de la Cruz López et al., 2021a). This process gets more complicated and challenging if more sustainability practices are used in a project, whereas more 'monitoring and control' is required to keep track of sustainability integration (Soares et al., 2024). The quality of the work is depending on the education level of individual team members, project profiles and role on project management domains of which sustainability is part of, the better adopted and understood, the more transparent and traceable processes are aligned with sustainability objectives (Keleş et al., 2025).
- **Perform integrated change control**
  Reviewing all change requests consists of approving and managing changes to deliverables, project documents and the main overarching PMP including baselines. This process requires continuous check and monitoring whether it has an effect on sustainability objectives (de la Cruz López et al., 2021a), as well as meeting the requirements and needs (Ojeda & Reusch, 2013). A change impacts others as well, it is not isolated, meaning that a scope change affects cost, schedule, risk and documentation simultaneously. Furthermore, this implies that sustainability impact must be assessed explicitly for every proposed change before approval is given, in order to make sure that sustainability commitments survive and do not diminish or erode along to project LC (Project Management Institute, 2017).
- **Close project or phase**
  Closing a project or phase is about finalizing all activities. The project or phase information is archived, the planned worked is completed and therefore the resources (of the team and organization) are available again to pursue new projects or opportunities. The final report of the project must include a section on sustainability about benefit realization (e.g. MKI outcomes or circular material used) and unresolved commitments for the receiving organization as well as for the lessons learned repository (Project Management Institute, 2017). Ojeda and Reusch (2013) states that a project sustainability report is produced once the project is complete, whereas Soares et al. (2024) added that evaluation of project success should also include sustainability criteria (e.g. environmental or social criteria) to integrate sustainability.

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.6 and Table 3.7.

PPS-component	Sustainability integration opportunities within Project Integration Management	Resource(s)
Products	1. Update project charter with explicitly SMART-formulated sustainability objectives 2. Flag sustainability-related conditions as a separate category in the assumption log 3. Embed sustainability in all project baselines (cost, time and scope) within the PMP and subsidiary plans 4. Include a section on sustainability changes, impacts and control within the change management plan 5. Include a sustainability category within the lessons learned register/repository. 6. Integrate sustainability metrics (e.g. MKI using DuboCalc, MCI using +CD Tool or CO_2 using the CO_2-Prestatieladder) in deliverables 7. Include sustainability impact fields per change request within the change log 8. Include sustainability benefit realization (e.g. CO_2 reduction and MKI outcomes) within the final report	1. [1], [2], [3] 2. [4], [5], [6] 3. [1], [7], [8] 4. [1], [6] 5. [7], [1], [9] 6. [7], [10] 7. [1] 8. [7], [1], [6]
Processes	1. Consider sustainability concepts during the project charter development (e.g. Social-Cost Benefit Analysis (SCBA) preparation, MKBA in Dutch) 2. Formulate SMART sustainability objectives before the PMP baseline setting 3. Integrate sustainability milestones into the project timeline 4. Assess sustainability impact as part of the integrated change control review and performance monitoring 5. Capture and transfer lessons learned related to sustainability into the OPAs and lessons learned repository 6. Integrate monitoring of sustainability metrics (e.g. MKI, MCI or CO_2) against baselines in the PMP throughout project LC 7. Identify sustainability opportunities ('meekoppelkansen') within risk and change management cycles	1. [11], [12] 2. [1], [13] 3. [1], [3] 4. [1], [6], [14] 5. [7], [1], [4], [9] 6. [10] 7. [7], [1], [3]
Services	1. Configure a PMIS like Relatics for example, to include sustainability requirements and enable real time tracking 2. Use the +CD Tool with the MKI metric for sustainability performance visualization on circularity 3. Organize Ambitieweb session as facilitator during project charter development 4. Make the organizational knowledge base and lessons learned register/repository accessible to future project teams 5. Review Change Control Board (CCB) or project manager function by expanding it in order to include sustainability impact assessments	1. [15], [16] 2. [10] 3. [8], [2] 4. [9], [1], [16] 5. [1], [6], [5]

Table 3.6: Sustainability integration opportunities across PPS-components within Project Integration Management (source: Author)

Nr.	Resource
[1]	de la Cruz López et al. (2021a)
[2]	Toljaga-Nikolić et al. (2020)
[3]	O. Lima et al. (2023)
[4]	Armenia et al. (2019)
[5]	Sroufe (2017)
[6]	Ahmed et al. (2024)
[7]	Soares et al. (2024)
[8]	Orieno et al. (2024)
[9]	Eken et al. (2020)
[10]	Rajabi et al. (2022)
[11]	Veličković et al. (2025)
[12]	De Wit and Over (2024)
[13]	L. Lima et al. (2021)
[14]	Sánchez (2015)
[15]	Kock et al. (2020)
[16]	Muflih et al. (2026)

Table 3.7: Resources Project Integration Management sustainability integration opportunities

3.2.2. Project Scope Management

The Project Scope Management domain, involves processes that are required to make sure the project includes all the work required and only the work required to finish the project successfully within estimate time span. The means maintaining boundaries, goals, deliverables and budget within a specific timeframe, without performing or adding work to the initial agreement (project charter or external contract). By doing so, scope changes like scope creep or expansion are prevented which affects other domains as well. In case sustainability is not included within the scope, it will not receive any attention in cost, schedule, quality or procurement decisions. In Dutch infrastructure practice, this is exactly where sustainability often fails. Therefore, during the FEDP it is essential to include sustainability early into project requirements, ensuring that it is explicitly incorporated in the project its scope and design boundaries. The Process Groups involved for this domain are stated in Table 3.8.

Nr.	Process	Elaboration
1.	Plan Scope Management	The process of creating a scope management plan that documents how the project and product scope will be defined, validated and controlled
2.	Collect requirements	The process of determining, documenting and managing stakeholder needs and requirements to meet project objectives
3.	Define scope	The process of developing a detailed description of the project and product
4.	Create WBS	The process of subdividing project deliverables and project work into smaller, more manageable components
5.	Validate scope	The process of formalizing acceptance of the completed project deliverables.
6.	Control scope	The process of monitoring the status of the project and product scope and managing changes to the scope baseline.

Table 3.8: Project Scope Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Scope Management**
  This plan contains information on how the project scope is defined, validated and controlled (preventing scope creep or expansion). Related to sustainability, it should include sustainability requirements as a category of scope, not as a secondary consideration. Additionally, it should define how sustainability related scope changes will be assessed, acted and steered upon throughout the entire project LC (Project Management Institute, 2017). Because, each LC phase contributes differently to sustainability, whereas the planning phase has the greatest potential to determine sustainability at a lower cost (Villena et al., 2021).
- **Collect requirements**
  Structurally collecting and documenting stakeholders' needs and expectations is critical to satisfy them during project development. This is the core task of turning sustainability into documented needs, project boundaries and deliverables. The evidence can come from a wide set of stakeholders, which makes it even more challenging to hear every voice, missing one can cause misalignment with environmental and user goals (de Almeida Vittori Ferreira et al., 2023). The sustainability requirements collected during this process are directly fed into the requirements traceability matrix (e.g. in practice through a digital system called Relatics). This is a document with a chain of accountability from contract to deliverable (Project Management Institute, 2017).
- **Create WBS**
  The total project scope is structured hierarchically into manageable work packages. Each of these work packages contain a unique identified (ID) that enables cost, schedule and resource integration making traceability easier. An additional WBS-dictionary helps to provide detailed information on each work package (Putro et al., 2022). Integrating sustainability into the WBS forces one to take sustainability into account, if not, then it will not be budgeted, scheduled or resourced and finally not even executed. Since it was not taken into account along project development (Project Management Institute, 2017).
- **Validate scope**
  Validation of the scope is formally done, when the completed deliverable/product is reviewed and accepted by the client or (authorized) stakeholder. This is done through an acceptance criteria of the deliverable as it should include the conditions to be satisfied in terms of sustainability (de la Cruz López et al., 2021a). Not only technical quality for example, but also on sustainability performance. This means that deliverables should not only meet structure and functional requirements as stated in the KES, but also satisfy the MKI targets or ecological commitments. If not, then it should not receive formal acceptance without documented resolution. This requires that the sustainability acceptance criteria are defined at an early phase, whereas the agreed upon terms should be bound contractually and not assessed informally only at project closure (Project Management Institute, 2017).
- **Control scope**
  Besides validation, it is essential to monitor the project scope to prevent unnecessary scope changes (scope creep or expansion). This is controlled by managing approved changes through the integrated change control process. Different control mechanisms can be used for different sustainability dimensions, so also for scope changes (Kivilä et al., 2017). Scope control has a more perspective function from a sustainability point of view, meaning that it guards projects against the erosion of sustainability work packages influences by timeline pressure or cost optimization. Every submitted change request that interferes with sustainability scope, must be formally assessed for the impact on sustainability commitments and decided upon the project manager or Change Control Board (CCB) with full transparency to the stakeholders and client (Project Management Institute, 2017).

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.9 and Table 3.10.

PPS-component	Sustainability integration opportunities within Project Scope Management	Resource(s)
Products	1. Define explicitly the sustainability requirements, constraints and acceptance criteria within project scope statements 2. Include sustainability work packages, such as LCA and LCCA analysis, MKBA/SCBA analysis or MKI calculations, at an appropriate decomposition level within the Work-Breakdown Structure (WBS) 3. Include sustainability-related scope descriptions per work package in the WBS-dictionary 4. Include sustainable performance, such as ecological, social and economic (TBL) factors, within the requirements documentation, for example KES, related to the scope 5. Link sustainability requirements from the contractor/charter, provided in the KES, with a requirements traceability matrix, for example using PMIS like Relatics, by deliverables containing sustainability metrics such as MKI and CO_2 6. Include sustainability constraints as unnegotiable boundary conditions within the defined scope baseline	1. [1], [7], [17], [18] 2. [1], [19], [20] 3. [1], [19], [21] 4. [7], [21], [18], [22] 5. [10], [1], [22], [8] 6. [10], [1], [23], [24]
Processes	1. Collect sustainability requirements from the client, including regulatory requirements that are interrelated 2. Define and outline project scope by translating ambitions, through for example an Ambitieweb session, from the project charter into a contractually grounded project scope statement with explicit sustainability boundaries 3. Create WBS decomposition of sustainability deliverables into manageable and assignable work packages 4. Validate the scope by formal client acceptance that sustainability deliverables meet defined acceptance criteria 5. Maintain and control scope by preventing scope creep or expansion that could diminish or eliminate sustainability work packages	1. [21], [7], [18] 2. [1], [17], [23] 3. [1], [19], [20] 4. [1], [17], [25] 5. [24], [10], [1]
Services	1. Use Aanpak Duurzaam GWW, for example Ambitieweb and Omgevingswijzer, as a methodology for sustainable scope definition 2. Use CO_2-Prestatieladder as an external system verifying scope-level sustainability commitments, managed by SKAO 3. Configure a PMIS like Relatics, for example, to include sustainability requirements and enable real-time tracking 4. Use the +CD Tool with the MCI metric for sustainability performance visualization on circularity 5. Use DuboCalc as a calculation service for validation of the MKI of the project scope at product or project level	1. [23], [8], [18] 2. [26], [27], [25] 3. [8], [10], [19] 4. [22], [10], [7] 5. [28], [29], [30]

Table 3.9: Sustainability integration opportunities across PPS-components within Project Scope Management (source: Author)

Nr.	Resource
[1]	de la Cruz López et al. (2021a)
[7]	Soares et al. (2024)
[8]	Orieno et al. (2024)
[10]	Rajabi et al. (2022)
[17]	Arabpour and Silvius (2023)
[18]	Mavi et al. (2021)
[19]	Villena et al. (2021)
[20]	Ramohlokoane et al. (2025)
[21]	Moshood et al. (2024)
[22]	Stanitsas and Kirytopoulos (2021)
[23]	Yu et al. (2018)
[24]	Mari et al. (2023)
[25]	Flores et al. (2016)
[26]	Rietbergen and Blok (2013)
[27]	Rietbergen et al. (2016)
[28]	Grünewald and De Schutter (2016)
[29]	Altaf et al. (2022)
[30]	Alaloul, Altaf, Musarat, Javed, and Mosavi (2021)

Table 3.10: Resources Project Scope Management sustainability integration opportunities

3.2.3. Project Time Management

The Project Time Management domain, involves processes that are need to make sure the project is completed within the approved timeline. Related to sustainability integration, this domains contains a risk that is known in Dutch infrastructure projects, whereas time pressure is the justified reason in practice for deprioritizing or eliminating sustainability activities during project execution. Sustainability activities (e.g. environmental permitting procedures or LC assessments) are underestimated in duration, not sequenced correctly related to design decisions or simply overlooked when the schedule doesn't allow it but all healthy for sustainability integration. The solution to this is straightforward and known, but not applied in practice for some reason. Sustainability activities must gain attention in the same way as others, by defining, sequencing, estimating and baseline them into specific schedules items from the outset with the same attention and care as done for any other project activity. The Process Groups involved for this domain are stated in Table 3.11.

Nr.	Process	Elaboration
1.	Plan Time Management	The process of establishing the policies, procedures and documentation for planning, developing, managing, executing and controlling the project schedule.
2.	Define activities	The process of identifying and documenting the specific actions to be performed to produce the project deliverables.
3.	Sequence activities	The process of identifying and documenting relationships among the project activities.
4.	Estimate activity durations	The process of estimating the number of work periods needed to complete individual activities with the estimated resources.
5.	Develop schedule	The process of analyzing activity sequences, durations, resource requirements and schedule constraints to create the project schedule model for project execution and monitoring and controlling.
6.	Control schedule	The process of monitoring the status of the project to update the project schedule and manage changes to the schedule baseline.

Table 3.11: Project Time Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Time Management**
  This plan describes the methodology, tools and governance procedure by which the project timeline will be developed, monitored and controlled. The timeline should integrate and explicitly recognize sustainability milestones and sustainability related activities (e.g. environmental permit procedure or LC assessment) as a formal scheduling category and define how (potential) delays due to these activities are managed and controlled (Project Management Institute, 2017).
- **Define activities**
  The definition of (sustainability) activities (e.g. MKI or MCI calculations and Ambitieweb sessions) is based on the decomposition of the work packages from the WBS, into individual actionable timeline activities, each with a defined scope of work, assigned resource and estimated duration. In case these are not individually mentioned in the activity list, but rather as a generic bundle of activities, it risks to become secondary and invisible to timeline monitoring resulting in a potential dropped activity (under time pressure) (Project Management Institute, 2017). This is a basis part of planning for tracking actual progress on sustainable development (Fesenko, 2022).
- **Sequence activities**
  Aside from defining, ordering the activities in a logical order is also essential for an optimized planning outline. This is related to dependencies between activities, by determining which must precede the other activity and which activities run in a parallel. By doing so, it let the project precisely understand what activities have to be performed, when it should be done, what cost and resources need to be employed for the sake of successfully generating the project deliverables (Yu et al., 2018). Therefore, (re)structuring or identifying these relationships between activities is essential to work efficient, effective and prevent any potential delays (resulting in elimination of potential sustainability integration) (Project Management Institute, 2017).
- **Estimate activity durations**
  Next, is about assigning realistic estimated duration to each timeline (sustainability) activity, based on resource availability, project complexity and historical data. Permitting can take up to 29 days in the Netherlands (Informatiepunt Leefomgeving, 2026) and the process can be even extended under the 'Omgevingswet' by 8 weeks for a decision period (Rijksoverheid, 2026). Therefore, these durations must be estimated as realistic as possible, which can be done by using information of lessons learned from compatible projects (using the lessons learned repository or knowledge base). These durations must include buffers as well, that takes into account the uncertainty or regulatory processes of these activities (for potential delays) (Project Management Institute, 2017). A sustainable timeline is therefore not only about delivering the result according to expectations, but also within budget, time and ensuring that decisions made are sustainable in the future (Dasović et al., 2020).
- **Develop timeline**
  Now that all aspects are determined, one can set-up a timeline, by integrating all defined activities, sequences, durations and resources into an overall timeline model using a Gantt chart, milestone chart or network diagram. Emphasizing sustainability it helps to incorporate sustainability review milestone at key decisions gates of a project (e.g. planfase, definitief ontwerp (DO), uitvoeringsontwerp (UO) and besteksfase) ensuring that sustainability performance is formally assessed and documents are used in the next phase. These milestones helps in providing moments for sustainability verification (governance) and provides direction to the project team by giving the team members concrete targets to work towards (incentive) (Project Management Institute, 2017).
- **Control timeline**
  The final timeline must be monitored to track the progress against the approved time baseline defined in the PMP, which identifies variances and initiates corrective actions if necessary. Controlling the timeline must extend beyond standard earned value indicators in order to monitor sustainability milestone achievements explicitly. Rajabi et al. (2022) developed a model that uses the construction planning optimization model to prepare the baseline plan to monitor the project its time, cost and sustainability performance. In case a sustainability milestone is at risk (due to e.g. unavailable resources) the PM must treat it with the same urgency and attention as is done for other traditional project drivers (cost, time and scope). Meaning that it should be escalated through the change control process instead of quietly absorbing the delay at the expense of sustainability deliverables (Project Management Institute, 2017).

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.12 and Table 3.13.

PPS-component	Sustainability integration opportunities within Project Time Management	Resource(s)
Products	1. Plan sustainability review milestone within the project timeline at the critical defined decision gates or handover moments 2. Create a list of specific sustainability milestones, which are contractually required 3. Include sustainability activity durations and dependencies, such as LCA, permit durations and stakeholder consultation periods, within the time baseline finalized in the PMP 4. Create a list with specific sustainability activities that are unique and assigned items within the timeline	1. [1], [7], [31] 2. [1], [17], [21] 3. [1], [32], [29], [31] 4. [1], [7], [31]
Processes	1. Identify and define the activities that are explicitly related to sustainability as unique schedule items instead of bundling them into generic tasks 2. Sequence activities in logical order by identifying sustainability task dependencies, for example MKI calculations that must precede procurement decisions 3. Estimate the duration of each activity by realistic time allocation for sustainability processes that are often underestimated, such as environmental permitting 4. Develop a timeline by integrating sustainability milestones into the critical path analysis 5. Control and maintain the timeline by monitoring sustainability achievements alongside standard time performance metrics	1. [32], [7], [18] 2. [33], [34] 3. [34], [35] 4. [34] 5. [10], [22], [36]
Services	1. Use software for creating the project timeline, such as MS Project or Project Plan 365, configured with specified sustainability milestone categories, for example represented in a Gantt chart 2. Consider completion time of time-sensitive service providers, such as external environmental permit advisors, in the timeline	1. [37], [35], [34] 2. [1], [31], [7]

Table 3.12: Sustainability integration opportunities across PPS-components within Project Time Management (source: Author)

Nr.	Resource
[1]	de la Cruz López et al. (2021a)
[7]	Soares et al. (2024)
[10]	Rajabi et al. (2022)
[17]	Arabpour and Silvius (2023)
[18]	Mavi et al. (2021)
[21]	Moshood et al. (2024)
[22]	Stanitsas and Kirytopoulos (2021)
[29]	Altaf et al. (2022)
[31]	Kehinde (2025)
[32]	Ershadi and Goodarzi (2021)
[33]	Banihashemi and Khalilzadeh (2022)
[34]	Kim (2020)
[35]	Dasović and Klanšek (2021)
[36]	Caselles and Guevara (2024)
[37]	Dasović et al. (2020)

Table 3.13: Resources Project Time Management sustainability integration opportunities

3.2.4. Project Cost Management

The Project Cost Management domain, is about all processes that are required to plan, estimate, budget, finance, fund, manage and control costs so that the project can be completed within the agreed and approved budget. Related to sustainability, in practice the problem is not that sustainability in considered too expensive, but that the cost framework applied in project management is almost only focused on capital expenditure (CAPEX) within the project boundary and timeline. Sustainability actually derives much of its value from operational cost reduction, ecological benefits, social return and LC performance that extend beyond project closure focused on operational expenditure (OPEX). As long as project cost management continues to evaluate sustainability as an upfront cost without account for LC value, taking the aspect of time into account, sustainability will automatically lose the economic argument. Integration of LCA, MKBA/SCBA methodologies and MKI calculations into the cost management domain is therefore a fundamental reorientation of how value is defined and measure in project costs. The Process Groups involved for this domain are stated in Table 3.14.

Nr.	Process	Elaboration
1.	Plan cost management	The process of defining how the project costs will be estimated, budgeted, managed, monitored and controlled.
2.	Estimate costs	The process of developing an approximation of the monetary resources needed to complete project work.
3.	Determine budget	The process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.
4.	Control costs	The process of monitoring the status of the project to update the project costs and manage changes to the cost baseline.

Table 3.14: Project Cost Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Cost Management**
  This plan is contains information regarding policies, procedures and documentations on how the project costs

will be estimated, budgeted and controlled. Regarding sustainability, the approach used must extend the cost management framework beyond conventional CAPEX accounting and explicitly include LCA. The plan must define how sustainability items (e.g. MKI calculations or SCBA/MKBA methods) are categorized, estimated and tracked. Also, the plan must included explanation on the cost evaluation criteria against which sustainability alternatives will be assessed during the project, specifying whether decisions are based on initial cost, total cost of ownership (CAPEX + OPEX) or a weighted combination that includes environmental impacts (Project Management Institute, 2017).

- **Estimate costs**
  Next, the costs are determined of a project on financial resources that are a required to complete each of the (sustainable) project activity related to its corresponding work package from the WBS. The cost estimation for sustainability is twofold, one at the direct cost; specific sustainability work packages from the WBS. The second at LC-value level; estimation process including DuboCalc, +CD Tool or LCCA frameworks to determine total cost of ownership, which helps with a realistic comparison between conventional and a more sustainable design alternative. Because, to evaluate future costs, LCCA is found to be an effective technique to determine the present worth of future costs (Altaf et al., 2022). This results into more operational savings through maintenance cost reduction and residual value. If the choice is made not to incorporate this twofold and realistic approach, sustainability alternatives remain more expensive than they genuinely are when evaluated over the entire asset LC (Project Management Institute, 2017).
- **Determine budget**
  This process is about the aggregation of the individual cost estimates into a cost baseline, adopted in the PMP, which the project cost performance will be measured against as a reference. This is where sustainability budgets or investments should be considered and made visible (if available). Increase of sustainability investment/budget can speed up the construction timeline of a project, while the environmental impact can be appropriately reduced and the increased investment in the early stage can reduce the maintenance cost of the later project (Peng et al., 2023). In case sustainability task are merged with generic tasks and thus the final budget (e.g. summed up with 'design costs' or 'engineering costs'), then it will be difficult to distinguish, monitor and manage sustainability tasks and costs. Sustainability budget lines must appear explicitly in the cost baseline, with an individual control account within the WBS structure, so the consumption of budget can be tracked and their preservation can be defended honestly through the change control process (Project Management Institute, 2017).
- **Control costs**
  Lastly, this process monitors cost performance against the final cost baseline in the PMP, identifies any variances and managed the approved changes. In Dutch context, cost control pressure is the main aspect that confront sustainability commitments and erodes them during execution or even before. In order to integrate sustainability in cost control, it is necessary to assess every proposed cost reduction measure that affects sustainability commitments for its impact on sustainability obligations (e.g. contractual, regulatory or reputational) before approval. This can be done through the concept of Earned Value Management (EVM), however it requires an extension for sustainability. This is done by a research of Rajabi et al. (2022), incorporating sustainability indicators developed to monitor the attainment of sustainability objectives in construction projects in addition to the traditional objectives. For example the MKI, CO_2 or MCI targets that are tracked, should be integrated and fed directly into cost control tools or reporting systems instead of existing as an indiviudal, isolated and disconnected monitoring system (Project Management Institute, 2017).

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.15 and Table 3.16.

PPS-component	Sustainability integration opportunities within Project Cost Management	Resource(s)
Products	1. Include sustainability cost-related items in the cost baseline, such as MKI calculations for variants, LCCA or CO_2 estimates during procurement, as explicit budget lines instead of additional or unforeseen costs 2. Estimate the cost per work package that is involved within the valuation of effects through the SCBA 3. Perform a Cost-Benefit Analysis (CBA) that expands potentially to a SCBA, making sustainability benefits quantifiable and visible 4. Create budget documentation that separates CAPEX from OPEX and total LC cost, which allows for LC-based comparison of sustainable alternatives	1. [29], [10], [38] 2. [11], [12], [39] 3. [12], [39], [11] 4. [40], [41], [29]
Processes	1. Estimate costs by including LC methodology, such as LCCA, alongside traditional CAPEX estimation, with MKI calculation integrated to oversee environmental impacts 2. Determine the budget by explicitly allocating sustainability budget lines in the approved baseline, in the PMP, instead of treating them as additional or unforeseen expenses 3. Control the costs by monitoring sustainability-related cost performance against the cost baseline and tracking MKI targets alongside financial EVM metrics 4. Expand EVM by including sustainability performance metrics, such as MKI, MCI or CO_2, representing an innovative integration point that could improve the view of sustainability impact in financial terms	1. [42], [38] 2. [11], [10] 3. [10], [43] 4. [43]
Services	1. Use DuboCalc as the primary MKI calculation service 2. Use consultancy services on LCCA for LC cost modeling beyond the typical project duration 3. Use advisory service for quantifying social and environmental benefits during SCBA 4. Use CO_2-Prestatieladder as an external system for cost performance verification, such as a tender with a fictive discount on bidding, managed by SKAO	1. [38], [42] 2. [29], [40] 3. [12], [11], [44] 4. [26], [42], [38]

Table 3.15: Sustainability integration opportunities across PPS-components within Project Cost Management (source: Author)

Nr.	Resource
[10]	Rajabi et al. (2022)
[11]	Veličković et al. (2025)
[12]	De Wit and Over (2024)
[26]	Rietbergen and Blok (2013)
[29]	Altaf et al. (2022)
[38]	Fregonara et al. (2022)
[39]	Henke et al. (2020)
[40]	Moins et al. (2020)
[41]	Arshad et al. (2021)
[42]	Taneja et al. (2021)
[43]	Abdi et al. (2018)
[44]	Ricci et al. (2021)

Table 3.16: Resources Project Cost Management sustainability integration opportunities

3.2.5. Project Quality Management

The Project Quality Management domain, requires all the processes that is needed to make sure that the project and its deliverables meet the defined requirements and stakeholders' expectations through the KES. Related to sustainability integration there exists an ambiguous situation currently in the Dutch infrastructure industry. Quality management and sustainability management operate as almost entirely separate management systems. Quality is often governed by technical standards (e.g. NEN norms, ISO certifications and other contractual specifications), whereas sustainability is steered upon through individual instruments (e.g. DuboCalc, CO_2-Prestatieladder and the internal +CD Tool and E-DNA at W+B). A consequence of this phenomena is that a project can achieve full technical quality compliance, while at the same time it fails to achieve its sustainability commitments and neither one influences or adjusts the other management system. Therefore, by formal integration of sustainability performance criteria into the quality management plan, quality metrics, quality control measurement and acceptance criteria, both systems come together as one. This emphasizes the importance of the practical necessity and contribution of this research. The Process Groups involved for this domain are stated in Table 3.17.

Nr.	Process	Elaboration
1.	Plan quality management	The process of identifying quality requirements and/or standards for the project and its deliverables and documenting how the project will demonstrate compliance with quality requirements and/or standards.
2.	Manage quality	The process of translating the quality management plan into executable quality activities that incorporate the organization's quality policies into the project.
3.	Control quality	The process of monitoring and recording the results of executing the quality management activities to assess performance and ensure the project outputs are complete, correct and meet customer expectations.

Table 3.17: Project Quality Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Quality Management**

This plan contains the identification of quality requirements and standards applicable to the project and its deliverables through the KES fo example, by documenting how the project demonstrates compliance. Related to sustainability, the document includes sustainability (performance) criteria as a formal quality requirement, by treating them equally to other technical and functional standards or requirements. The plan should elaborate on applicable sustainability instruments, with a paragraph on how the measurement methodology works, what thresholds are accepted, what responsibilities there are regarding verification and what the reporting frequencies. In case of a requirement stemming from a contractual or regulatory obligation, the plan should contain a traceable link (e.g. using a PMIS like Relatics). This makes certain that sustainability criteria are not treated as wishful target, but as a binding performance standards subject to the same audit and verification analogy as technical or safety requirements.

- **Manage quality**
  Managing the quality of a project or work is also referred to as quality assurance, which involves structural execution of quality activities to make sure the project uses all processes required to meet defined requirements in the KES. Quality performance in construction is the degree of compliance with the specifications against which the work was executed (Raouf & Al-Ghamdi, 2020). Integrating sustainability should be done by including sustainability review moments at specific milestones throughout the project LC and not only a phase gates in case of handovers (Alawag et al., 2024). By doing so, sustainability procedures are followed, data is recorded and design or procurement decisions are assessed before they are approved. This indicates a proactive approach and allows for corrective action before project delivery. Findings from the project should be documented in the lessons learned repository, while inconsistencies should be addressed through the integrated change control process.
- **Control quality**
  Lastly, the quality should be monitored and the result of quality activities should be recorded to assess performance and recommend changes (if necessary). This process is basically the project its verification function, which is the point where completed deliverables are measured against defined quality criteria to confirm that they meet before the formal acceptance. Shaawat et al. (2023) states that project management is becoming more integrated, performance measurement of projects is expanding to include more aspects and criteria of performance. In case of sustainability deliverable that do not meet defined criteria, the quality control process should suggest defect repair request or corrective actions through the integrated control process. This prevents that poor sustainable performance becomes normalized as an acceptable project outcome.

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.18 and Table 3.19.

PPS-component	Sustainability integration opportunities within Project Quality Management	Resource(s)
Products	1. Include sustainability acceptance criteria besides technical quality criteria within the Quality Management Plan 2. Integrate sustainability metrics within quality metrics, such as MKI, MCI or CO_2 reduction percentage, in the Quality Management Plan 3. Document sustainability performance with quality control measurements against the defined criteria at each project phase gate or handover 4. Provide quality reports that contain sustainability performance to involved stakeholders 5. Automatic test and evaluation of documents that include sustainability verification evidence, such as MKI or CO_2-Prestatieladder reports	1. [21], [46] 2. [22], [47], [48] 3. [49], [7], [32] 4. [21], [50], [51] 5. [46], [48]
Processes	1. Integrate explicit sustainability requirements as quality criteria in the Quality Management Plan and define the measurement methods for these requirements, such as DuboCalc, +CD Tool, Ambitieweb, Omgevingswijzer or CO_2-Prestatieladder 2. Execute sustainability quality assurance activities throughout the entire project LC to manage overall quality and not only at project closure 3. Formally verify that sustainability deliverables meet defined acceptance criteria at each phase gate or handover to control overall quality	1. [22], [52] 2. [46], [48], [50] 3. [49]
Services	1. Use DuboCalc as the primary MKI calculation service 2. Obtain acknowledgment by getting certified as a company for the CO_2-Prestatieladder usage, managed by SKAO 3. Use the CO_2-Prestatieladder as an external audit and certification service after acknowledgment, managed by SKAO 4. Use independent analysis and verification by a third party of current sustainability workflow processes by a process manager	1. [50], [48] 2. [51], [13] 3. [51], [50] 4. [53], [48], [21], [46]

Table 3.18: Sustainability integration opportunities across PPS-components within Project Quality Management (source: Author)

Nr.	Resource
[7]	Soares et al. (2024)
[13]	L. Lima et al. (2021)
[21]	Moshood et al. (2024)
[22]	Stanitsas and Kirytopoulos (2021)
[32]	Ershadi and Goodarzi (2021)
[46]	Scherz et al. (2022)
[47]	Fallah and Moini (2026)
[48]	Haouat et al. (2025)
[49]	Alawag et al. (2024)
[50]	Barbhuiya and Das (2023)
[51]	Griffiths et al. (2018)
[52]	Salah et al. (2023)
[53]	Kivilä et al. (2017)

Table 3.19: Resources Project Quality Management sustainability integration opportunities

3.2.6. Project Resource Management

The Project Resource Management domain, consists of all processes that are required to identify, acquire, develop, manage and control the human and physical resources necessary to complete the project successfully. In terms of sustainability, this domain deals with the most fundamental and most recognized constraint, namely human capital. All project related variables (e.g. instruments, criteria and scope commitments) are all depended an defined by the competence and awareness of the people involved during project development. In practice (at W+B), sustainability expertise within project teams is concentrated at special units, divisions or department (called PMC's at W+B). Meaning that depending on a role and PMC, an individual is more or less involved within the topic 'sustainability'. Therefore, effective collaboration is essential to integrate sustainability at its highest possible degree. This can not be simply resolved by producing better sustainability documents, but by treating sustainability expertise as an explicit, planned and monitored resource equipment across all project phases. The Process Groups involved for this domain are stated in Table 3.20.

Nr.	Process	Elaboration
1.	Plan resource management	The process of defining how to estimate, acquire, manage and utilize physical and team resources.
2.	Estimate activity resources	The process of estimating team resources and the type and quantities of material, equipment and supplies necessary to perform project work.
3.	Acquire resources	The process of obtaining team members, facilities, equipment, materials, supplies and other resources necessary to complete project work.
4.	Develop team	The process of improving competencies, team member interaction and the overall team environment to enhance project performance.
5.	Manage team	The process of tracking team member performance, providing feedback, resolving issues and managing team changes to optimize project performance.
6.	Control resources	The process of ensuring that the physical resources assigned and allocated to the project are available as planned, as well as monitoring the planned versus actual use of resources and performing corrective action as necessary.

Table 3.20: Project Resource Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Resource Management**
  This plan is involves how project resources (both human and physical) are estimated, acquired, managed and controlled. In terms of sustainability (integration), the plan must explicitly consider sustainability expertise as a unique resource category. Meaning that sustainability skill sets are required at each project phase (and activities), roles carry sustainability responsibilities and how sustainability performance will be incorporated into team performance expectations. A Resource-Breakdown Structure (RBS) helps in this, to identify sustainability specialists as distinct resource types. This allows for their acquisition, allocation and monitoring to be planned alongside other project roles. In case expertise is unavailable the RBS helps to search for a gap and defines an alternative strategy. This ensures that sustainability expertise is involved early enough in the project LC to influence decisions rather than only validate them afterwards, which is part of project planning (Alghamdi, 2025; Yu et al., 2018).
- **Estimate activity resources**
  The type, quantity and characteristics of resources is defined in this part of of the process, whereas each scheduled activity within the timeline is estimated on this. In regards to sustainability (integration), specific activities it is essential to ensure that sustainability activities (e.g. MKI calculations, LCA or SCBA studies) are assigned realistic resource estimate both on expertise level and timeframe. Assigning them to unspecialized team members or overallocate experts can reduce quality, cause delays and lead to sustainability tasks being removed from the project plan. This should be drawn on the lessons learned from comparable projects to be efficient and effective, in case

of available historical data, estimates should be based on expert judgment from specialist who understand the complexity, dependencies and timeframe of activities (Yu et al., 2018).

- **Acquire resources**
  This process is about acquiring human and physical resources that are required to complete project activities. Related to sustainability (integration), the acquisition mut be set around key milestones and decisions points, besides that investments in employees helps for a better environmental performance (Tahir et al., 2024). Additionally, alignment and partnerships with similar sustainability objectives activates sustainability integration and innovation (Goel et al., 2019; Kivilä et al., 2017). Late involvement of the right resources limits documenting or validating decisions already made. Sustainability resource acquisition should therefore be treated as a time-critical project management activity rather than optional specialist input
- **Develop team**
  Next process is the development of a team, which involves activities aimed at improving competencies, interaction, overall team environment and capacity to improve project performance. In terms of sustainability integration, team development should address the knowledge gaps that is mostly found in project teams. Sustainability competencies should therefore be developed as a planned project activity rather than an optional addition. Ogbeibu et al. (2020) refers to this as 'green team creativity' that is part of 'green human resource management' (Alrifae, 2026). Relevant activities may include knowledge-transfer sessions, participation in Ambitieweb sessions and workshops on MKI calculations or +CD Tool use. These activities strengthen project capabilities and contribute to the organizational lessons learned repository. The project manager also plays a key role by communicating sustainability objectives and positioning them as shared performance ambitions rather than merely contractual obligations
- **Manage team**
  This process involves monitoring team performance, providing feedback, resolving issues and managing changes (Alrifae, 2026; Tahir et al., 2024). With regards to sustainability, responsibility for sustainability tasks must be explicitly assigned and included in individual performance expectations. If not done, sustainability may risk to be deprioritized when trade-offs arise. Departments, disciplines (or in case of W+B called PMC's) should not be evaluated only on design quality and budget performance, but also on their contribution to sustainability objectives. The PM is responsible to maintain visibility of individual progress and intervene when tasks are delayed, reassigned or delegated to other team members without the required expertise or authority. Sustainability commitments should thus be embedded as concrete responsibilities in daily project management rather than treated as abstract ambitions
- **Control resources**
  The last process of this domain, is about comparing the planned and actual resource deployment throughout the project LC and initiates corrective actions (if necessary) where variances occur. Related to sustainability (integration), the process includes monitoring the availability and involvement of sustainability specialists against the resource schedule. If specialists are reassigned, unavailable or engaged later than planned, the impact on deliverables, decision points and milestones should be assessed through the formal change-control process. Resource control models exists with sustainable indicators, while physical resource control is still associated with performance (Rajabi et al., 2022).

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.21 and Table 3.22.

PPS-component	Sustainability integration opportunities within Project Resource Management	Resource(s)
Products	1. Include a required resource category for sustainability expertise that is explicitly stated in the Resource Management Plan 2. Include sustainability specialists, such as LCA experts and environmental engineers/managers, within the Resource-Breakdown Structure (RBS) as a distinct resource type 3. Define sustainability responsibilities per team and role within the team charter, not only for the project manager, by involving individuals explicitly 4. Document which team member holds sustainability competencies and where gaps exist, using project team assignments 5. Include sustainability tasks as assignable responsibilities and keep track of them using a Responsibility Assignment Matrix (RAM/RACI)	1. [54], [55] 2. [54], [56] 3. [57] 4. [58], [59] 5. [57]
Processes	1. Identify and implement sustainability expertise requirements per project phase and work package in the Plan Resource Management 2. Obtain resources, such as sustainability specialists, either internal or external, aligned with the project its sustainability objectives and intermediate milestones 3. Develop the whole project team by schooling on sustainability competencies, such as performing training, workshops and Ambitieweb sessions, as an explicit team development activity 4. Manage the project team by including sustainability task delivery as a measurable result in group or individual performance management or indicators 5. Control resources by monitoring the availability and deployment of sustainability specialists/experts against the project timeline	1. [54] 2. [54], [56] 3. [58], [59] 4. [10] 5. [57], [54]
Services	1. Set up and maintain internal sustainability knowledge networks, such as practising communities or PMC's within W+B, as a supporting function for project teams to profit from 2. Utilize sustainability experts as contracted service providers in specific tasks, such as LCA experts, ecologists or economic advisors 3. Obtain acknowledgment by getting certified as a company for the CO_2-Prestatieladder usage, managed by SKAO 4. Use the CO_2-Prestatieladder as an external audit and certification service after acknowledgment, managed by SKAO	1. [60], [61] 2. [54], [50], [62] 3. [54], [50] 4. [54], [50]

Table 3.21: Sustainability integration opportunities across PPS-components within Project Resource Management (source: Author)

Nr.	Resource
[10]	Rajabi et al. (2022)
[50]	Barbhuiya and Das (2023)
[54]	de la Cruz López et al. (2021b)
[55]	Friedrich (2021)
[56]	Larsen et al. (2022)
[57]	Suhanda and Pratami (2021)
[58]	Cabral and Dhar (2019)
[59]	Tahir et al. (2024)
[60]	Schröpfer et al. (2017)
[61]	Ruuska and Vartiainen (2005)
[62]	Dsilva et al. (2023)

Table 3.22: Resources Project Resource Management sustainability integration opportunities

3.2.7. Project Communication Management

The Project Communication Management domain, involves al processes required to make sure that a project information is planned, collected, shared, stored, retrieved, monitored and finally disposed of in a timely and appropriate manner. In Dutch infrastructure projects, this domain is often treated as an administrative function (e.g. the production and distribution of progress reports, meeting minutes and status updates). However, for sustainability integration, this domain involves much more since it is should be used as a more strategic project management capability that shapes how sustainability commitments are understood, normalized and acted upon by all parties and stakeholder involved. If communication becomes undervalues, then the consequence might be that sustainability intentions in the project charter are not consistently translated into the working understanding of PMC leads, clients and (sub)contractors. By using visualizations of the results from DuboCalc of the +CD Tool helps to clarify sustainability commitments towards the stakeholders that are involved related. Good communication boosts sustainability integration and therefore requires communication management, as an active governance function. This domain mainly ensures that sustainability information reaches the right people in the right format and moment, with sufficient clarity to inform decisions and sufficient transparency to support accountability. The Process Groups involved for this domain are stated in Table 3.23.

Nr.	Process	Elaboration
1.	Plan communications management	The process of developing an appropriate approach and plan for project communication activities based on the information needs of each stakeholder or group, available organizational assets and the needs of the project.
2.	Manage communications	The process of ensuring timely and appropriate collection, creation, distribution, storage, retrieval, management, monitoring and the ultimate disposition of project information.
3.	Monitor communications	The process of ensuring the information needs of the project and its stakeholders are met.

Table 3.23: Project Communications Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Communication Management**
  This plan is a communication approach based on stakeholder information needs, EEFs and OPAs and specific requirements that are necessary for the project. In terms of sustainability integration, the plan should define what information each stakeholder group requires, at what level of detail, how frequently and through which channel (Ishola et al., 2024; Soares et al., 2024). External clients (e.g. Rijkswaterstaat or ProRail) require formal reporting against contractual indicators (e.g. MKI) per month through e-mail, whereas internal teams need operational information on current performance and upcoming milestones per week in a meeting. Therefore, sustainability information should be integrated into regular project communication channels at W+B (being part of their SOPs), rather than addressed only in separate meetings. The plan should also establish a formal escalation protocol specifying how sustainability concerns are raised, by whom, to whom and within what timeframe.
- **Manage communication**
  Secondly, it must be ensured that project information is created, shared and received and understood in accordance and compliance with the plan above. Related to sustainability integration) the PM must translated technical data into formats that are clear, meaningful and actionable for all involved stakeholders (e.g. MKI and CO_2-reduction might be clear to technical professionals but less to community stakeholders). Visuals (e.g. dashboards) can help to communicate and understand performance more effectively than figures and text only. Therefore, this process entails taht information should be understood, rather than simply presented. Sustainability requirements should be reinforced through structured information sharing, confirmation and regular dialogue within standard project meetings. This guarantees that sustainability information is understood and acted upon by those influencing project performance (Bovea et al., 2021; Rusu et al., 2024)
- **Monitoring communication**
  Besides managing communication, it is also about ensuring that the initial main communication management plan is followed, stakeholder information needs are met and communication methods still remain appropriate as the project develops (if not, adjustments are required). In terms of sustainability integration in this processes, monitoring should assess whether sustainability information influences decisions and behavior, rather than only checking if it is produced and distributed. Reports that are archive and used (in order to review or act upon) do not qualify for effective communication. Monitoring should therefore identify whether sustainability information reaches relevant stakeholders in time to support decision-making. Where gaps occur, such as unread reports or delayed performance data, the communication management plan should be revised through formal change control and corrective action (Manning et al., 2018; Perrini & Tencati, 2006)

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.24 and Table 3.25.

PPS-component	Sustainability integration opportunities within Project Communications Management	Resource(s)
Products	1. Specify sustainability reporting requirements, formats, frequencies and audience for communication guidelines towards the internal team, client and public stakeholders in the Communications Management Plan 2. Standardize sustainability sections within the work performance reports, also progress reports, including metrics that provide evidence, such as MKI, MCI or CO_2 3. Visualize sustainability by using a dashboard or Sankey diagram, for example using the +CD Tool representing MCI, as a communication product/tool 4. Use stakeholder-specific communication channels regarding sustainability, such as environmental communication for public stakeholders and sustainability reports for clients at governance level	1. [63], [64] 2. [64], [10] 3. [65], [66] 4. [67], [68]
Processes	1. Map information flows in the Plan Communications Management about who needs what type of sustainability data, at what frequency and format 2. Manage communication and periodic sharing, for example per milestone, about progress and updates on sustainability performance using defined communication channels for all internal and external stakeholders 3. Monitor communications by collecting feedback and verifying whether sustainability information is received, understood and acted upon 4. Visualize or translate technical sustainability data, such as MKI, MCI or CO_2, which makes it accessible and understandable for non-technical or less technical stakeholders	1. [63], [69] 2. [67], [68] 3. [70] 4. [71], [72]
Services	1. Use the software or application of W+B, the +CD Tool, as a digital service for sustainability data visualization and reporting 2. Use BIM platforms, such as Revit or AutoCAD models, which provide the capacity and service to communicate sustainability data and integrate it with other 3D models 3. Use the service of an environmental manager or expert for environment management, which bridges the project sustainability commitments with public or community stakeholders 4. Use digital collaborative platforms, such as SharePoint and Teams, that are configured with sustainability reporting templates or channels as communication infrastructure during project development	1. [65], [71], [72] 2. [63], [69], [73] 3. [67], [68] 4. [73], [63], [69]

Table 3.24: Sustainability integration opportunities across PPS-components within Project Communications Management (source: Author)

Nr.	Resource
[10]	Rajabi et al. (2022)
[63]	Halttula et al. (2020)
[64]	Rusu et al. (2024)
[65]	Ashabi et al. (2024)
[66]	Lupton and Allwood (2017)
[67]	Ishola et al. (2024)
[68]	Cortés et al. (2023)
[69]	Raitviir and Lill (2024)
[70]	Stocker et al. (2020)
[71]	Andrieu et al. (2024)
[72]	Viles et al. (2023)
[73]	Tumpa and Naeni (2025)

Table 3.25: Resources Project Communications Management sustainability integration opportunities

3.2.8. Project Risk Management

The Project Risk Management domain, involves the processes used to identify, analyze, plan and implement responses and monitor risks throughout the project LC. The PMBoK described risk as an uncertain event or condition that, if it occurs then it has either a positive (opportunity) or negative (threat) effect on the project. This is an important distinction since it is important to sustainability integration, because it is often overlooked. Sustainability comes with both unrecognized threats (e.g. late regulatory changes, permitting delays or biodiversity impacts) and underused opportunities (e.g. subsidy programs or LC cost savings). If sustainability is not embedded in risk management, the project develops an incomplete risk profile which can have negative impacts. Meaning that sustainability threats remain hidden until they emerge at a later stage and cause problems, whereas sustainability opportunities are not identified, assessed or exploited. Going forward in this way, the project value reduces, LC costs increases and the organizational strategic position degrades. Including sustainability within this domain requires a shift in expanding the risk register with sustainability specific threat categories, as is investigated by Wong (2024) and a shift in formal practice for identifying, evaluating and exploiting sustainability opportunities as part of routine risk management. The Process Groups involved for this domain are stated in Table 3.26.

Nr.	Process	Elaboration
1.	Plan risk management	The process of defining how to conduct risk management activities for a project.
2.	Identify risks	The process of identifying individual project risks as well as sources of overall project risk and documenting their characteristics.
3.	Perform qualitative risk analysis	The process of prioritizing individual project risks for further analysis or action by assessing their probability of occurrence and impact as well as other characteristics.
4.	Perform quantitative risk analysis	The process of numerically analyzing the combined effect of identified individual project risks and other sources of uncertainty on overall project objectives.
5.	Plan risk responses	The process of developing options, selecting strategies and agreeing on actions to address overall project risk exposure, as well as to treat individual project risks.
6.	Implement risk responses	The process of implementing agreed-upon risk response plans.
7.	Monitor risks	The process of monitoring the implementation of agreed upon risk response plans, tracking identified risks, identifying and analyzing new risks and evaluating risk process effectiveness throughout the project.

Table 3.26: Project Risk Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Risk Management**
  This plan defines how risk management activities are structured, resourced and implemented across the project life-cycle. In order to integrate sustainability, the plan includes a separate risk category, with the a specific risk breakdown structure, organizing risks within the risk register and defining probability and impact scales that extend beyond traditional project driver criteria (time, cost and scope) using the TBL or QBL dimensions (Elseknidy et al., 2025). Besides this, the plan should assign clear responsibilities for risk identification, ownership and monitoring. Because sustainability risks, should not only remain with the sustainability advisor, but should be distributed to accountable risk owners. This avoids an unfair distribution of responsibilities. Lastly, the risk capacity and threshold should be defined, with the aim to clarify which sustainability risks are accepted, mitigated as threats or actively pursued as opportunities. Missing this specification, sustainability risks may be assessed using generic cost and time criteria, undervaluing their significance for the project and W+B.
- **Identify risks**
  Second, the identification of risks takes place, that may affect project objectives and records them in the risk register (El-Sayegh et al., 2018). In terms of sustainability integration, the risks representing both threats (e.g. ecological risks) and opportunities (e.g. partnership that supports knowledge sharing) should be included that are often not

considered in conventional risk assessments. Including these categories ensures that sustainability is treated not as a checklist, but as a structured source of both risk visibility and value creation

- **Perform qualitative risk analysis**
  As a next process, risks are assessed by their probability and impact using a PI-matrix. With regards to sustainability integration, the impact criteria should include dimension from the TBL or QBL (Coskun et al., 2023), which is important since sustainability risks may appear little in terms of financial terms, but significant on ecological, legal or social consequences. For example, the late discovery of a protected species may require mitigation measures, permitting delays, design changes or temporary project suspension. Sustainability opportunities should likewise be assessed against relevant indicators, such as MKI, MCI and CO_2 or cost savings. This enables the project team to prioritize both threats requiring mitigation and opportunities receiving active attention
- **Perform quantitative risk analysis**
  During the quantitative analysis, one evaluates the combined effects of the identified on project objectives quantitatively (Habib et al., 2022). In relation to sustainability integration, uncertainties should be translated into measurable impacts on cost, time or carbon performance. Several techniques can be used to do so (e.g. Monte Carlo simulations) (Bakhtawar et al., 2021). By doing so, it provides a probabilistic assessment of sustainability risk exposure within the fixed project baselines and converts general concerns into explicit forecasts. The results help to inform on contingency reserves (buffers) for cost and time, ensuring that sustainability uncertainties are incorporated into the project budget and timeline.
- **Plan risk responses**
  After this, actions must be addressed and defined for both over project risks and individual risks. In terms of sustainability integration, threats and opportunities should receive the same amount and equal attention. Threats can be avoided, transferred, mitigated or accepted, but this depends on their nature, whereas for opportunities they may be exploited, enhanced, shared or accepted, but should not remain passive entries in the risk register. Effective response planning therefore assigns suitable strategies to threats and actively resources opportunities that can increase project value, reduce environmental impact or strengthen market positioning.
- **Implement risk responses**
  After the responses are defined through planned risk responses, they but be implemented during project development. In terms of sustainability integration, it addresses the gap between documents risks and actual action. Responses might fail when ownership is unclear, resources are unavailable or when timeline pressure takes priority. Every sustainability risk should therefore, have an owner with the right authority, capacity and resources to act upon the risk(s). These response activities should be included in the project timeline as defined work packages with deadlines, dependencies and responsible person or group. As last, the project manager must monitor both their timely implementation and effectiveness, turning sustainability risk management from a documentation exercise into an operational control process.
- **Monitor risks**
  The last process evaluated the effectiveness of risk management and verifies whether the initially planned responses are implemented (using 'voortgangrapportages'). This is important for sustainability integration, since the risk profile of infrastructure project changes throughout design, procurement, permitting and execution. Meaning that new findings, regulatory changes and developments may introduce new risks at any stage. This implies that this remains an iterative process. The risk register should therefore reviewed and updated regularly to remain representative and relevant to the project.

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.27 and Table 3.28.

PPS-component	Sustainability integration opportunities within Project Risk Management	Resource(s)
Products	1. Implement an extra explicit category for sustainability risks (as done by (Wong, 2024)) in the risk register (e.g. regulatory, ecological and material risks) 2. Include a section with a summary on the overall project risk exposure related to sustainability in the (final) risk report 3. Expand the risk register by including sustainability opportunities (positive risks) as well (e.g. innovative materials, subsidy programs or circular procurement strategies)	1. [74], [75], [76] 2. [75], [77] 3. [78], [7]
Processes	1. Identify risks through systematic inclusion of sustainability risk categories through risk identification procedures or workshops with the project team (e.g. environment analysis or ecological pre-survey) 2. Perform a qualitative risk analysis by assessing probability and impact of sustainability risks, including sustainability specific impact criteria (e.g. ecological impact, LC cost impact) 3. Perform a quantitative risk analysis through Monte Carlo simulations or sensitivity analysis to sustainability related risks (e.g. permitting delays) 4. Define explicit response strategies for sustainability risk, including exploitation strategies for sustainability opportunities in the plan risk responses 5. Implement risk responses by integrating sustainability risk responses into the project execution plan 6. Monitor risks by monitoring sustainability risk triggers throughout the project LC	1. [79] 2. [80] 3. [81], [82] 4. [77], [83] 5. [78], [80] 6. [84], [80]
Services	1. Early ecological field survey services, which can be used as an early stage risk identification service whereas timing is a critical risk factor in projects 2. Utilize environmental permit advisors like the environmental services (omgevingsdiensten) as external risk assessment services 3. Use legal advice from laws and regulations (Omgevingswet) to support the identification of risks (legal and governance) 4. Use of risk management software based on the RISMAN methodology, which can be extended with sustainability risk categories	1. [85] 2. [82] 3. [74], [79], [83] 4. [77], [80]

Table 3.27: Sustainability integration opportunities across PPS-components within Project Risk Management (source: Author using (Project Management Institute, 2017))

Nr.	Resource
[7]	Soares et al. (2024)
[74]	El-Sayegh et al. (2018)
[75]	Wuni (2024)
[76]	Wong (2024)
[77]	Coskun et al. (2023)
[78]	Elseknidy et al. (2025)
[79]	Alawneh et al. (2024)
[80]	Habib et al. (2022)
[81]	Bakhtawar et al. (2021)
[82]	Erdenekhuu et al. (2022)
[83]	AbdelHaffez et al. (2025)
[84]	Duong et al. (2023)
[85]	Wang (2023)

Table 3.28: Resources Project Risk Management sustainability integration opportunities

3.2.9. Project Procurement Management

The Project Procurement Management domain, involves the processes requires to purchase or acquire resources from outside the project team. Related to sustainability integration, this domain has the biggest levers available to the project manager, since procurement decisions directly influence supplier behavior, material choices, construction methods and supply chain collaboration (ketensamenwerking). Sustainable oriented procurement is mature in Dutch infrastructure practices compared to the other PM-domains. As elaborated earlier in Chapter 3, the CO_2-Prestatieladder influences tender evaluation by rewarding supplies (using a fictive discount) with a high sustainable CO_2 performance. The MKI score or weighting through the MEAT creates an incentive for bidders to compete and reduce the environmental impact of materials and execution methods (aligning with the SEB strategy). Lastly, Aanpak Duurzaam GWW also provides a framework on how to integrated sustainability across the procurement LC of civil infrastructure projects. However, in practice there still exists a remaining gap between sustainability ambition during tendering and sustainability governance during execution. Sustainability criteria are weighing heavy during the selection phase, but after the contract award they are not always monitored, verified and maintained with the same discipline as is done for cost, time and (technical) quality. This results in situations where sustainability is only functioning as a competitive instrument during procurement instead of being a mandatory performance requirement throughout delivery. The main central challenge of sustainable procurement management lies in closing this gap. Realizing this, makes procurement not only a sourcing function, but also forces parties to realize sustainability commitments in projects that were once made in the tender. The Process Groups involved for this domain are stated in Table 3.29.

Nr.	Process	Elaboration
1.	Plan procurement management	The process of documenting project procurement decisions, specifying the approach and identifying potential sellers.
2.	Conduct procurements	The process of obtaining seller responses, selecting a seller and awarding a contract.
3.	Control procurements	The process of managing procurement relationships, monitoring contract performance, making changes and corrections as appropriate and closing out contracts.

Table 3.29: Project Procurement Management Processes and their elaboration (Project Management Institute, 2017)

- **Plan Procurement Management**
  This plan contains procurement decisions, defines the procurement approach and identifies potential suppliers. In terms of sustainability integration, the plan establishes requirements for all sourcing decisions, both from major contracts to equipment hire. The plan specifies evaluation criteria (e.g. MKI, MCI and CO_2), their weighting within the Most Economically Advantageous Tender (MEAT, in Dutch EMVI) evaluation and how performance will be verified both before and after contract award. Additionally, make-or-buy decision should consider LC costs and sustainability performance along cost and delivery criteria (Khahro et al., 2021), whereas low-CAPEX options may generate higher higher impacts over time. Procurement should therefore be assessed over total value instead of lowers initial price. Depending on the contract type (e.g. UAV-gc, D&C, E&C or DBFM(O)) stated in the plan, sustainability responsibilities and control are also different. Integrated contract transfer responsibilities for design and material choices to contractors, creating verification challenges and incentives to consider LC performance (Ershadi et al., 2021b). However, early contractor involvement can further strengthen sustainability integration, provided that commitments made during collaborative design are translated into binding contractual requirements for execution (Fath et al., 2024).
- **Conduct procurements**
  As a second process, supplier responses are obtained, suppliers are selected and contracts are awarded (Hoseini et al., 2021). In terms of sustainability integration, the sustainable procurement ambitions are translated into contractual obligations (Ruparathna & Hewage, 2015). Sustainability criteria are applied consistently and transparently thought the MEAT evaluation, suing the weighting defined in the procurement management plan. Tender deliverables should be verified accurately to prevent incorrect bidder rankings and potential legal disagreements. The market dynamics (consultation and early supplier dialogues) help to determine what sustainability performance is feasible before the tender is presented. This allows project teams to establish criteria that are both ambitious and realistic. In Dutch context, accessible platforms such as PIANOo can support market engagement, knowledge exchange and circular procurement, which should be actively incorporated into projects with high sustainability ambitions (PIANOo & Rijksoverheid, 2021).
- **Control procurements**
  The last process is about managing supplier relationships, monitoring contractual performance and implementing corrective actions (if necessary). With regards to sustainability integration, this process ensures that commitments made during the tender are actually delivered during execution. Sustainability performance should be monitored alongside traditional project drivers (cost, time and scope). In addition to this, the topic 'sustainability' should remain a standard agenda item in contract and performance meetings, supported by evidence-based reporting. Deviations from acceptance criteria, should trigger corrective action, escalation and if applicable, contractual or financial consequences (Ershadi et al., 2021a). The obligations made should extend through the entire supply chain ('ketensamenwerking'), while the main contract is accountable for subcontractor and supplier performance. At contract closure, sustainability documentation should be verified, archived and incorporated into the OPAs and lessons learned repository to support future projects.

Overall, taken all 'Process Groups', there are some identified opportunities for sustainability integration on PPS-component level for Project Procurement Management, as shown in Table 3.30.
Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.30 and Table 3.31.

PPS-component	Sustainability integration opportunities within Project Procurement Management	Resource(s)
Products	1. Specify sustainability requirements for all sourcing decisions including materials, equipment and involved (sub)contractors in the Procurement Management Plan 2. Use of selection criteria with sustainability weighted evaluation criteria (e.g. CO_2-Prestatieladder, MKI score or MCI score) 3. Include sustainability performance obligations for contractors and suppliers in the procurement statements of work 4. Record and maintain supplier and contractor sustainability performance as a project document and feed it into the OPAs and knowledge base for future procurement decisions 5. Contract document with sustainability metrics as a binding performance obligation with verification requirements	1. [86], [87] 2. [38], [88] 3. [87] 4. [86], [89], [90] 5. [87], [91], [92]
Processes	1. Define sustainability requirements per procurement category (e.g. materials, equipment, subcontracting and specialist services) in the Plan Procurement Management 2. Perform procurements by including sustainability evaluation criteria in tender assessment (e.g. MEAT with CO_2-Prestatieladder weighing) 3. Control procurement by monitoring the sustainability performance of contractors and suppliers against contractual obligations throughout the entire execution 4. Close procurements by verifying and documenting sustainability performance at contract closure and incorporate the results into the OPAs and knowledge base (lessons learned repository)	1. [93] 2. [92], [94], [95] 3. [90], [91], [86] 4. [86], [96], [90], [89]
Services	1. CO_2-Prestatieladder as an external audit and certification service for procurement (after acknowledgment), managed by SKAO 2. Use DuboCalc as a calculation service for MKI verification of supplied materials and products 3. Use platforms that are suitable for circular procurement market engagement between parties 4. Use the service of a independent company to assess the sustainability of the whole chain ('ketensamenwerking') for evaluating supplier CO_2 and circular performance 5. Make platforms like PIANOo accessible as an advisory service or knowledge base for contracting authorities	1. [97], [90] 2. [38], [98] 3. [38], [99] 4. [89], [90], [97], [96] 5. [95], [32], [38]

Table 3.30: Sustainability integration opportunities across PPS-components within Project Procurement Management (source: Author using (Project Management Institute, 2017))

Nr.	Resource
[32]	Ershadi and Goodarzi (2021)
[38]	Fregonara et al. (2022)
[86]	Ershadi et al. (2021a)
[87]	Montalbán-Domingo et al. (2023)
[88]	Hoseini et al. (2021)
[89]	Giannakis et al. (2020)
[90]	Khan et al. (2018)
[91]	Montalbán-Domingo et al. (2018)
[92]	Sarpong et al. (2023)
[93]	Wirahadikusumah et al. (2019)
[94]	Lam (2019)
[95]	Montalbán-Domingo et al. (2019)
[96]	van Hoek and Udesen (2023)
[97]	Adesanya et al. (2020)
[98]	Braulio-Gonzalo and Bovea (2020)
[99]	Tushar et al. (2022)

Table 3.31: Resources Project Procurement Management sustainability integration opportunities

3.2.10. Project Stakeholder Management

The Project Stakeholder Management domain, involves the processes that are required to identify people, groups and organizations that may affect or be affected by the project and analyze their expectations and interests by developing strategies for engaging them effectively throughout the project LC. Related to sustainability integration, this domain is complex in Dutch infrastructure practice, because sustainability expands the variety of stakeholders beyond the general project triangle of client, contractor and end user. Sustainability bring in the stakeholders who are mainly involved in the aspects of the TBL or QBL (e.g. regulatory authorities, nature organizations, local communities and knowledge institutions). Managing this broader landscape of stakeholders requires more than standard stakeholder mapping and communication. Identifying sustainability relevant stakeholders as contributors to project outcomes is essential to use them as leverage for the realization of sustainability integration. Implying that their knowledge, concerns and expectation should be incorporated into project decision making where they can improve sustainable aspects of a project and their role should not be reduced to 'external risks' or 'compliance obligation'. The main challenge in stakeholder management is to move from a defensive engagement to a collaborative participation. Sustainability stakeholders should be engaged early, transparently and continuously, so that sustainability concerns and opportunities can shape the project before key design, procurement and permitting decisions become difficult to change. The Process Groups involved for this domain are stated in Table 3.32.

Nr.	Process	Elaboration
1.	Identify stakeholders	The process of identifying project stakeholders regularly and analyzing and documenting relevant information regarding their interests, involvement, interdependencies, influence and potential impact on project success.
2.	Plan stakeholder engagement	The process of developing approaches to involve project stakeholders based on their needs, expectations, interests and potential impact on the project.
3.	Manage stakeholder engagement	The process of communicating and working with stakeholders to meet their needs and expectations, address issues and foster appropriate stakeholder engagement involvement.
4.	Monitor stakeholder engagement	The process of monitoring project stakeholder relationships and tailoring strategies for engaging stakeholders through the modification of engagement strategies and plans.

Table 3.32: Project Stakeholder Management Processes and their elaboration (Project Management Institute, 2017)

- **Identify stakeholders**
  The initial process is identifying stakeholders and documenting their interests, involvement, dependencies, influence and potential impact on project success (often using a PI-matrix). Related to sustainability integration, the identification should extend beyond conventional project actors to include those with relevant authority, knowledge, interests or influence (Bal et al., 2013; G. Silvius & Schipper, 2019). In Dutch context, they may include regulatory authorities (e.g. environmental services, nature organizations, local communities and knowledge partners) all listed in a register. This stakeholder register records each stakeholders' sustainability interests, formal positions, decision-making power and potential role as a risk or opportunity. By doing so, it allows for different engagement strategies rather than a generic approach.
- **Plan stakeholder engagement**
  After identification a plan is made for engagement approaches based on stakeholders' needs, expectations, (conflicting) interests, influence and potential impact, often visualized through a PI-matrix (Bahadorestani et al., 2019). In terms of sustainability integration, the plan should also consider each stakeholder's sustainability affinity, meaning how they should be approached on a certain level of detail (Ezeh et al., 2024). Regulatory authorities require a structured, evidence-based engagement approach for example, preferably before permit submission, to reduce uncertainty and deal with compliance issues at an early stage. Nature and ecology organization should be approached for their knowledge, which can improve outcomes and reduce later potential objections or discussions. Local communities require transparent, accessible and responsive communication, explaining both mitigating measures and unavoidable impacts, as well as how concerns can be submitted ('zienswijzen') and addressed. Collaborative sessions (e.g. Ambitieweb session) support collective development of sustainability ambitions during project initiation. The outcome should be included into the project charter and PMP to make sure that stakeholder engagement provides binding project direction rather than being an isolated exercise (Bernat et al., 2023).
- **Manage stakeholder engagement**
  The next process is managing the stakeholder engagement throughout the project LC with the aim to manage expectations (alignment), address issues and support their participation in decision-making. In terms of sustainability integration, the process requires continuous and proactive interaction rather than periodic information sharing (Ezeh et al., 2024). Regulatory authorities prefer timely responses, early notification of potential concerns and documented evidence (of compliance). Whereas nature and ecology organizations remain involved beyond the early design phase, especially when ecological commitment (e.g. species protection) affect realization and construction. Also, local communities should receive regular progress updates, accessible channels for questions and complaints, combined with transparent responses when the project falls short during development. This is important as it will strengthen trust and collaboration (Song et al., 2025). Their feedback should be treated as valuable input, because residents and businesses may identify environmental impacts before formal monitoring systems do. Implying the importance of effective engagement which requires the necessary skill from a project manager to handle it.
- **Monitor stakeholder engagement**
  The last and final process is about monitoring stakeholder relationships and adjust engagement strategies if necessary. In terms of sustainability integration, monitoring should assess not only whether planned activities occurred, but also whether they improved sustainability outcomes. Regulatory authorities prefer verification of sufficient documentation that is provided to support permitting, for nature and ecology organization it means assessing whether their input influences mitigating measure before decisions are finalized and lastly for local communities it involves evaluating whether sustainability commitments are understood and trusted. Often stakeholder interests differ, meaning that monitoring criteria should be tailored accordingly as well. Where engagement is ineffective, corrective actions should be implemented through formal change control (by for example the CCB or PM) (Bal et al., 2013; G. Silvius & Schipper, 2019). All relevant findings should be documented in the lessons learned register/repository to strengthen future project practices.

Based on the understanding of these Process Groups, several identified opportunities are gathered from literature on sustainability integration at PPS-level for this domain, as shown in Table 3.33 and Table 3.34.

PPS-component	Sustainability integration opportunities within Project Stakeholder Management	Resource(s)
Products	1. Extend the stakeholder register with a sustainability interest dimension per stakeholder, not only focusing on the classical PI-matrix but also specifying their sustainability stake 2. Include targeted sustainability communication and engagement strategies per stakeholder group in the stakeholder engagement plan 3. Use communication materials suited to stakeholder knowledge level and interest on sustainability impact, such as technical MKI reports for client engineers and plain-language summaries for communities	1. [100], [101], [102] 2. [67], [103], [100] 3. [67], [73], [104]
Processes	1. Identify sustainability-relevant stakeholders beyond the traditional main project stakeholder triangle 2. Define different sustainability strategies per stakeholder type, with a clear escalation path for sustainability concerns within the stakeholder engagement plan 3. Manage stakeholder engagement by having active sustainability dialogues and not only information provision, making stakeholders feel included by setting up participatory processes, such as Ambitieweb sessions or co-design sessions, that build a shared sustainability ambition 4. Monitor stakeholder engagement by tracking whether stakeholders are satisfied or still have concerns as a formal project monitoring metric	1. [104], [101], [105] 2. [101], [103], [102], [106] 3. [67], [107] 4. [101], [104]
Services	1. Use the service of environment management, using an internal or external environmental manager mediating between project sustainability commitments and community stakeholders 2. Use participation platforms like public consultation portals as digital engagement services 3. Use independent sustainability mediators or environmental services where conflicts arise between project sustainability claims and stakeholder experience	1. [103], [73] 2. [103], [67], [73] 3. [103], [106]

Table 3.33: Sustainability integration opportunities across PPS-components within Project Stakeholder Management (source: Author using (Project Management Institute, 2017))

Nr.	Resource
[67]	Ishola et al. (2024)
[73]	Tumpa and Naeni (2025)
[100]	G. Silvius and Schipper (2019)
[101]	Bal et al. (2013)
[102]	Santos and Fernandes (2024)
[103]	Ezeh et al. (2024)
[104]	Maddaloni and Sabini (2022)
[105]	de Almeida Vittori Ferreira et al. (2023)
[106]	Bahadorestani et al. (2019)
[107]	Mathur et al. (2008)

Table 3.34: Resources Project Stakeholder Management sustainability integration opportunities

After identifying the most promising PPS-components for sustainability integration within the 10 PM-domains, a comprehensive overview was developed in Table 3.35. This overview will be used for the Semi-Structured Interviews (SSIs) discussed in Chapter 4. During the final question of the interview (SSIs-Q4), this overview is evaluated together with the participant. Not all PM-domains are discussed, only the domains that the participant frequently encounters in their projects and has affinity with. After analyzing all the findings of the interviews, subsequently, in Chapter 5, an MCDA will be used to select the most promising PM-domain(s), including its corresponding PPS-components for sustainability integration, for which a framework will be developed.

Table 3.35: Overview of sustainability integration opportunities across PM-domains and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017)

PM-domain	Product	Process	Service
1. Project Integration Management	• Update project charter with explicitly SMART-formulated sustainability objectives • Flag sustainability related conditions as a separate category in the assumption log • Embed sustainability in all project baselines within the PMP • Include sustainability changes, impacts and control within the change management plan • Include sustainability category within the lessons learned repository • Integrate sustainability metrics (e.g. MKI, MCI or CO_2) in deliverables • Include sustainability impact fields per change request within change log • Include sustainability benefit realization paragraph in the final report	• Consider sustainability concepts during project charter development • Formulate SMART sustainability objectives before PMP baseline setting • Integrate sustainability milestones into the project timeline • Assess sustainability impact as part of integrated change control review (by CCB or PM) and performance monitoring • Capture and transfer sustainability lessons learned into OPAs and lessons learned repository • Integrate monitoring of sustainability metrics against baselines in PMP throughout the project LC • Identify sustainability opportunities within risk and change management cycles	• Configure PMIS (e.g. Relatics) for sustainability requirements and tracking • Use +CD Tool for sustainability performance visualization on circularity • Organize Ambitieweb sessions as facilitator during project charter development • Make organizational knowledge base and lessons learned repository accessible • Expand CCB or PM review to include sustainability impact assessment
2. Project Scope Management	• Define explicitly sustainability requirements, constraints and acceptance criteria in scope statements • Include sustainability work packages in the WBS • Include sustainability scope descriptions per work package in the WBS dictionary • Include TBL or QBL performance in requirements documentation (KES) • Link sustainability requirements through a requirement traceability matrix (e.g. Relatics) • Include sustainability constraints as unnegotiable boundary conditions within scope baseline	• Collect sustainability requirements from client and regulatory context • Translate ambitions into a contractually grounded scope statement with explicit sustainability boundaries • Create decomposition of sustainability deliverables into assigned manageable work packages in WBS • Validate formally sustainability deliverables against acceptance criteria • Maintain and control scope to prevent elimination of sustainability work packages	• Use Aanpak Duurzaam GWW, including Ambitieweb and Omgevingswijzer for scope definition • Use CO_2-Prestatieladder as external system for scope level sustainability commitments • Configure PMIS (e.g. Relatics) for sustainability requirements and tracking • Use +CD Tool for sustainability performance visualization on circularity • Use DuboCalc for MKI validation at product or project level
3. Project Time Management	• Plan sustainability review milestones at decision gates or handover moments • Create a list of contractually required sustainability milestones • Include sustainability activity durations and dependencies in the time baseline • Create specific sustainability activities as unique timeline items	• Define sustainability activities as unique schedule items • Sequence sustainability task dependencies • Estimate realistic durations for sustainability processes • Integrate sustainability milestones into critical path analysis • Monitor sustainability achievements alongside time performance	• Use planning software such as MS Project or Project Plan 365 • Consider completion time of environmental permit advisors and other time-sensitive service providers
4. Project Cost Management	• Include sustainability cost items as explicit cost baseline budget lines • Estimate costs per work package involved in SCBA • Perform CBA, potentially expanded to SCBA • Separate CAPEX, OPEX and total LC cost	• Include LC methodology, e.g. LCCA, in cost estimation • Allocate sustainability budget lines in the approved baseline • Monitor sustainability cost performance and MKI targets • Expand EVM with sustainability performance metrics	• Use DuboCalc as primary MKI calculation service • Use consultancy services for LCCA • Use advisory services for SCBA • Use CO_2-Prestatieladder for cost-performance verification
5. Project Quality Management	• Include sustainability acceptance criteria in the Quality Management Plan • Integrate sustainability metrics into quality metrics • Document sustainability performance at phase gates or handovers • Provide quality reports containing sustainability performance • Test and evaluate sustainability verification evidence	• Define sustainability requirements as quality criteria • Define measurement methods such as DuboCalc, +CD Tool and CO_2-Prestatieladder • Execute sustainability quality assurance throughout the project LC • Verify sustainability deliverables at phase gates or handovers	• Use DuboCalc as primary MKI calculation service • Obtain company certification for CO_2-Prestatieladder usage • Use CO_2-Prestatieladder as audit and certification service • Use third-party verification of sustainability workflow processes
6. Project Resource Management	• Include sustainability expertise in the Resource Management Plan • Include sustainability specialists in the RBS • Define sustainability responsibilities in the team charter • Document sustainability competencies and gaps • Include sustainability tasks in a RAM/RACI	• Identify sustainability expertise requirements per phase and work package • Obtain internal or external sustainability specialists • Develop sustainability competencies through training and workshops • Include sustainability task delivery in performance management • Monitor availability and deployment of sustainability experts	• Maintain internal sustainability knowledge networks • Use sustainability experts as contracted service providers • Obtain certification for CO_2-Prestatieladder usage • Use CO_2-Prestatieladder as audit and certification service
7. Project Communications Management	• Specify sustainability reporting requirements in the Communications Management Plan • Standardize sustainability sections in work performance reports • Visualize sustainability through dashboards or Sankey diagrams • Use stakeholder-specific sustainability communication channels	• Map sustainability information flows • Share sustainability progress periodically through defined channels • Monitor whether sustainability information is received, understood and acted upon • Translate technical sustainability data for non-technical stakeholders	• Use +CD Tool for sustainability visualization and reporting • Use BIM platforms such as Revit or AutoCAD • Use environmental management expertise for public communication • Use SharePoint or Teams with sustainability reporting templates
8. Project Risk Management	• Add sustainability risks as a separate category in the risk register • Include sustainability risk exposure in the risk report • Include sustainability opportunities as positive risks	• Identify sustainability risks through workshops and pre-surveys • Assess probability and impact of sustainability risks • Perform quantitative analysis for sustainability-related risks • Define responses for sustainability risks and opportunities • Integrate sustainability risk responses into project execution • Monitor sustainability risk triggers throughout the project LC	• Use ecological field survey services • Use environmental permit advisors and environmental services (omgevingsdiensten) • Use legal advice regarding Omgevingswet-related risks • Use RISMAN-based risk software with sustainability risk categories
9. Project Procurement Management	• Specify sustainability requirements in the Procurement Management Plan • Use sustainability-weighted selection criteria • Include sustainability obligations in procurement statements of work • Record supplier and contractor sustainability performance • Include sustainability metrics as binding contract obligations	• Define sustainability requirements per procurement category • Include sustainability criteria in tender assessment • Monitor contractor and supplier sustainability performance • Verify sustainability performance at contract closure	• Use CO_2-Prestatieladder as procurement audit and certification service • Use DuboCalc for MKI verification • Use circular procurement market engagement platforms • Use chain analysis services for supplier CO_2 and circularity performance • Use PIANOo as advisory service or knowledge base
10. Project Stakeholder Management	• Extend the stakeholder register with sustainability interest dimensions • Include targeted sustainability engagement strategies • Use stakeholder-specific sustainability communication materials	• Identify sustainability-relevant stakeholders beyond the traditional project triangle • Define sustainability strategies per stakeholder type • Manage active sustainability dialogue through participatory processes • Monitor stakeholder satisfaction and sustainability concerns	• Use environmental management services • Use public consultation portals as digital engagement services • Use independent sustainability mediators or environmental services

4

Exploratory research and data collection

In this chapter, the findings from the '*Semi-Structured Interviews*' (SSIs) with relevant practitioners from W+B are discussed. The findings from this chapter are also included within Appendix C. These findings are retrieved from the interviews using ATLAS.ti and the extended Gioia methodology. The goal with these SSIs was to generate initial insights or hypotheses from practice related to this topic. 'Semi' indicates that space is preserved for the narrative and for validating the findings from the SLR, whereas 'structured' refers to the systematic verification of the research problem. The initial 3 main questions guided the collection of information related to the research context. However, during the interviews, additional insights emerged that expanded the understanding and scope of the topic beyond the original focus.

4.1. Semi-Structured Interviews set-up and participants

The participants involved in this conversation were internal experts from the company. The reason for selecting internal staff as candidates for my research is that the approach to sustainability integration is being developed in-house. This means it directly relates to the confidential work structure and information associated with project development during the planning and design phases. The assessment on who is suitable for the interviews is done with my company supervising team, resulting into a list. This list was variable in terms of roles and PM-domains on purpose, this had to do with the objective of capturing overall information on sustainability integration by speaking with practitioners from various disciplines and divisions within an engineering consultancy firm, in order to capture practical experiences from multiple perspectives. This approach was essential because sustainability is a highly abstract concept and its definition can vary significantly from one individual to another. The procedure of how this list is defined is as follows:

- Identifying the target group (people from an engineering consultancy firm, W+B)
- Choose respondents/participants (participants with affinity in sustainability (integration))
- Select multiple participants rather than only a few individual (18, meeting the minimum requirement for master thesis' of 12 by (Adler & Adler, 2012))

After finalizing the list, each participant has been contacted by e-mail or Teams to introduce myself, the research and pin-down a date and time for the actual interview (after agreement and formally signing the consent form, read Appendix B). The reason a semi-structured interview is conducted, is because of the fact that not a lot of information on sustainability within the context of this research is known, which allows to explore particular themes or responses by using this methodology, asking a set of pre-determined open questions to prompt discussion (Barclay, 2018). The main questions asked during the SSIs were as follows:

(SSI-Q1) What tasks fall within your current role?

(SSI-Q2) What sustainability-related activities do you already carry out within these responsibilities?

(SSI-Q3) What sustainability opportunities do you see that are not being utilized today?

(SSI-Q4) The attached document includes PPS-components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?

The document stated in question number 4, was a preliminary table showing the PPS-components per PM-domain that was based upon the SLR done in Chapter 3 and completely done. The invitation and informed consent templates for this interview can be found in Appendix C.

P	R	Abbr.	YoE	MPMD	Anonymization
[P1]	Project Leader	PL	6–10	Project Integration Management	SSIs-P1-PL-6/10
[P2]	Environmental Manager	OM	6–10	Project Stakeholder Management	SSIs-P2-OM-6/10
[P3]	Technical Manager	TM	>10	Project Integration Management	SSIs-P3-TM->10
[P4]	Sustainability Advisor	DA	0–5	Project Stakeholder Management	SSIs-P4-DA-0/5
[P5]	Contract Manager	CM	>10	Project Procurement Management	SSIs-P5-CM->10
[P6]	Project Advisor	PA	>10	Project Integration Management	SSIs-P6-PA->10
[P7]	Cost Engineer	CE	>10	Project Cost Management	SSIs-P7-CE->10
[P8]	Project Control Manager	MPB	6–10	Project Time Management	SSIs-P8-MPB-6/10
[P9]	Project Manager	PM	>10	Project Integration Management	SSIs-P9-PM->10
[P10]	Contract Manager	CM	6–10	Project Procurement Management	SSIs-P10-CM-6/10
[P11]	Technical Manager	TM	>10	Project Integration Management	SSIs-P11-TM->10
[P12]	Cost Engineer	CE	0–5	Project Cost Management	SSIs-P12-CE-0/5
[P13]	Technical Manager	TM	6–10	Project Resource Management	SSIs-P13-TM-6/10
[P14]	Project Control Manager	MPB	>10	Project Scope Management	SSIs-P14-MPB->10
[P15]	Technical Manager	TM	>10	Project Integration Management	SSIs-P15-TM->10
[P16]	Project Leader	PL	>10	Project Stakeholder Management	SSIs-P16-PL->10
[P17]	Project Control Manager	MPB	>10	Project Time Management	SSIs-P17-MPB->10
[P18]	Designer	BIM	>10	Project Integration Management	SSIs-P18-BIM->10

P = Participant - R = Role - Abbr. = Role abbreviation - YoE = Years of Experience - MPMD = Main Project Management Domain

Table 4.1: Overview of interview participants and anonymization (source: Author)

The batch of 18 participants/respondents of the SSIs are shown in Table 4.1, as one can see the variety between the participants is high and therefore, the understanding of sustainability context is widened for this research. In this chapter, the findings from the interviews are analyzed and presented. The analysis is structured thematically, which involves different sections covering finding from the most relevant topic which are eventually synthesized. This is done by levels (general approach of ATLAS.ti) by the use of the first-order concepts, derived from the interviews and recurring themes. Eventually, the barriers and enablers are identified that are related to sustainability integration on how project development copes with this in practice and how this impacts the reality. Finally, a framework is defined in Chapter 5 after an MCDA that is based on the scope of this research and results from practice .

To provide additional context for the empirical foundation of this study, Figure 4.1 and Figure 4.2 show how the participants are distributed across different role categories and levels of professional experience. The group includes a wide range of project functions, such as project leadership, technical management, project control, procurement, advisory roles and design-oriented positions. This diversity makes it possible to examine sustainability-related challenges and opportunities from multiple perspectives within the planning and design phase of infrastructure projects.

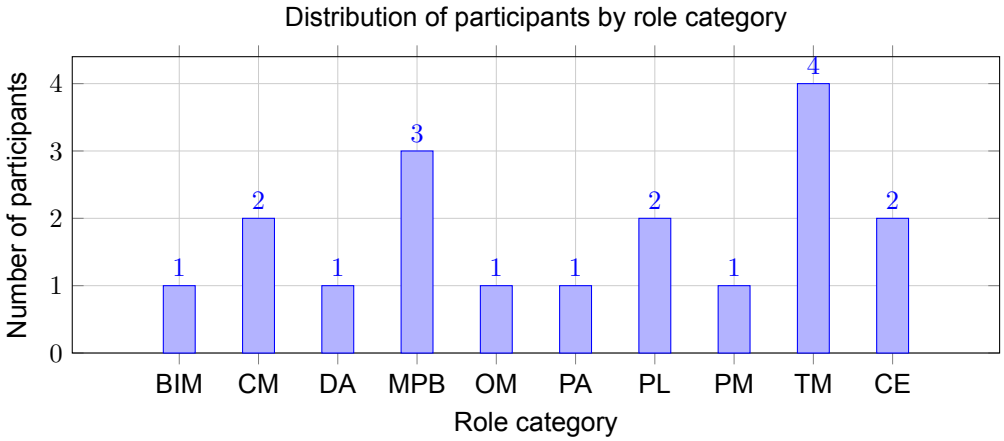


Figure 4.1: Overview of participant roles represented in the informal meetings (source: Author).

Most participants, as shown in Figure 4.2, have more than ten years of professional experience, along with mid-level and early career respondents. As a result, the findings have more analytical depth since they are grounded in substantial practical experience and still reflect variation among career stages. Together, the diversity in roles and experience levels contributes to the robustness of the thematic analysis and supports the interpretation of the identified barriers and enablers for integrating sustainability. Providing relevant information for the framework in Chapter 5.

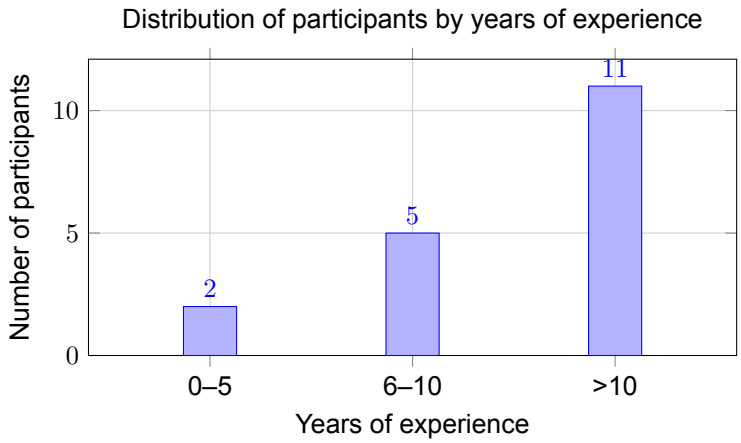


Figure 4.2: Distribution of interview participants according to years of professional experience (source: Author).

During the analysis of the interview findings, particularly from SSIs-Q1, the 10 roles of the participants were identified. These roles are described both from a theoretical perspective and in practical terms relevant to an engineering consultancy firm, including their main tasks. An important note, is that there is no separate 'risk manager' role for risk management, this is mainly integrated within the tasks of a MPB, PM, PL and/or TM.

4.1.1. Project Leader (PL)

The Project Leader (PL) is responsible for the day-to-day management of the project team and the delivery of results within the agreed scope, schedule, budget, quality standards and contractual frameworks. This individual is responsible for making sure that the project is executed as intended, integrated, controlled and supported by a functioning project team. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.2. Environmental Manager (OM)

The Environmental Manager (OM) makes sure that the project has societal support, is feasible and viable from a permitting perspective, taking into account regulations and external stakeholders within the project scope. This role requires a strong understanding of legal and administrative complexities, combined with social and communication skills to strategically translate project impacts to stakeholders and the other way around. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.3. Technical Manager (TM)

The Technical Manager (TM) is responsible for the technical quality, integration and constructability of the design within the cost, time, scope and risk baselines and (sustainability) frameworks. Basically, operating in the interface of engineering and management, where they are responsible for both the technical content leadership and the overall integration within projects. Making sure that decisions are technically valid, robust and practical. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.4. Sustainability Advisor (DA)

The Sustainability Advisor (DA) translates (policy) ambitions and sustainability objectives into concrete measurable and achievable projects decisions, whereas this role safeguards these throughout the planning and design process. It involves guaranteeing that sustainability is measurable, sufficiently supported and completely integrated into design, contracts and decision-making. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.5. Contract Manager (CM)

The Contract Manager (CM) is responsible for making sure that the project is set up and executed in a contractual, strategic and risk controlling manner, with primary focus on the Iron Triangle (cost, quality and time). This role is centered on delivering the project successfully, not only from a technical perspective, but also in terms of legal, strategic and commercial feasibility. Sustainability and risks are also taken into account, as they are explicitly embedded in the contract. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.6. Project Advisor (PA)

The Project Advisor (PA) supports project management and the clients by providing practical, strategic and governance related advice to improve decision-making and risk management. Besides that, the role helps ensuring that the project remains focused on doing the correct things (achieving defined objectives and ending the project successful). Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from

practice during the SSIs.

4.1.7. Cost Engineer (CE)
The Cost Engineer (CE) is responsible for estimating, analyzing and evaluating project costs (based on alternatives), including LC and other sustainability aspects. The role supports decision-making with financial scenarios and makes sure that choices are economically responsible as well as technically and sustainably correct. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.8. Project Control Manager (MPB)
The Project Control Manager (MPB) makes sure that the project stays aligned with the agreed scope, time and cost baseline, as well as risk and quality standards. The role focuses on identifying and communicating deviations in an appropriate manner to support informed decision-making. It also involves measuring project performance, making variances (causing delays) transparent and ensuring that decisions are supported and evidence-based. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.9. Project Manager (PM)
The Project Manager (PM) is in the end, responsible for delivering the project within the agreed scope, time and cost baseline, quality standards, contractual frameworks and governance expectations. This role and individual represents the engineering consultancy firm to the client and acts as a project figurehead (reputational weight). This role makes sure that the project is systematically, organizationally, financially and strategically successful. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

4.1.10. Designer (BIM)
The Designer (BIM) translates functional requirements, policy frameworks and contractual conditions into a technical, feasible, safe and constructible (and sustainable) design. This role requires the ability to convert abstract requirements and ambitions into a concrete, realizable solution, while simultaneously considering safety, cost and sustainability aspects. Besides this theoretical definition, Table 4.2 shows the definition and main tasks related to this research context obtained from practice during the SSIs.

With the roles in this research context defined both theoretically and practically, including their core responsibilities, the interviews were conducted. The collected data is subsequently analyzed using the ATLAS.ti software package, following the principles of the extended Gioia methodology, which will be elaborated in the next paragraphs of this report.

Table 4.2: Overview of the involved participant roles, responsibilities and sustainability-related tasks within infrastructure projects (source: Author).

Role	Abbr.	Description with research context	Main tasks
Project Leader	PL	Operates in the planning study phase of infrastructure projects and leads integrated project teams focused on complex societal challenges. The role is strategic, politically sensitive, relationship-oriented and process-driven rather than technically detailed	• Integrated project management • Decision-making preparation (MCDA) and alternative analysis • Stakeholder and environmental management • Sustainability as governance ambitions • Team development and knowledge management
Environmental Manager	OM	Bridges the project organization and external environment through participation, stakeholder management and environmental coordination. Responsible for embedding stakeholder interests into project requirements and governance processes.	• Participation planning and reports • Stakeholder analysis • Client Requirements Specification (KES) management • Formal objection procedures • Social Impact Analysis (SIA/SEIS) • Interface management and coupling opportunities
Technical Manager	TM	Responsible for technical leadership and integration within projects. Operates at the interface of engineering and management and regularly combines technical coordination with integrated project steering (using e.g., the IPM-framework (Rijkswaterstaat, 2026c)).	• Technical leadership • Integrated project coordination • Sustainability integration • Organizational knowledge development • Strategic technical reflection
Sustainability Advisor	DA	Strategic and content-driven role focused on operationalizing sustainability in infrastructure projects through tools, dashboards, calculations, Ambitieweb sessions and organizational development.	• Ambitieweb facilitation and organization • MKI and LCA calculations • Develop and maintain sustainability dashboards • Develop opportunity lists • Develop internal guidelines • Knowledge sharing • Strategic sustainability advisory
Contract Manager	CM	Operates at the interface between FEDP and market execution with active involvement in procurement, tendering and contractual sustainability integration.	• Contracting and tendering • Procurement and market strategies • Sustainability integration in procurement • Risk and pricing mechanisms • Balancing ambition and feasibility
Project Advisor	PA	Acts as strategic advisor and thematic sustainability expert focused on integrated design processes, Sustainable Design Principles (DOPs) and international knowledge development.	• Sustainable Design Principles (DOPs) • Nature-Based Solutions (NBS) • International knowledge development (e.g. EcoShape and NL2120) • Strategic integrated advisory in design processes • Sustainability trade-off structuring
Cost Engineer	CE	Operates primarily within Project Cost Management and supports procurement, risk and sustainability valuation through financial and LC analysis.	• Cost estimates throughout LC • Variant studies • Financial trade-offs • LCC analysis • Sustainability valuation • Strategic cost advisory • Advisory and warning role
Project Control Manager	MPB	Responsible for integrated control of GROTIK aspects through planning, monitoring, systems engineering, dashboards and process assurance. Less focused on technical content and design choices, but more on assurance, integrated alignment and controllability of the project. Sustainability is embedded through steering and governance mechanisms.	• Planning (deterministic and probabilistic) and progress control • Financial monitoring and internal budget control • Risk management • Contract management (client and company) • Scope and change control • Systems engineering • Dashboarding and reporting
Project Manager	PM	Ultimately responsible for contractual obligations, client coordination and safeguarding sustainability commitments throughout project execution and delivery phases.	• Contractual responsibility • Ownership of promises in the tender • Point of contact for client • Responsible for verification at project completion • Sustainability safeguarding • Phase transitions and handovers • Project (team) steering
Designer	BIM	Focused on integration, visualization and multidisciplinary coordination through BIM and 3D modelling. Makes sustainability consequences visible to support decision-making and facilitate discussions.	• 3D modelling (new and existing) • Design integration of other PMC's • Visualization as decision-support • Sustainability signaling

4.2. Data analysis in ATLAS.ti

4.2.1. Extended Gioia methodology

The findings of the interview are analyzed after conducting the Gioia methodology, which is useful and applicable for inductive, qualitative research and is based on two core assumptions. Firstly, the reality within organizations is socially constructed and secondly that it contains an interpretive approach, which means that the subject of the research (sustainability integration) should be investigated in such a way that it reflects the participants' processes and understandings, while avoidance of any opinion forming from external meanings by the researcher. The participants or respondents are the so called 'knowledgeable agents', individual that know what they are doing, how they are doing it and why. The Gioia methodology prioritizes the voice of the informants during the early stage of data collection and analysis, this is essential especially for topics that have less to none data availability, contain high abstract level or are too complex (e.g. innovation and sustainability). Therefore, the Gioia methodology follows a structured 3-level approach; 1st-Order Concept, 2nd-Order Themes and 3rd-Order Aggregate Dimensions (Gioia et al., 2013). This methodology is used in this research is an extended Gioia methodology, including a 4th-Order Fitted Dimensions, used to fit the actual dimension better within the context of this research.

1st-Order Concepts

In the first step, interview transcripts were coded into first-order (sub)codes. These codes closely reflect the literal content and meaning of participants' statements and are stored as raw codes within ATLAS.ti, also called '1st-Order Concepts', this is often used within 'Grounded Theory' practices with open coding. Doing so, allows the researcher for creative interpretation and experiences of the 'knowledgeable agents', in this report called participants/respondents, According to Gioia, 10 interviews with 10 participants can cover 50-100 '1st-Order Concepts', which don't need to consists of a single word, but can also take the form of short sentences, also referred to (sub)-labels in ATLAS.ti (Gioia et al., 2013). Having 18 participants, means having a lower boundary that sums up to approximately 900 and upper boundary to 1900 '1st-Order Concepts'.

2nd-Order Themes

After all '1st-Order Concepts' are finalized. The next step is to categorize the concepts into theoretical (abstract) context, calling it the '2nd-Order Themes'. The goal is to analyze the (sub)-labels and assess them whether its concept suggest potential themes that describe and explain the observed data. This way, by using information from the SLR and identification of underlying theoretical background, this process evolves from a pure inductive to incorporating elements of abductive reasoning. In this phase, data and existing theories are considered together, however these abstract themes make a shift away from the literal language of the data (quotations from transcripts). In fact, data collection, is stopped in case no new '2nd-Order Themes' are discovered (also called, theoretical saturation). This is related to and dependent on the type of data that is gathered during the interviews. A point of saturation was noticed after 14 interviews, whereas a lot of similar and repetitive data was obtained during the interviews. Nevertheless, all 18 participants were heard within this research context and different perspectives were collected (Gioia et al., 2013).

3rd-Order Aggregate Dimensions

Before the last step, the data collection phase through the '1st-Order Concepts' and '2nd-Order Themes', the last step is to group the themes. An approximate ratio between the '2nd-Order Themes' and '3rd-Order Aggregate Dimensions', is that for each 25-30 '2nd-Order Theme' there are 3-5 summarized '3rd-Order Aggregate Dimension' (Gioia et al., 2013). The dimensions are the last step and should provide a unified framework for organizing the emerging findings, which is eventually used to setup the sustainability integration framework in Chapter 5.

4th-Order Fitted Dimensions

Finally, the last '4th-Order' Aggregate Dimensions are analyzed an made suitable in terms of the research context. This provides a better understanding of the 'fitted' dimension related to the scope of this research.

In summary, in ATLAS.ti these levels are constructed by organizing individual, low-level codes into hierarchical structures (categories and sub-codes) or by grouping related codes together. These themes represent broader patterns or topics, where parent codes (categories) act as themes and child codes (sub-codes) act as specific, granular facets of that theme, facilitating thematic and dimensional analysis. These were defined per question (SSIs-Q1 to SSIs-Q4). Figure 4.3 describes the iterative analytical workflow applied in the qualitative data analysis using ATLAS.ti based on the extended Gioia methodology. The procedure was carried out and recorded as a matrix in Excel for each question (SSIs-Q1 to Q4). Based on this matrix, a flowchart visualization was created to clearly and systematically show which quotes and topics were relevant in forming each fitted dimension. In the following paragraphs, the findings for SSIs-Q1 through SSIs-Q4 are presented. Because SSIs-Q3 and SSIs-Q4 address the missing opportunities and validation of PPS-components of sustainability integration, within the context of current project management theories of PMBoK. They are examined in greater depth including visualizations of the extended Gioia methodology for the relevant fitted dimensions. On the other hand, the results for SSIs-Q1 and SSIs-Q2 are summarized more concisely about current roles, project context and contribution to sustainability integration. More detailed information on this is elaborated in Appendix C.

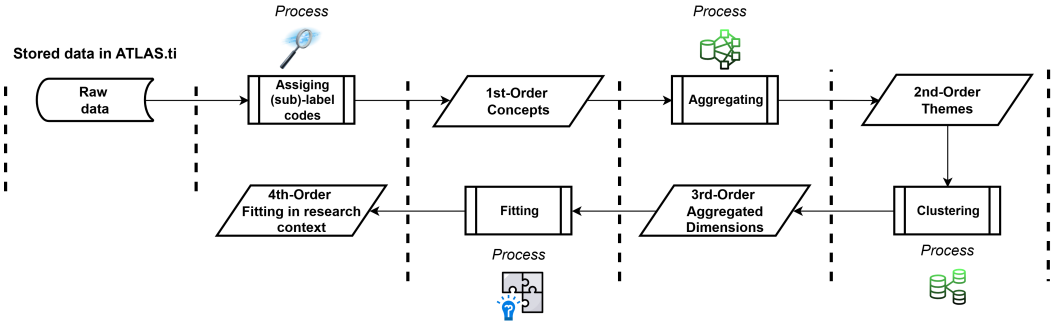


Figure 4.3: Flowchart of aggregation procedure in ATLAS.ti (source: Author)

The analysis resulted in the identification of 28 themes across 4 questions (SSIs-Q1 to Q4), with each question containing seven themes, see Table 4.3 these fitted dimension will be explained later in this report, however, for more information on how these are defined is explained in Appendix C. These themes were then visualized in ATLAS.ti using the Code–Document Analysis functionality, presented either as a Sankey diagram or as a table. The Sankey diagram is difficult to interpret, as it contains a total of 486 connections (18 participants × 28 themes, read Appendix C). For this reason, a table was used instead, supported by a heatmap visualization that indicates the relative intensity between the associated (sub)codes, themes and participants, as shown in Table 4.4.

FD	(SSIs-Q1)	(SSIs-Q2)	(SSIs-Q3)	(SSIs-Q4)
1	Project context and role positioning	Integrating sustainability in design and decision-making processes	Underutilized sustainable design and technical opportunities	Strategic positioning of sustainability within project scope and governance
2	Project leadership and project control	Quantifying and substantiating sustainability	Insufficient quantification and valuation of sustainability	Process-oriented embedding of sustainability
3	Stakeholder and environmental management	Embedding sustainability through processes and project structures	Sustainability insufficiently embedded in processes and governance	Role clarity, responsibilities and ownership
4	Contracting and procurement / tendering	Stakeholder- and participation-oriented sustainability	Governance, client behavior and institutional barriers	Practical applicability and usability of PPS components
5	Engineering, design and data	Advisory and signaling role in sustainability	Advisory potential and proactive sustainability roles	Integration with existing tools, standards and corporate frameworks
6	Organization, strategy and knowledge development	Organizational and knowledge-driven sustainability	Lack of knowledge sharing, learning and standardization	Stakeholder interaction and participatory value of PPS components
7	Quality and assurance / testing	Constraints and boundary conditions in current practice	Missed system-level and programmatic sustainability opportunities	Organizational learning, development and missing elements

FD = Fitted Dimension

Table 4.3: Overview of the Fitted Dimensions (FD) across the four interview questions (source: Author).

Theme	SSIs-P1-PL-6/10	SSIs-P2-OM-6/10	SSIs-P3-TM->10	SSIs-P4-DA-0/5	SSIs-P5-CM->10	SSIs-P6-PA->10	SSIs-P7-CE->10	SSIs-P8-PC-6/10	SSIs-P9-PM->10	SSIs-P10-CM-6/10	SSIs-P11-TM->10	SSIs-P12-CE-0/5	SSIs-P13-TM-6/10	SSIs-P14-MPB->10	SSIs-P15-TM->10	SSIs-P16-PL->10	SSIs-P17-MPB->10	SSIs-P18-BIM->10	Total
(SSIs-Q1) FD 1	3	2	5	3	3	2	4	6	3	4	3	4	4	3	2	4	6	4	65
(SSIs-Q1) FD 2	3	1	3	0	1	2	0	1	1	0	3	1	1	5	2	5	6	0	35
(SSIs-Q1) FD 3	0	9	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	2	17
(SSIs-Q1) FD 4	0	0	0	0	9	0	2	1	1	5	0	2	0	0	0	1	2	0	23
(SSIs-Q1) FD 5	0	1	1	3	0	2	2	1	1	0	2	2	3	1	5	0	0	6	30
(SSIs-Q1) FD 6	1	0	1	3	0	4	1	1	0	0	0	0	4	1	0	1	0	0	17
(SSIs-Q1) FD 7	1	0	0	0	0	0	1	0	0	0	2	2	0	1	0	0	0	0	7
(SSIs-Q2) FD 1	3	1	8	2	2	3	1	0	1	3	5	2	5	1	6	0	2	1	46
(SSIs-Q2) FD 2	2	0	1	5	0	1	4	0	3	1	3	6	2	0	1	1	4	0	34
(SSIs-Q2) FD 3	3	1	1	3	3	3	2	2	5	2	3	1	1	4	3	2	7	1	47
(SSIs-Q2) FD 4	1	4	0	1	0	2	0	0	1	0	1	0	1	0	2	7	0	1	21
(SSIs-Q2) FD 5	1	1	2	0	6	0	3	1	1	1	2	4	0	1	2	2	2	3	32
(SSIs-Q2) FD 6	0	0	2	4	1	6	0	0	1	5	0	0	4	3	7	3	2	1	39
(SSIs-Q2) FD 7	0	0	2	0	1	1	1	3	1	4	1	2	1	8	4	1	5	7	42
(SSIs-Q3) FD 1	0	1	8	0	1	0	4	1	1	4	2	2	3	0	5	0	1	7	40
(SSIs-Q3) FD 2	1	1	4	0	0	1	3	2	1	0	2	5	0	0	1	0	2	1	24
(SSIs-Q3) FD 3	3	1	0	0	0	2	1	2	2	1	3	0	2	3	1	0	6	1	28
(SSIs-Q3) FD 4	3	1	2	0	4	2	1	3	0	1	2	0	1	1	3	7	2	1	34
(SSIs-Q3) FD 5	0	1	0	3	0	0	0	0	1	0	0	1	0	1	0	4	0	0	11
(SSIs-Q3) FD 6	8	6	18	9	8	8	10	9	8	10	10	10	12	8	14	12	14	14	188
(SSIs-Q3) FD 7	1	1	2	2	3	3	2	1	2	3	0	2	4	3	4	3	1	2	39
(SSIs-Q4) FD 1	5	0	2	0	1	1	2	4	2	0	2	2	2	6	1	2	2	0	34
(SSIs-Q4) FD 2	6	10	9	8	10	8	10	10	9	9	8	9	12	10	10	12	11	9	170
(SSIs-Q4) FD 3	0	1	0	0	0	2	0	1	2	1	2	1	1	1	1	1	0	0	14
(SSIs-Q4) FD 4	0	0	1	2	1	1	1	0	1	0	1	1	3	2	4	1	5	2	26
(SSIs-Q4) FD 5	6	10	9	8	10	8	10	10	9	9	8	9	12	10	10	12	11	9	170
(SSIs-Q4) FD 6	0	8	0	4	2	0	0	0	0	2	0	0	2	0	1	4	0	5	28
(SSIs-Q4) FD 7	0	1	1	1	6	1	4	1	0	4	1	3	3	0	1	4	1	1	33
Totals	**51**	**62**	**82**	**64**	**72**	**63**	**69**	**60**	**57**	**69**	**66**	**71**	**83**	**73**	**90**	**92**	**92**	**78**	**1294**

Table 4.4: The heatmap visualizes relative intensity of coded associations rather than statistical correlation coefficients, with darker shading indicating higher frequencies of co-occurrences between participants and questions with related themes in ATLAS.ti (source: Author, see Appendix C for more elaboration)

As can be seen in Table 4.4, some fitted dimensions (rows) for SSIs-Q3 (underutilized opportunities) and SSIs-Q4 (PPS-components) are highlighted. In this research, the selection of the fitted dimensions is based on the principle that at least 50% of the collected data must be analyzed. This approach was applied to both questions, out of the 7 available fitted dimensions, 4 were selected, which exceeds the required minimum. Additionally, the top 4 largest fitted dimensions (the dimensions to which the highest number of quotations were linked in ATLAS.ti, see summation at the most right column) were selected for further analysis, making sure that the analysis focuses on the most relevant data. From this heatmap visualization in Table 4.4, it becomes clear that the following fitted dimensions are of particular interest for further elaboration within the scope of this study:

- (SSIs-Q3) Which sustainability opportunities do you see that are currently not being utilized?
  - Fitted Dimensions 1: Underutilized sustainable design and technical opportunities
  - Fitted Dimensions 4: Governance, client behavior and institutional barriers
  - Fitted Dimensions 6: Lack of knowledge sharing, learning and standardization
  - Fitted Dimensions 7: Missed system-level and programmatic sustainability opportunities
- (SSIs-Q4) The attached document (see Table 3.35) includes PPS components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?
  - Fitted Dimensions 1: Strategic positioning of sustainability within project scope and governance
  - Fitted Dimensions 2: Process-oriented embedding of sustainability
  - Fitted Dimensions 5: Integration with existing tools, standards and corporate frameworks
  - Fitted Dimensions 7: Organizational learning, developments and missing elements

4.2.2. Findings and results

SSIs-Q1 - Roles and project context

The findings from SSIs-Q1 related to roles and project context, spans 7 fitted dimensions, as shown in Table 4.5, derived from the applied extended Gioia methodology. They reflect roles and tasks within W+B across different functions and disciplines (also called Product-Market Combination (PMC). The findings mainly indicate that sustainability is present within planning and design practices, but its integration remains fragmented (1), dependent on individual roles (2), implicit (3) and dependent on contextual conditions (4) ***(FD1–4)***. This fragmented and inconsistent approach (1) to sustainability integration is not unique to W+B. As it is identified that integrated project leadership responsibilities add value by safeguarding integration across PMC's and interfaces (handover moments). Ensuring that fragmented project components come together as a whole ([P11]) ***(FD2)***. Some sustainability research in the construction industry and identified significant gaps in project management integration are inconsistent in use of sustainable metrics (e.g. MKI or MCI) and weaken organizational practices for sustainability implementation. Adding to that, not actively maintaining focus and awareness by putting sustainability consistently on the agenda, by identifying opportunities and monitoring progress using tools and sessions ([P4],[P13]), leaves sustainability at risk to become fragmented and deprioritized within current W+B's governance structure. This requires a corrective action if this occurs, as W+B professionals fulfill their general signaling or warning function ([P14],[P16],[P17]), Despite the fact, that sustainability is becoming and increasingly acknowledge topic, it is still inconsistently anchored in decision-making processes. Often, sustainability is addressed when it aligns with existing tasks or when individuals prioritize it, instead of being a fixed mandate. The designer even mentioned that design solutions, get adjusted to the SDGs, meaning that SDGs do not lead or determine what is produced but instead W+B reshapes it to that direction ([P18]).

Furthermore, sustainability integration is dependent on individuals within W+B (2), since sustainability progress relies on intrinsic motivation ***(FD2)***. Also it was stated that professionals perceive sustainability as a 'nice to have' activity rather than a core element of their role or company's long term success. This situation becomes a barrier to collective action, which aligns with observation that sustainability implementation at consultancy firms is shaped by resource constraints, client demand and the profession of consultants. Furthermore, sustainability efforts also depend on individual intrinsic motivation to keep pushing for it rather than organizational arrangements ([P13],[P16],[P18]) ***(FD2)***. Not having a clear sustainability ambassador or missing a specified role within the PMC weakens ownerships, accountability and continuity of sustainability integration ([P2],[P4],[P16]). Indicating that current sustainability efforts are not uniformly integrated across roles, but instead relies on personal commitment and recommendation ***(FD6)***. Meaning that it remains secondary to other priorities as it is not a hard project constraint, unless specified in project goals, scope and responsibilities ([P1],[P11]). An example is the GROTIK (Geld = Money, Risico = Risk, Tijd = Time, Informatie = Information and Kwaliteit = Quality) framework, that is used structurally within W+B as a project control framework used to monitor and steer in traditional control variables ([P17]). However, sustainability is not yet anchored as an GROTIK-equivalent control dimension, meaning that it competes with the other variables rather than complements the established governance structures at W+B ([P14]) ***(FD2)***. Not only does sustainability integration benefit the organization, but it also contributes to broader (even national) interest. In order be aware of this, it requires a collective shift in mindset (from e.g., silo thinking to systems thinking) where sustainability becomes a shared responsibility instead of an isolated effort. Mapping sustainability integration effects for the whole of Netherlands to understand impacts might trigger understanding. One must dare to take

risks and act in the interest of the 'Dutch enterprise' ([P3],[P15]). Speaking of risk, the risk allocation between client and contractor contribute to this as well during contracting and procurement, particularly during renovation and replacement (R&R) projects. The CO_2-Prestatieladder scores used in award and selection criteria for sustainability, influences this as the procurement strategy is designed by the contract manager and project leader ([P5]). The sustainability risk allocation within the contract, therefore determines which party has responsibility for sustainability performance. This makes early procurement decisions in achieving sustainability results in the later stages of the project critical ([P5]). Confirming that procurement is not an isolated task but an integrated process combining technical, financial and strategic expertise.

Implicitness (3) of sustainability ambitions is still a challenge within W+B, meaning that these ambitions are insufficiently (SMART) specified at the start of infrastructure projects, limiting their impact during planning and design (due to lock-in potential) ([P5]) ***(FD1 and FD2)***. This is due to high level formulated sustainability objectives, that lack concrete target (using sustainable metrics e.g., MKI, MCI or CO_2) or performance criteria. Also it was concluded that organizations lack defined sustainability strategies and found out that companies may express sustainability values, but due to insufficient operationalization of non-SMART formulated objectives there exists a gap between ambitions and concrete practice. As a consequence, sustainability considerations tend to compete with more established project (control and management) drivers such as time, cost, scope and functionality rather than functioning as an integrated design parameter ***(FD2)***. Project control within W+B, relies on dashboards and data-driven reporting, with traditional control variables like scope, time and costs still remaining dominant ([P17]). However, a growing responsibility for integrating sustainability within these structures exists internally ([P9]). Other analytical like the MCDA and probabilistic cost estimation using Monte Carlo simulations are more often used within W+B to support decision making during the FEDP ([P1],[P12]). LCA data is translated into cost structures and combined with probabilistic techniques to compensate for uncertainties in quantities and unit prices ([P12]), while MKI is just started with being incorporated into frameworks, but is not yet a standard practice across roles and PMC's, which confirms the implicitness and consistency as discussed earlier ***(FD2)***.

Regarding contextual conditions (4) ***(FD1)*** the allocation and delimitation of responsibilities are highlighted, especially when decisions are made on whether design tasks are kept or delegated to the contractor ([P5],[P8]). The latter might bring a risk of sustainability integration as information during the handover might be interpreted differently, therefore careful transfer is essential. Roles that are limited engaged with design activities ([P14],[P16],[P17]) and instead having a more coordinating or signaling function ([P14]) might also risk losing overview on sustainability integration and may thus lead to fragmentation ***(FD1 and FD2)***. Timing of role involvement is essential too, because some roles are concentrated in the pre-planning and contract preparation phase, where sustainability ambitions have high potential to be locked or lost ([P1],[P10]), missing out now means difficult integration later as shown in Figure 4.4 ***(FD1)***.

Besides role and contextual positioning, the findings and results show that sustainability integration is also mediated through formal participation processes. Coordinating participation plans, formal replies to stakeholder submissions (zienswijzen) and ensuring compliance with client requirement specifications (KES) are critical to anchor sustainability-related commitments ([P2]). Missing or receiving a delayed permit as a consequence of an unresolved environmental concern can lead to project delays, which underlines the importance of proactive stakeholder management ([P16]). However, it was mentioned that within W+B not all roles are equally positioned to engage with external stakeholders, designers are more interacting with internal teams, whereas project leaders serve more as a translator of technical expertise and client communication ([P16],[P18]).

Apart from the fragmentation of sustainability, W+B recognizes the potential of quantification methods (e.g. DuboCalc, +CD Tool and CO_2-Prestatieladder) which is almost standard practice internally, however the lack of standardization in their application limits their effectiveness. Implying that designs made with leading principles like the IFD and DOPs should only be suitable for the application ***(FD5)***. Some research developed a framework that integrates multilevel indicators across project LC-phases, proving that phase specific selection can improve measurability and verifiability of sustainability performance. This proves the gap where sustainability metrics are not standard practice yet and differ during project development. In case they are formalized, measurable and verified during projects, then it becomes useful ([P9]). Standardized cost estimation frameworks (e.g. SSK) for infrastructure provide a basis for calculating and comparing project costs within W+B ([P12]) ***(FD2)***. But, despite this, the MKI metric is gradually included as standard component within these analytical framework, but still not yet uniformly applied. Highlighting the gap between available instruments and their inconsistent use ([P4]). As a consequence this affects the quality of work. Compensating, there are some domain-specific expertise within W+B (e.g. concrete performance and hardening control) that directly affects infrastructure quality and durability, however the formal responsibility for organizing and managing quality processes is more given to the project managers than uniformly anchored across all roles ([P13],[P14]) ***(FD7)***. This highlights the broader pattern of sustainability integration within W+B, expert knowledge is available but the governance and accountability structures do not yet translate that knowledge into standard practices.

However, the application of these instruments is not yet standard practice and varies between projects and roles, limiting their impact during the planning and design phase. Knowing what instruments to use for what, comes from experience. The more projects are done (by trial and error), the more lessons are learned and the better choices one can make on which indicator(s) to include for which project phase, discipline (PMC) or assign to project team member or task ***(FD6)***. Related to choices, Figure 4.4 highlights the influence region of design decisions and what capacity of sustainability

integration can be 'locked-in' during the planning and design phase, particularly expressed in LC-impact and costs. During this phase, the range of possibilities is at its highest and the impacts are still minimal and decisions are not final. However, as the project moves into the construction stage, a break-even point is reached. Beyond this point, the flexibility to influence sustainability outcomes decreases and increasing rigidity becomes embedded in further project development.

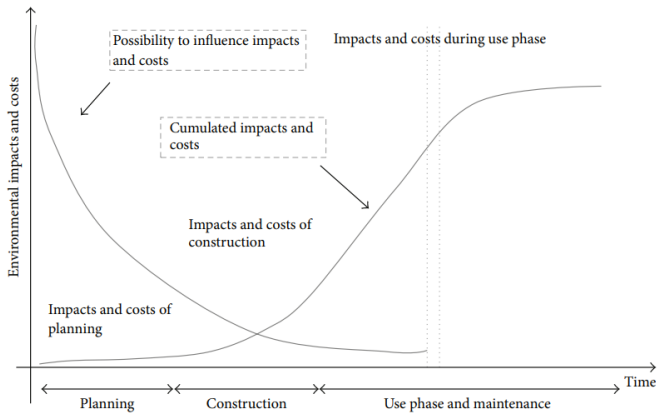


Figure 4.4: Influence region of design decision expressed LC-impact and costs (Bragança et al, 2014)

Along the quantification instruments and methods that are available, the organizational positioning (defined by the EEFs and OPAs of an organization) and role clarity affect how sustainability is integrated during project development. A project control manager stated that his ability to influence sustainability outcomes within the planning and design is constrained by his role ([P14]), whereas a sustainability advisor encounters more sustainability due to an assigned work package in the WBS related to the KES. This is enforced by the fact that W+B as an engineering consultancy firm has a role and mandate that are primarily advisory in nature. This limits the real output of a project in practice. The way a project is structured and delivered, fundamentally constrains or enables what sustainability advisors/consultants can accomplish based on their scope/playground. The project control manager explicitly proves that integration is often interpreted as laying outside one's direct responsibility and verifies that sustainability is not yet embedded within project governance structures, but instead scattered across roles and PMC's. Some professionals' role remain underexplored, showing how important the understanding of professional collaboration is, in order to incorporate responsible design goals. Improving professional collaboration as a 'consultant', it is essential to know how to operate. Regardless of the industrial scope, Stevenson (2013) found 6 key factors:

1. The knowledge and understanding of how to address responsible design goals
2. The consultant's motivations
3. The consultant's capabilities
4. The opportunity available
5. The level of influence the consultant has
6. What is implemented

These 6 key factors together 'determine the consultant's possibility to achieve responsible design'. Each factor is determined and dependent by a series of other influencing factor, which are in turn affected by characteristics of the consultant's circumstances. Factor 5 directly related to the discussion about how organizational positioning and role clarity affect sustainability integrations, especially the constraints faced by advisory companies like W+B in influencing sustainability outcomes. Employees at W+B each play a big role as the operational aspect of embedding sustainability during project development is essential. Especially the organizational factors (EEFs and OPAs) that influence sustainable design integration. Chatty et al. (2022) concluded that consultancy firms face inherent limitations and constraints in sustainability integration and implementation due to:

A. Client/stakeholder buy-in
This is critical since project managers noting difficulty of 'communicating the value of sustainable design to clients' who primarily seek engineering support rather than sustainability services. As the project manager is mainly responsible for what they have promises in terms of sustainability ([P9])

B. Role-based influence
Different roles have varying levels of influence on sustainability suggestions/outcomes. Project managers have most client/stakeholder interaction and can influence sustainability integration. A designer for instance is barely/not in contact with (external) stakeholders that are involved within the scope of the project for instance ([P18]).

C. Scope of influence
The engineering consultancy firm has the biggest impact on material selection (e.g. types of timber with a database

on CO_2 values) ([P7],[P12]) and project design (influencing MKI, MCI and CO_2) ([P4]). Incorporating specific design principles like the DOPs and IFD for long term value ([P6]). Transport is not something one can influence, however inspections at the location and a technical investigation are performed in practice ([P15]). The decision on what type of material or how thick a beam is not up to the designer as the final decision, because it needs to comply with structural safety and integrity of the structure or asset ([P18]), this is more related to the job of a structural engineer.

D. Organizational culture
Sustainability integration requires embedment 'into their organizational culture' and 'DNA', not just workflows. This is more and more done within W+B, by developing guidelines on how to integrate sustainability in projects in general and how to start ([P5]).

This summarizes all the 7 fitted dimensions (FD) for the first question (SSIs-Q1) regarding the roles and project contexts within W+B and its relation towards sustainability integration. The overview is shown in Table 4.5. More about these fitted dimensions is discussed in Appendix C.

FD	(SSIs-Q1)
1	Project context and role positioning
2	Project leadership and project control
3	Stakeholder and environmental management
4	Contracting and procurement / tendering
5	Engineering, design and data
6	Organization, strategy and knowledge development
7	Quality and assurance / testing

FD = Fitted Dimension

Table 4.5: Overview of the Fitted Dimensions (FD) related to SSIs-Q1 (source: Author).

SSIs-Q2 - Current contribution to sustainability integration
The findings from SSIs-Q2 related to the current contribution to sustainability integration, spans 7 fitted dimensions, as shown in Table 4.6, derived from the applied extended Gioia methodology. They reflect how W+B professionals across different PMC's currently contribute to sustainability integration within their roles as described in SSIs-Q1. The findings highlight two main issues, namely that sustainability integration occur through design optimization, LC thinking and quantification practices (1) ***(FD1 and FD2)*** and that these contributions remain constrained by fragmented governance, institutional barriers, knowledge gaps and missed programmatic opportunities within W+B ***(FD3–7)***.

The findings proof that within W+B sustainability is more integrated within design and decision-making processes, but the consistency of application across roles and project context differs ***(FD1)***. Sustainability is not only about optimizing design, but also about reconsidering how performance is defined and managed (e.g. propose monitoring as an alternative to over-dimensioning, the phenomena of conservative and excessive material use), hence managing uncertainties through adaptive methods instead of unsustainable design ([P3]). Aligning with the principle that sustainability must be included from early design decisions instead of being an afterthought. The planning phase is critical for incorporating sustainability and defining its impact if its not considered during plan development. This leaved insufficient room for any changes, as regulatory, contractual and technical constraints are defined ([P1]). Pathways to sustainability are shaped by system lock-ins, which makes the early planning stage (FEDP) crucial because later the options become constrained, proving the 'lock-in' effects discussed in SSIs-Q1. Design optimization, at W+B, extends from material selection to the application of structural design principles (e.g. the IFD and DOPs). Indicating that design choices are influenced by proposed materials (e.g. timber options) grounded in one these principles that are based on both cost and sustainability considerations ([P3],[P12]). However, the designs must satisfy technical conditions (e.g. strength, stiffness stability) in order to be a valid option. Incorporating these principles at early design phases, increases the probability that they are realized in execution and supports adaptability and reuse possibilities in the future ([P10],[P11]).

Internally, the LC perspective (considering 'cradle-to-cradle') is taken into account, meaning that the entire life span (CAPEX + OPEX) ([P6],[P11]) is considered during design. Avoiding replacement is the most sustainable option as it doesn't expose any CO_2-emissions, a new structure immediately triggers pollution ([P3]). W+B's approach is therefore strategical on life span extension (e.g. from 80 to 120 years) measures (e.g. use of protective coating or material optimization) in infrastructure to minimize degradation over time ([P3],[P13]). Besides design, during inspections for circularity potential W+B using the R-ladder strategy as well, to assess reuse, repurpose and reclaimed materials ([P3],[P10],[P15]). W+B also tries to use more synergies or co-benefits ('meekoppelkansen') of projects to increase sustainability integration. Meaning that gains from one project are combined with the demand of another (e.g. reuse material flows or optimizing resource use) ([P2],[P15]). This programmatic approach has led to questioning the traditional requirements, because of lower thresholds could imply more sustainable solutions without sacrificing safety or functionality ([P10]). Anyhow, time will tell, as monitoring these designs and comparing them through alternative analysis (e.g. using MKI-calculations) supports informed decision-making in the future ([P1],[P17]) ***(FD1)***. Doing so, might confront the client as reused material may not look 'as-new' or perform according to expectations (=risk), which may created tension between reaching sustainability goals and stakeholder demands ([P5]). Another project related tension, is that in case time pressure occurs, the

priorities shift towards necessity and speed over sustainability, reducing flexibility and priority to integrate sustainability ([P15]). Decision-making on sustainability therefore requires a consistent process of balancing competing criteria, including cost, risk, quality and performance (evaluated within the TBL or QBL framework. Making sure that environmental, social and economic values are all considered ([P6],[P10],[P11],[P13]) ***(FD1)***.

Quantifying and substantiating sustainability is also recognized within W+B as a primary challenge, proving the purpose of this research, to understand, compare and defense decision-making processes. Currently, the main used core methods are MKI and LCA calculations, which are applied to quantify environmental impact ([P4]). These are used to compare alternatives across design variants and baseline scenarios, which makes sustainability performance explicit and accessible ([P4]). Visualizing design and integrating financial consequences alongside environmental impacts is highlighted by the cost department as an desire and need ([P12]). Finding more metrics that could quantify sustainability could of course strengthen the decision-making and support ([P11]). Some research developed a framework, that integrated environmental, social and economic information together, which helps decision-makers to translate sustainability into an assessable manageable project parameter. Currently, W+B is working on this integration, whereas CO_2 values are linked to material cost database and embedding MKI as a criterion during tenders ([P7],[P12]). Furthermore, quantification within W+B take place over the entire LC using 'Total Cost of Ownership' (TCO) (represented as CAPEX + OPEX, as mentioned earlier), making sure that sustainability is evaluated across the entire life span rather than a single point ([P11],[P15]) ***(FD2)***. Methods used for this are the Social Cost-Benefit Analysis (SCBA), in which both social impacts are considered as port of the sustainability assessment ([P6]). In case decisions are made using an MCDA within a project, sustainability is integrated as a weighted criteria alongside other project control variables (e.g. cost and risk) ([P1]). Before all these methods are applied, at a preliminary phase the ambitions of stakeholders are identified by using the Ambitieweb and Omgevingswijzer ([P11]), however they remain non-SMART formulated and remain abstract. At a later stage, like the tender phase, sustainability is directly integrated in procurement through MKI-based scoring or fictive discounts on bids ([P12]). Lastly, W+B used evidence-based evaluation as this is critical for discussion on whether outcomes really are as they expected initially (e.g. standard solution outperforming a Nature-Based Solution (NBS)) against specific criteria ([P6]). This underlines the importance of objective, evidence-based assessment over assumptions about what is intuitively 'more sustainable' ***(FD2)***.

The sustainability integration realization is also dependent on how it is anchored through processes and project structures within W+B ***(FD3)***. The findings indicate that sustainability ambitions are currently more and more included in formal project structures (e.g. contracts or procurement documents). However, when it gets framed as a 'standard component' within tendering processes, it becomes vulnerable and start to shift from a voluntary consideration towards an standardized expectation within project governance ([P5]). In order to push sustainability through, W+B tries to incorporate sustainability requirements in client requirement specifications (KES), which ensures that sustainability becomes part of the formal project obligations rather than a parallel activity ([P14]). Some studies verify that sustainable project management requires proactive stakeholder participation and sustainability to be anchored in planning, monitoring and control processes (by directly using the KES), instead of treating sustainability as an addition to project delivery. Along to process of sustainability integration the main challenge lies in maintaining continuity of sustainability across project phases (preventing fragmentation as mentioned earlier). All sustainability related decisions, risks and ambitions needs to be explicitly transferred between phases and project teams to prevent this fragmentation and therefore 'watering down' of sustainability goals ([P9]). The 'sustainability baseline' (ambitions and upfront sustainability decisions) must be included in initiation documents and project definitions, as decisions made at that stage are leading to which extent sustainability can be integrated later ([P18]). The project control managers expressed that anchoring sustainability within the GROTIK governance framework linking it to risk management structures provide a practical mechanism ([P8],[P17]) to keep sustainability visible (Wong, 2024). Lastly, incorporating a programmatic approach where sustainability is developed across different and multiple projects allows organization learning, scaling and continuous improvement rather than on a project-by-project basis ([P9],[P16]) ***(FD3)***.

Integrating sustainability within W+B is shaped through interaction with involved stakeholders and the broader project environment ***(FD4)***. Implying that sustainability is not only a technical or internal matter, but also a social, relational and participatory process (regardless of the intrinsic motivation within W+B). Involvement of market parties and contractor during the tender process creates a healthy and competitive environment for sustainable and innovative bids which challenges bidders to propose new ideas ([P5]). Correcting stakeholders' misconceptions on the assumption that sustainable alternative are always more expensive is in itself a form of contributing to sustainability ([P5]). Aside from correcting stakeholders, involving them in the whole process from sustainability dialogue from the tendering and initiation phase ensures that sustainability is anchored in project definitions before constraints are defined or shaped ([P9],[P16]). In order make sure this is done relationship management is essential in maintaining positive 'goodwill' among stakeholders which further contributes to smooth project development and reduces conflicts that could perhaps undermine the sustainability goals ([P2]) ***(FD4)***. W+B tends to translate and reinforce existing customer policies within a project (part op participatory contribution), whereas project leaders refer back to policy documents and previously stated sustainability ambitions if they risk to be overlooked ([P1],[P16]). This helps to remind them of their own sustainability goals or confront them with it when cost pressure or other priorities seem to push them into the background ([P15]). Furthermore, without a shared vision on sustainability among all stakeholders, projects risk fragmentation and conflicting interpretation, also called 'alignment' ([P11]). W+B creates alignment by performing a collaborative Ambitieweb sessions to create a col-

lective understanding and a shared direction at an early stage ([P4]). Additionally to 'shared', it is essential to provide value within the chain ('ketensamenwerking'), through strategic allocation of responsibilities to those best positioned to act within the chain, instead of assuming that every stakeholder has equal influence ([P10]) ***(FD4)***.

W+B as a company, as mentioned earlier, carries an advisory role as a company, but so does the employees ('consultants') rather than decisive authority. This means that sustainability integration or contribution is provided through signaling, raising awareness and structuring information rather than direct decision-making ***(FD5)***. A designer provides input (e.g. models of options) to the technical manager to present the options and so does the technical manager by raising questions during the presentation towards the external stakeholders ([P11],[P18]). Regardless of indirect influence, within W+B, by raising awareness of how early design decisions determine long-term sustainability outcomes represent a useful leverage within the capacity of employees ([P10]). Advisory input focused on sustainability strategies, such as reuse of material for example, are often overlooked because of limited financial incentives or a preference for new materials (to look 'as-new') ([P5],[P7]). However, by linking this advice to quantified metrics (e.g. MKI or MCI), the argument is strengthened and evidence-based which perhaps leads to another final result ([P12]). Internally, the strategy to make sustainability visible during conversation is highlighted, even when not formally included in the scope (part of the advisory role). This is done by actively introducing sustainability topics makes them to be considered without any formal obligation ([P9]), whereas the designer provides visualization as a way to initiate dialogue and support mutual understanding (again, 'alignment') ([P18]). Aside from the advisory or signaling role, some have a 'duty to warn' as was already stated by the cost engineer about 'correcting misconceptions' about real sustainability and sustainability illusion. The duty to warn is a more ethical and proactive grounded behavior of the advisory role, where where overlooked sustainability risks or suboptimal choices are flagged without being explicitly requested ([P7],[P14]). Contradictory, taking imitative in introducing and influencing decisions indirectly, even in projects where sustainability objectives are not strongly defined ([P17]) ***(FD5)***.

Currently, within W+B there are some ongoing initiative to drive sustainability integration by organizational learning, knowledge-driven sustainability and cultural change ***(FD6)***. This is done by spreading sustainability insights across the organization using discipline forums, internal meetings and thematic sessions which transforms individual project knowledge into collective organizational knowledge ([P13]). The internal established standards, guidelines ([P6]) and knowledge platforms helps to standardize sustainability practices and makes them reusable across projects rather than dependent on project-by-project application ([P10]). If the lessons learned repository or register is maintained and translated into organizational knowledge, the platform will support continuous improvement and provide a basis for evidence-based decision-making in future projects ([P13],[P17]). Within W+B, it is observed that moreover the younger employees tend to grow awareness of sustainability, which indicates a cultural change that is partly driven by a generational shift within current workforce ([P18]). Actively taking a role for an sustainability initiative means that it comes with the responsibility of transferring and developing that specific sustainability initiative, for example for the DOPs ([P6]). Aside from roles, within W+B, sustainability is also translated from data and calculation to a broader audience using strategic communication which allows the organization to position sustainability within communications and decision-making ([P4]) ***(FD6)***.

Despite all contributions described within earlier paragraphs across ***(FD1–6)*** sustainability integration within W+B also takes place within clear constraints and boundary conditions which limits depth and consistency ***(FD7)***. In practice, sustainability ambitions (even when initially expressed) tend to diminish when confront with cost implications or stakeholder resistance, verifying that sustainability is not only a technical challenge but also one of overcoming organizational and financial barriers ([P16]). 'Pragmatic delimitation' exists only when active steering regarding sustainability only takes place if the limits remain feasible, which leads to a reduction in monitoring or where ambition setting as project condition becomes stricter ([P17]). Besides this, some sustainability contributions are bounded by a specific domain of expertise (e.g. material choices determined by structural engineering), meaning that sustainability is often approached within predefined areas of responsibility rather than company-wide across the project ([P13]). Budget limitation tend to override sustainability ambitions, which leads to downscale interventions or complete elimination of sustainability initiative when additional investments are required ([P15],[P17]), regardless of initially being included in project agendas ([P18]). Becasue without financial incentives or formal mandates, sustainability in project delivery remains symbolic rather than operational. The structural integration of sustainability remains limited within W+B, as it depends on individual awareness, expertise and intrinsic motivation (as mentioned earlier) instead of being part of role responsibilities and standard workflows ([P12],[P18]. Within W+B because of the organizational hierarchies, contractual boundaries or limited decision-making authority cause constrained sustainability influence, whereas signaling or warning functions are seen as ineffective or ignored ([P14],[P18]). Additionally, the long-term performance uncertainty (e.g. extended life span is difficult to predict and verify) is even strengthened due to short-termism and reduces confidence in sustainability proposals ([P15]) ***(FD7)***. This summarizes all the 7 fitted dimensions ***(FD)*** for the second question regarding the current contribution to sustainability integration within W+B. More about these fitted dimensions is discussed in Appendix C.

This summarizes all the 7 fitted dimensions (FD) for the first question (SSIs-Q1) regarding the current contribution to sustainability integration within W+B. The overview is shown in Table 4.6.

FD	(SSIs-Q2)
1	Integrating sustainability in design and decision-making processes
2	Quantifying and substantiating sustainability
3	Embedding sustainability through processes and project structures
4	Stakeholder- and participation-oriented sustainability
5	Advisory and signaling role in sustainability
6	Organizational and knowledge-driven sustainability
7	Constraints and boundary conditions in current practice

FD = Fitted Dimension

Table 4.6: Overview of the Fitted Dimensions (FD) related to SSIs-Q2 (source: Author).

SSIs-Q3 - Sustainability integration opportunities

The findings from SSIs-Q3 focused on identifying opportunities related to sustainability integration within the responsibilities mentioned in SSIs-Q1 & Q2. Based on the responses, a total of 7 fitted dimensions were derived through the extended Gioia methodology, as shown in Table 4.7.

Aside from organizational, individual or procedural aspects, the findings show that participants put an emphasis on technical and design-related sustainability opportunities that are currently not optimally used during the FEDP of an infrastructure project ***(FD1-Underutilized sustainable design and technical opportunities)***. The early design phase is fundamental to key sustainability decisions, however sustainability considerations are often introduced too late or remain secondary to traditional design drivers (e.g. cost, time and constructability related to structural safety). Decision made at this stage determine the project's direction, however there remains a tension between customization and standardization in sustainable design (e.g. IFD or DOP). The IFD and DOP offer clear sustainability advantages, but remain underused due to cultural resistance, especially from design-oriented stakeholders. Causing inefficiencies and missed opportunities when sustainable alternative are not considered or normalized ([P10]). Unique design hinder reuse potential, scalability and circularity because unique elements are difficult to repurpose and often end up as waste ([P15],[P18]) and pushing resources towards visual quality ([P7]). Due to phase lock-in effects, sustainability outcomes are limited because of the design choices that are made during the initial phase. These effects tend to exist throughout the entire project LC, which limits possibilities for disassembly (IFD) and reuse (DOP) that are often finalized during the FEDP ([P10]). Dutch infrastructure is often designed based on outdated assumptions instead of anticipating on future development (e.g. NEN standards), causing a gap in solutions that are not adaptable or aligned with long-term sustainability goals ([P7]). This is currently an ongoing issue with the R&R projects within the Dutch infrastructure. Less drastic strategies (e.g. strengthening instead of replacing, monitoring instead of overdesigning or reusing existing materials) are not always considered within W+B. This shows a bias towards conventional solutions when more sustainable alternatives are available ([P3],[P12]). Aside from alternatives, on a smaller scale, techniques can be used (e.g. proof loading or design based on proven strength) that are still underused within W+B, despite its potential to reduce material and avoid unnecessary interventions for maintenance ([P3]). Unlocking these opportunities and potential requires a shift within the company towards a flexible, performance-based and LC design approach. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.5.

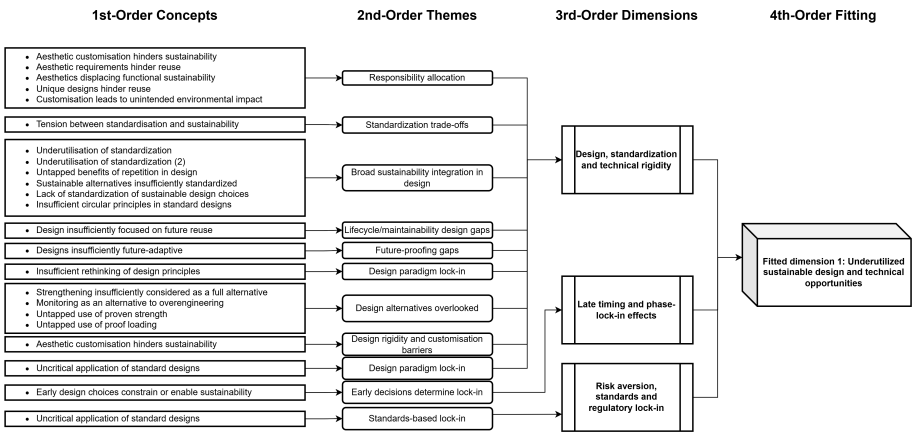


Figure 4.5: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q3 (source: Author)

Insufficient quantification and valuation of sustainability ***(FD2)*** is driven by the dominance of one-dimensional financial metrics in decision-making. When decisions are primarily driven by direct costs, more sustainable options such as circular demolition or reuse are frequently dismissed, as what is not monetized or measured remains invisible in decision-making ([P12]). A project control manager stated that evidence exists that sustainability can generate cost savings, however this potential is not systematically recognized or exploited ([P8]). A cost engineer mentioned a lack of insight into the cost of non-intervention, leading to a bias toward conventional and often less sustainable solutions ([P12]). LCC and broader economic evaluation methods such as SCBA are acknowledged as important but barely used in practice, particularly in

long-lifespan infrastructure projects ([P3],[P7]). A sustainability advisor mentioned that sustainability trade-offs are often handled at a highly abstract level without being translated into concrete, actionable criteria in a SMART-manner, limiting their practical impact on project-level decisions ([P4]). Although metrics and monitoring tools exist within W+B, their application is inconsistent and collected data is not always integrated into organizational systems or decision-making processes, leaving valuable sustainability insights underutilized ([P3],[P9]). Timing also plays a crucial role, as sustainability considerations are often introduced too late in the project LC, particularly in financial evaluations during the FEDP when flexibility is already reduced ([P17]). Furthermore, a strong indication of short-termism and horizon bias exists in decision-making, as sustainability benefits often appear over longer time horizons, potentially causing ambition erosion, while costs are immediate and tangible. This mismatch leads to underinvestment in sustainable solutions, especially when long-term impacts such as maintenance, LC emissions or durability are not accounted for ([P2],[P12]).

Still, the contributions to sustainability integration as mentioned in the paragraphs earlier remain insufficiently anchored in W+B's internal processes and governance structures ***(FD3)***. The current way of working internally leads to fragmentation of sustainability across multiple PM-domains, which occurs due to silo thinking. This means that several actors, colleagues or employees involved in project development remain bounded by their own operational boundaries (e.g. budget, standards and organizational routines), which diminishes rather than strengthens sustainability integration. This limits synergies (also co-benefits or coupling opportunities, referred to in Dutch as 'meekoppelkansen') and integrated decision-making ([P9]). In addition, sustainability is not structurally embedded within planning and is often not effectively connected to other design and project teams, which reinforces its treatment as a parallel or isolated topic ([P17]). The absence of clearly defined roles, such as a sustainability ambassador or structurally embedded responsibilities within the PMC, weakens ownership, accountability and continuity Besides the internal processes, workflows and governance structures, intrinsically motivated employees have a significant contribution to sustainability integration ([P13],[P16],[P18]), which is consistent with the pattern identified in SSIs-Q1. Currently, sustainability is not seen as a hard project constraint within W+B, but remains secondary to other priorities unless it is explicitly specified in project goals, scope and responsibilities ([P1],[P11]). The organizational and client-level ambitions tend to exist but are still insufficiently translated into concrete project objectives, planning decisions and execution ([P14],[P15],[P17]). Additionally, sustainability is weakly anchored in planning and risk management. Although it is sometimes implicitly considered, it is rarely treated as an explicit and structurally monitored risk category, despite recent efforts within W+B to include a dedicated sustainability category in tender submissions, building on the method proposed by Wong (2024). The overall finding is that sustainability is not completely absent from projects, but is insufficiently standardized and depends too much on personal initiative.

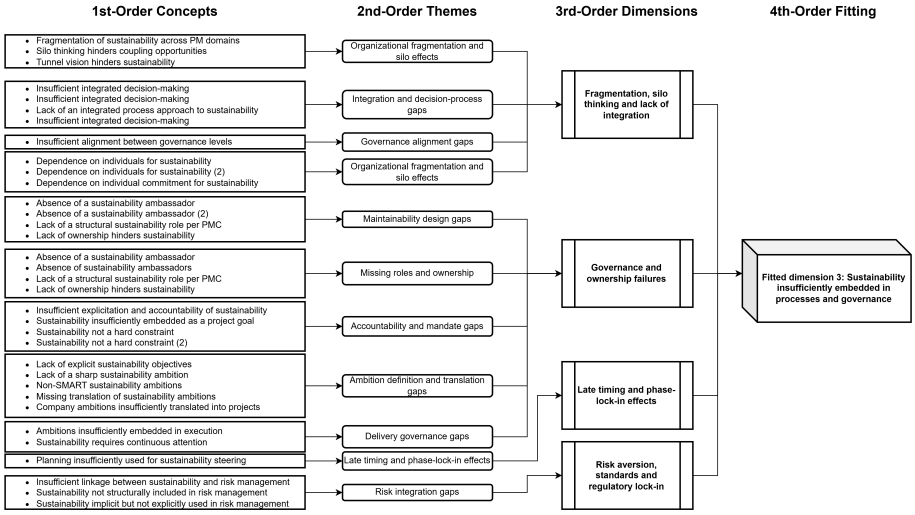


Figure 4.6: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q3 (source: Author)

Besides the internal process fragmentation within W+B, sustainability integration is even more contained by broader governance, client behavior and institutional barriers ***(FD4-Governance, client behavior and institutional barriers)***. Even when sustainability ambitions are provided and presented by W+B, they are the first to be dropped in case the budgets are insufficient or when the choices related to those ambitions are seen as 'non-essential' compared to the core delivery tasks ([P15],[P16]). In practice, this is even reinforced by budget cuts due to maintenance cost, procurement frameworks and the existing perception that sustainability adds cost rather than value ([P3],[P8]). Indicating that in practice functionality, safety and stakeholder demands take priority, whereas sustainability is only pursued if the budget allows ([P11]). Cost constraints or dominance is the most frequent cited barrier to sustainability integration in infrastructure projects and without any explicit financial incentives or mandates, sustainability just remains aspirational. This is challenging, as in practice within W+B, existing contractual and financial agreements fail to reward long-term sustainable value creation, which makes it difficult to justify investments that reduce costs or environmental impact only over a longer time horizon ([P7],[P18]). In addition, sustainability is often introduced too late in the project, meaning that after final design, contractual or permitting decisions have already been made, which significantly narrows the room for

change ([P1],[P6],[P17]). Once a specific technical solution is embedded in contracts, permits and design assumptions, it becomes difficult to shift towards more sustainable alternatives ([P1]). At the same time, sustainability ambitions often remain at the policy and organizational level, without being translated into concrete project goals, assigned accountability or operational requirements ([P16],[P18]). Incentives during tender (e.g. fictive discounts) are insufficient to steer upon sustainability integration, especially when cost pressure or stakeholder resistance emerges later in project development ([P5],[P16]). In practice within W+B, sustainability is only realized when the client requests it explicitly and becomes part of the procurement scope or when it is tied to the EMVI criteria ([P9],[P17]). Furthermore, sustainability opportunities are sometimes perceived as risks due to potential delays, uncertainty or procurement challenges, leading projects to revert to conventional solutions and minimum compliance ([P2],[P5]). Rules and regulations are often applied rigidly, while sector-specific guidelines such as those of RWS can unnecessarily limit design freedom when uncritically copied into another project context ([P10],[P11],[P13],[P15]). Currently, W+B also appears to cope with a lack of courage at the executive and management levels to make sustainable choices under political or organizational pressure, which leads to more conservative decision-making ([P1],[P14],[P16]). Sustainability is therefore still too often assessed through a short-term lens, while governance and procurement practices insufficiently account for long-term value, LC performance and delayed benefits, weakening the institutional position of sustainability in practice.

The late timing and phase 'lock-in' effects (as mentioned earlier), compound these governance barriers. The findings indicate that within W+B, sustainability is often introduced after the final design, contractual or permitting decisions have already been made, which narrows the room for change ([P1],[P6],[P17]), as shown earlier in Figure 4.4. Once a technical solution is embedded in contracts, permits, stakeholder communications and other documentations, it is hard to move towards another (sustainable) alternative ([P1]). Risk aversion and regulatory limitations add to the institutional barriers, where sustainability opportunities are sometimes perceived as threats because of potential delays, procurement risks or limited market response that might occur ([P2],[P5]). This results into more conventional solutions and minimal compliance behavior over more ambitious and innovative solutions ([P4],[P5]). Additionally, this can be potentially strengthened because of overly conservative lifespan assumption (especially for R&R projects), strict availability requirements and spatial constraints for zero-emission construction (SEB), which delays this processes even more and reduces room for sustainable choices ([P1],[P8],[P10]). Even guidelines from RWS (e.g. the ROK) used during project development W+B are applied rigidly or copied, which limits design freedom ([P10],[P11],[P13],[P15]). Lastly, short-termism (giving priority to immediate profit or reward) weakens institutional position of sustainability, since many sustainable solutions only prove their value over a longer period ([P2],[P11],[P13]). Current governance and procurement practices within W+B insufficiently account for long-term value, LC performance and delayed benefits ***(FD4-Governance, client behavior and institutional barriers)***. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.7.

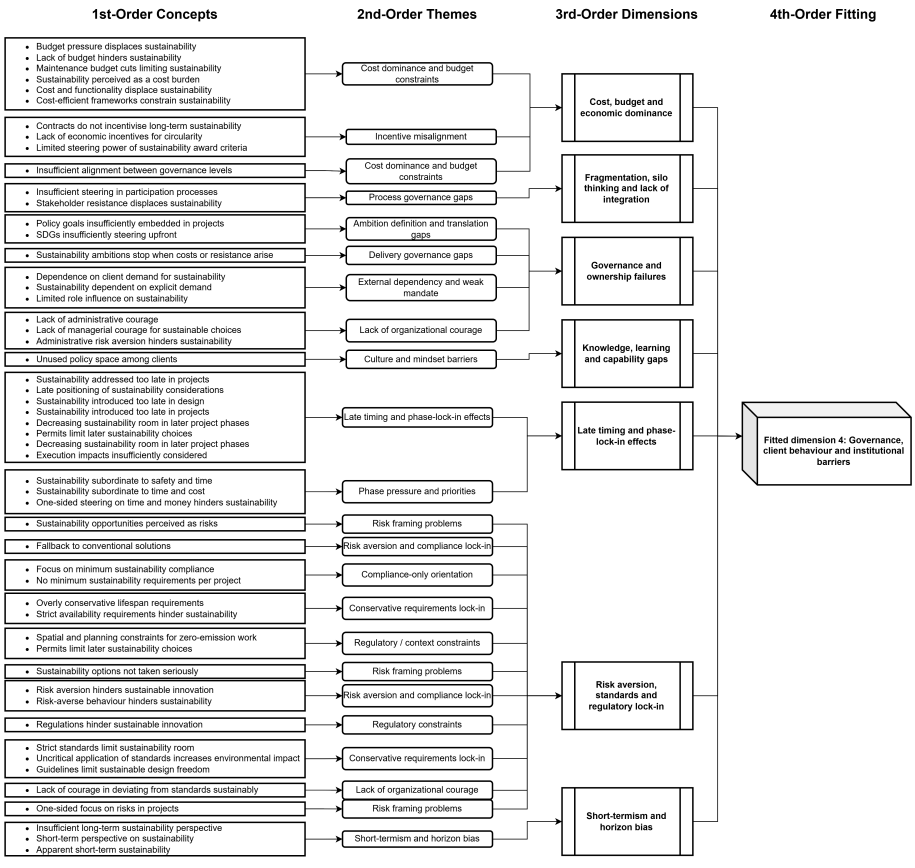


Figure 4.7: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q3 (source: Author)

W+B as a company is a 'consulting' company and therefore provides advice towards clients on different projects. The findings show a gap between the sustainability potential embedded within advisory roles and the degree to which that potential is actually used ***(FD5)***. Some employees remain within their comfort zone and therefore contribute minimally to sustainability integration, while others have the capacity to enlarge their playing field. This means that part of the unrealized sustainability potential is linked to the willingness and ability of individuals to stretch their mandate and act more strategically ([P4]). This highlights a governance challenge where roles at W+B do not determine outcomes by themselves, but where sustainability progress also depends on whether individuals are willing and able to use the influence they already have. For example, a cost engineer did not raise the alternative of strengthening a bridge and extending its lifespan by 50 years to the client, even though this was a technically viable and potentially more sustainable option ([P12]). This indicates that advisory roles contain more sustainability potential than is currently used within W+B. Realizing this potential requires a more proactive and confident attitude. Not only does the ability to influence sustainability outcomes depend on formal mandate, but also on the ability to act beyond minimum requirements. Conclusively, improving this within W+B requires a mindset shift at the individual level, supported by organizational structures that encourage and reward proactive sustainability contributions and ideas ***(FD5)***.

A structural knowledge gap further constrains sustainability integration within W+B ***(FD6-Lack of knowledge sharing, learning and standardization)***. A project leader expressed frustration that extensive effort is invested in developing sustainability ideas, yet nothing is formally committed to afterwards, which is demotivating for the project team ([P16]). This reflects a misalignment between earlier ambitions and subsequent decision-making and ownership, resulting in promising sustainability initiatives failing before implementation. Insufficient commitment at later stages undermines both outcomes and future motivation to invest in sustainability thinking. Not every colleague or partner is equally open to sustainability arguments, even when framed through the People, Planet and Profit/Prosperity (TBL) framework ([P6]). Governance challenges therefore involve not only structural factors but also varying levels of acceptance and prioritization. Conceptual fragmentation further compounds this, as there is confusion between sustainability and its sub-themes such as climate adaptation or biodiversity, as well as an absence of a balanced consideration of all three dimensions of the People, Planet and Profit/Prosperity framework ([P6]). This leads to a narrow interpretation of sustainability, where CO_2 becomes the dominant decision criterion while broader societal impacts are overlooked ([P3]). The lack of a shared definition across individuals and teams results in divergent interpretations ([P11]).

At an operational level, participants identified a lack of clear frameworks, limited availability of practical tools and a missing central knowledge base ([P17],[P18]). As stated earlier, sustainability knowledge is hard to find and access due to limited sharing, resulting in low visibility of both expertise and opportunities ([P3],[P4]). Weak learning and feedback mechanisms reinforce this, as there is limited transparency about sustainability outcomes, insufficient evaluation of what works and a lack of systematic learning from past projects ([P9],[P13]). In addition, the absence of open dialogue, particularly around failure, further limits collective learning ([P10]). Sustainability is sometimes approached too technically or seen as an add-on rather than an integral mindset ([P7],[P14]) and in some cases even perceived as a barrier rather than an opportunity, particularly in relation to biodiversity ([P3]). Improving knowledge access alone is therefore insufficient; a shift towards a shared sustainability mindset, supported by accessible frameworks and stronger organizational learning processes, is also required ***(FD6-Lack of knowledge sharing, learning and standardization)***. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.8.

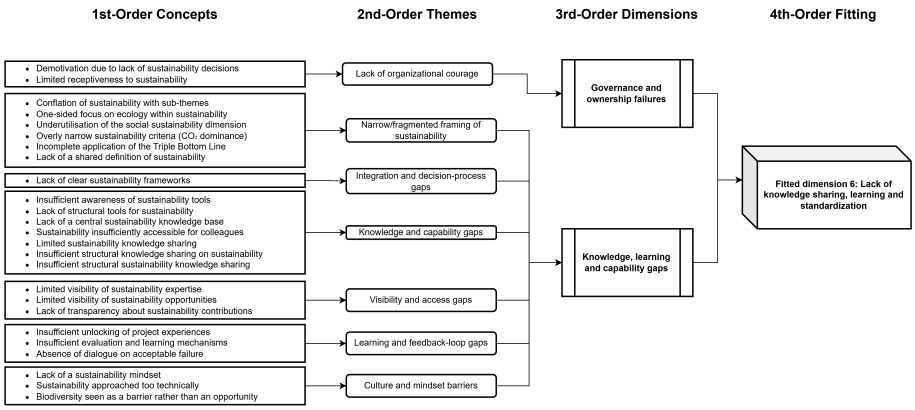


Figure 4.8: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q3 (source: Author)

The most strategic layer of missed opportunity concerns system-level and programmatic sustainability, where the biggest wins are not in individual projects but across projects, supply chains and governance levels ***(FD7)***. A contract manager explained that dedicated sustainability budgets can create room for additional measures, but these funds are not always allocated or structurally available ([P5]). A project control manager added that levers in procurement and tendering are underused to steer sustainability more explicitly into project choices ([P17]). A project leader noted that variant studies, though promising, are underused as a tool to compare alternatives not only on cost and time but also on environmental impact, constructability, sustainability performance and policy fitness ([P16]). Together, these findings suggest that budgets, tenders and comparative evaluations can be used strategically rather than procedurally to significantly

strengthen system-level sustainability ***(FD7-Missed system-level and programmatic sustainability opportunities)***. Chain collaboration and cross-project coupling represent a further missed opportunity. A contract manager and technical manager highlighted that sustainability gains depend on whether actors in the supply chain share a common language, whether responsibilities are clearly distributed and whether contractors are enabled to contribute from their own strengths ([P10],[P15]). Currently, chain alignment is often lacking and frameworks for coupling opportunities between projects or governance levels remain underdeveloped ([P6],[P16]). The phenomenon of 'meekoppelkansen' is widely recognized, yet difficult to realize in practice because coordination, shared financing and joint ownership across projects and organizations are insufficiently organized ([P2]). Developing shared material databases and programmatic coordination mechanisms could enable reuse flows between projects, but these remain underdeveloped ([P7],[P12]). These systemic sustainability gains in infrastructure require exactly this kind of programmatic and cross-project coordination, rather than isolated project-level optimization. This is only realized through an integrative approach.

Reuse, circularity and lifespan extension strategies are also insufficiently leveraged. In practice, there is more room for preventive maintenance, lifespan extension, circular demolition and IFD/DOPs design than is currently used ([P3],[P10],[P15]). Technical managers noted that preventive measures are not considered early enough, while maintenance and durability are undervalued compared to replacement-oriented thinking ([P3],[P13]). Material reuse is described as 'a neglected child', with barriers such as lack of reuse systems, material libraries and integrated coordination between demolition and new-build projects ([P7],[P10],[P12]). There is a gap between the theoretical circular potential and practical implementation, particularly when circular options score high on sustainability but low on financial calculations, such as circular demolition ([P11],[P12]). Additionally, CO_2 reduction and circularity are not always aligned, requiring more integrated system-level assessment rather than separate evaluation of each principle ([P3]). Project control managers identified that dashboards, central sustainability databases and accessible knowledge platforms would allow project teams to compare alternatives, identify reuse opportunities and build on lessons from earlier projects ([P8],[P17]). In summary, the findings show that many sustainability opportunities are already visible in practice but remain underused because the institutional and organizational infrastructure for linking projects, actors and resources is underdeveloped. Sustainability is still largely handled at individual project level, while the largest gains lie in programmatic steering, cross-project learning, chain collaboration and integrated system-level planning ***(FD7-Missed system-level and programmatic sustainability opportunities)***. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.9. More about these fitted dimensions is discussed in Appendix C.

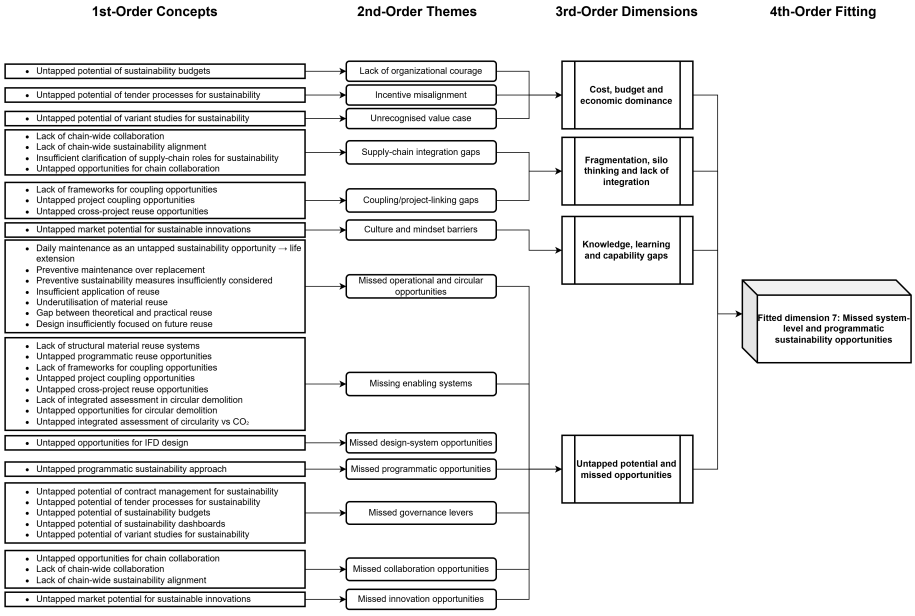


Figure 4.9: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q3 (source: Author)

Conclusively, these findings indicate that sustainability integration opportunities within W+B span a wide range of 7 fitted dimensions ***(FD)***, from design and technical rigidity to governance barriers, knowledge gaps and missed programmatic opportunities. While sustainability is increasingly recognized across roles and PMC's, its realization remains constrained by institutional arrangements, individual dependence and the absence of system-level coordination in practice, as shown in Table 4.7.

FD	(SSIs-Q3)
1	Underutilized sustainable design and technical opportunities
2	Insufficient quantification and valuation of sustainability
3	Sustainability insufficiently embedded in processes and governance
4	Governance, client behavior and institutional barriers
5	Advisory potential and proactive sustainability roles
6	Lack of knowledge sharing, learning and standardization
7	Missed system-level and programmatic sustainability opportunities

FD = Fitted Dimension

Table 4.7: Overview of the Fitted Dimensions (FD) related to SSIs-Q3 (source: Author).

SSIs-Q4 - Evaluation PPS-components

The findings from SSIs-Q4 focused on the evaluation of the PPS-components obtained from the PMBoK project management guideline and their effectiveness on sustainability integration. From the responses, a total of 7 fitted dimensions were derived through the extended Gioia methodology, as shown in Table 4.8.

In order to position sustainability strategically within project scope and governance at W+B, it requires formal contractual anchoring as a basis ***(FD1- Strategic positioning of sustainability within project scope and governance)***. Actors tend to deliver only what is contractually bound and required, which implies that when sustainability is not explicitly mentioned in the assignment, then it will quickly disappear and become secondary ([P5],[P10]). This is even intensified when a project becomes uncertain or risky, which results in stakeholders rather pick safe and conventional choices and deprioritizing (sustainable) ambitions ([P5]). Additionally, an Ambitieweb sessions is efficient only when there is sufficient financial room and willingness to realize the defined ambitions, this implies that economic steering mechanisms within the PPSs provided can perhaps help in this ([P16]). However, in practice it is found that sustainability is the first aspect to be reconsidered when the budget is at risk, while tunnel vision focus on the CAPEX rather than LC value further limits sustainability choices ([P7]). The Project Start-Up (PSU) phase is therefore referred to as a critical moment where sustainability agreements can and should be anchored, because when sustainability is not made explicit from the start, it will potentially erode (ambitions erosion) over the course of the project ([P9],[P13]). Furthermore, unclarity of scope boundaries across organizational levels and project phases for an obstacle for sustainability implementation ([P17]), whereas a governance gap in practice is a responsible individual who can ensure sustainability is included and maintained within project scope ([P1]). As sustainability integration requires a responsible person to maintain oversight and make trade-offs across competing objectives, as it is not a lack of knowledge, but a lack of action and decisiveness at W+B ([P3]). The main reason why sustainability integration is failing is due to the fact that it is not prioritized, mandated and proactively followed up within governance structures ([P5]). Additionally, within W+B it is observed that there is no need for an entirely new sustainability PM-domain, but rather a tool that integrate sustainability into existing ones, like a sustainable case that connects scope, quality, risk, resources and planning ([P8]). The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.10

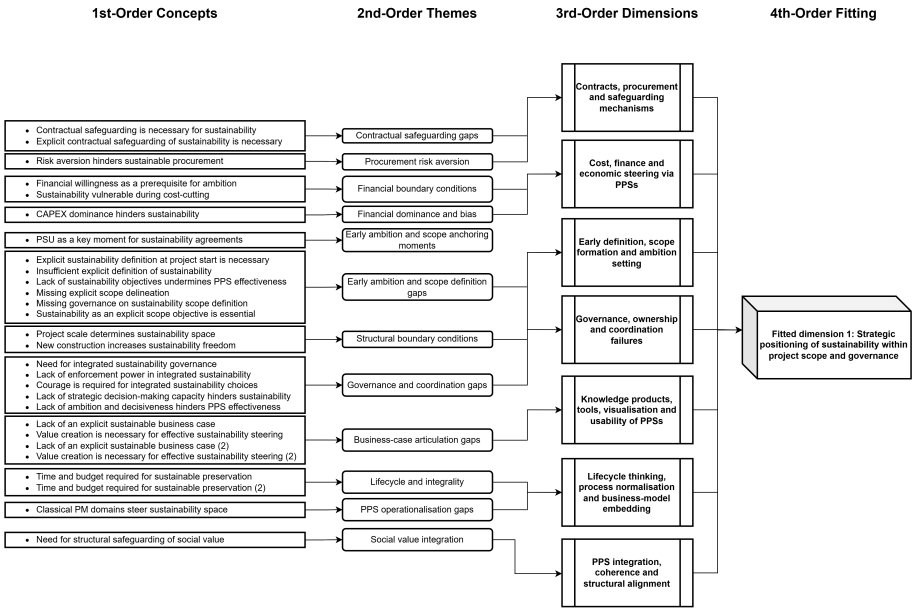


Figure 4.10: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q4 (source: Author)

Process-oriented embedding of sustainability is essential to anchor sustainability within existing project management structures at W+B ***(FD2-Process-oriented embedding of sustainability)***. Sustainability can be integrated within already existing management documents and control mechanisms, such as the PMP, where a dedicated sustainability

section can be added for larger projects ([P13]). This shows that sustainability does not require completely new structures, but rather needs to be anchored within current processes at W+B. Quality assurance is not seen as a competing element, but instead as a mechanism to prevent sustainability loss, this is done by making sure that agreed ambitions remain visible throughout execution and verification ([P15]). Therefore, early definition and embedding are essential, as topics like sustainability, operation and management and long-term considerations already start in the design phase and should be included from the start of the project (FEDP) where scope and long-term subjects are defined ([P3],[P6],[P11]). When this is not done, then agreements tend to weaken, especially during phase transitions or project handovers, which shows that specifically these processes are crucial to maintain sustainability ambitions ([P9]). From a LC perspective, sustainability should be approached as preservation, extended lifespan and performance over the full project LC, rather than focusing only on the construction phase ([P3],[P6],[P15]). Even small decisions within the LC can have a significant impact on sustainability outcomes ([P12]). In practice at W+B, sustainability must be monitored just as actively as planning, budget and scope, otherwise it disappears from attention and priority. As was verified by the participants, that if it is not measured or recorded, it will not be steered upon ([P6],[P8],[P9],[P11]). This indicates the need for continuous monitoring during the design phase, using tools such as MCI-dashboards (e.g. the +CD Tool), as well as recording risks in risk registers and opportunities in opportunity lists ([P4],[P8]). Besides this, existing integration management instruments and documents, such as the Project Charter, PMP and Sustainable Management Plan, are therefore logical places to structurally anchor and safeguard sustainability within projects ([P3],[P9],[P11],[P18]). However, projects tend to change in each phase throughout the entire timeline, which might influence sustainability ambitions and integration ([P1],[P17]). This shows that sustainability integration is not a single action, but requires continuous attention and process-based safeguarding. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.11

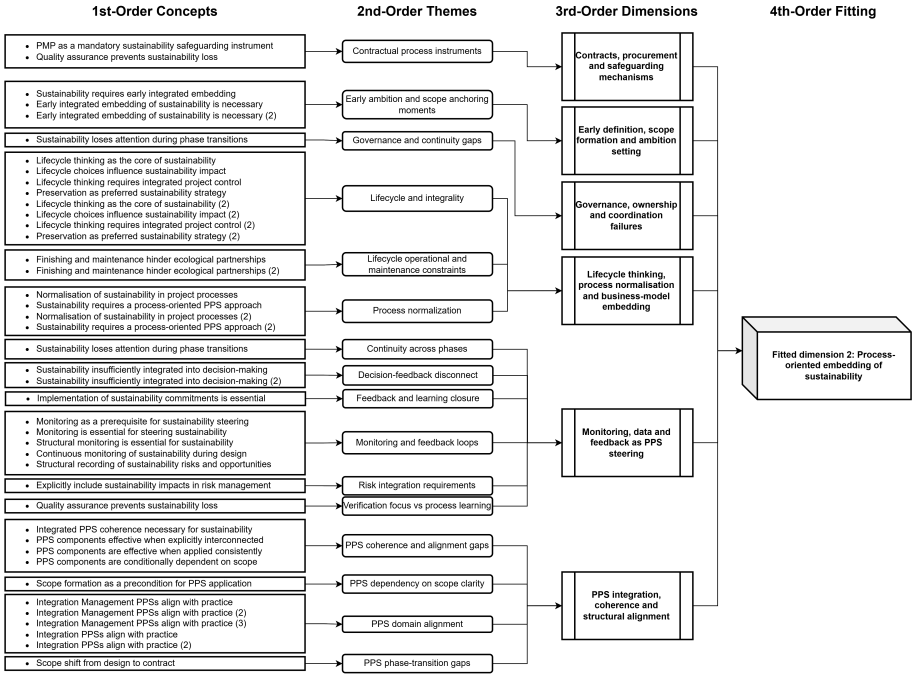


Figure 4.11: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q4 (source: Author)

Role clarity, responsibilities and ownership are essential in order to maintain sustainability throughout the project LC ***(FD3)***. In practice at W+B, it is observed that every change or adjustment within a project pushes sustainability back in priority or makes it the first subject to be reconsidered ([P6],[P9],[P11]). All these 'small' decisions that shift away from initial ambitions gradually build op over time, which potentially undermines overall sustainability performance at the end ([P3]). Due to this, without having clear responsibilities and active steering, sustainability does not maintain its position on the priority list and become secondary within decision-making. In case no one is explicitly responsible for safeguarding sustainability, it risks falling between roles (in Dutch; collective responsibility mean no responsibility) and loses coordination across teams ([P11]). Thus, a coordinating role is necessary that monitors interdependencies and makes sure that alignment between disciplines throughout the project is maintained ([P6]). If sustainability is not clearly assigned to an individual, it will remain non-committal and then it will lose its priority in practice at W+B ([P9]). This means that someone or a small group must be explicitly responsible and actively steer on sustainability, otherwise ambitions will eventually diminish over time ([P10],[P11]). Having a team or influential sustainability individual within the project team is helpful, as this person can drive the 'sustainable' agenda in a meeting and has the authority to influence decisions ([P16]). As a consultant within W+B, individuals have a signaling and warning role, this supports integration even more, whereas team members actively signal risks and provide advice when sustainability is at stake. This is an extension beyond their basic project tasks ([P12]). This indicates that sustainability integration depends not only on structures and processes, but also on clearly assigned ownership and proactive behavior within project teams.

Practical applicability and usability of the initial provided PPS-components proof that the design phase is seen as the main leverage point for sustainability 'lock-in' within projects ***(FD4)***. At W+B, real sustainability gains are achieved through design outputs, as choices made here directly determining long-term impact ([P17]). As it is connected to it, procurement and contractual aspects should not be handled separately, but instead use them to their advantage to steer and safeguard sustainable design decisions ([P17]). However, at the same time, without incentives ('uitvraag'), sustainability often remain voluntary. In case a penalty or reward system is not present, then sustainability is seen as optional rather than an integral part of the project ([P10]). Cost engineers mentioned that organization tend to do only what is required to comply, without unnecessary going beyond minimum criteria ([P5],[P10]). However, sometimes sustainability is already included in some cases through tender documents, templates and predefined design principles (e.g. IFD or DOP), which allows it to be addressed early at the FEDP of infrastructural projects ([P13]). Proving that required documents or instruments are not completely missing, but already available within existing processes ([P13]). PPS-components that are within procurement (e.g. sustainable procure practices or MEAT criteria) are in principle effective ways to integrate sustainability ([P5]). However, the consistency and incomplete application is where the main issue lies ([P5]). This means that contract and procurement instruments currently serve mainly as compliance tools, rather than as drivers of sustainability ambition. Their impact can be strengthened by linking them more directly to design outcomes, by embedding incentives and accountability structures and by applying them consistently throughout the project LC.

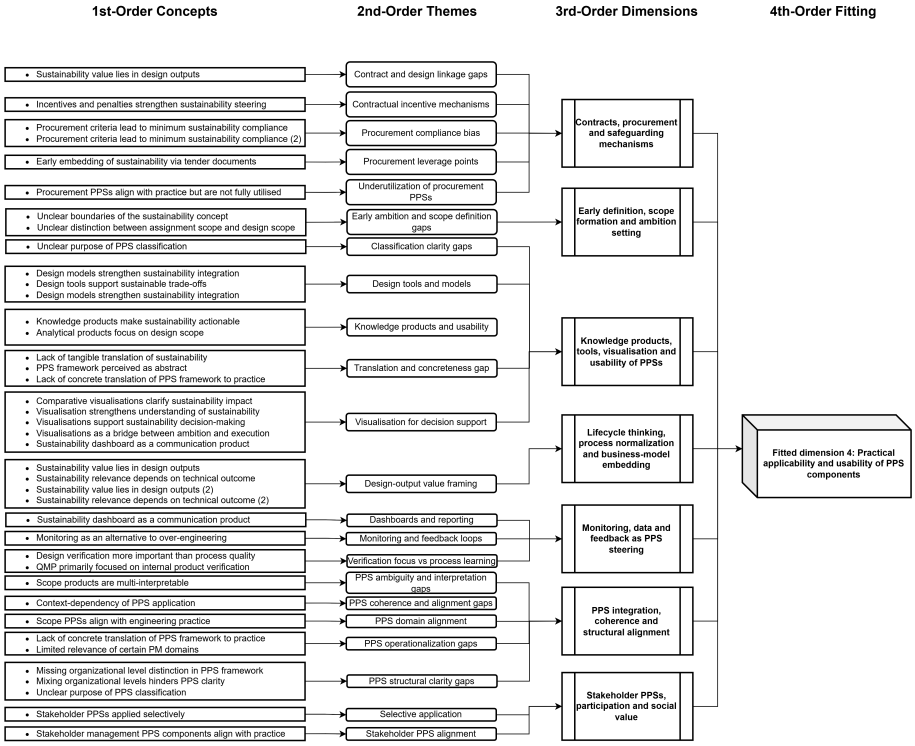


Figure 4.12: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q4 (source: Author)

The integration within existing tools, standards and corporate framework ***(FD5-Integration with existing tools, standards and corporate frameworks)*** highlight that sustainability is often only taken seriously if it is translated into financial terms (so basically '€'s) . At W+B, sustainable alternatives gain more attention when they are compared within standard cost assessment (financial decision-making), but environmental impacts are currently not included as costs in these calculation ([P7]). Indicating that sustainability remains external to financial decision-making and is just treated like another additional consideration rather then a core criterion. Not incorporating sustainability into financial model, means that it gets easily overridden during trade-offs. However, financial transparency is a strong steering mechanism, because when sustainability impacts as are expressed as monetary terms, then they can directly influence or even drive decision-making ([P7]). This is a chance to develop (currently done at W+B with the C3 Project), linking sustainability to financial logic is essential as it creates leverage and relevance in project decision-making. Other techniques, like cost consultancy for green procurement allows for a better and objective comparison between design alternatives. Approaches like the LCCA and NPV can help in integrating sustainability into strategic decision-making (strategic layer). Adding to that, proactive cost advice helps to prevent 'false or illusional sustainability' by critically assessing assumption behind materials and execution choices ([P12]). Unfortunately, these techniques are often applied too late in the process, for example when the LCCA is introduced after key design decisions are already made. This prevents or limits the ability to influence outcomes ([P7]). Timing is therefore crucial, as financial sustainability insights should integrated earlier in the project (preventing to run out of budget, eliminating sustainability ambitions). In short, translating sustainability into tangible, cost-related metrics improves both advisory quality and the ability to accurately assess and compare alternatives in a structured way ([P12]). Although existing W+B's tools such as sustainability-focused business models canvases and links to internal SDGs strategies already exist ([P8],[P14]), they are not yet fully integrated into PPS-driven decision-making or -support.

This is similar for CO_2 data and existing knowledge bases, as they are also not sufficiently anchored in financial and decision-making structures ([P8],[P17]). This implies the hidden and non-shared information related to sustainability as observed earlier. As a result of this, information remains descriptive rather than guiding project team members. This shows that the main challenge is not the availability of tools or data, but their integration into core decision-making processes and awareness. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.13.

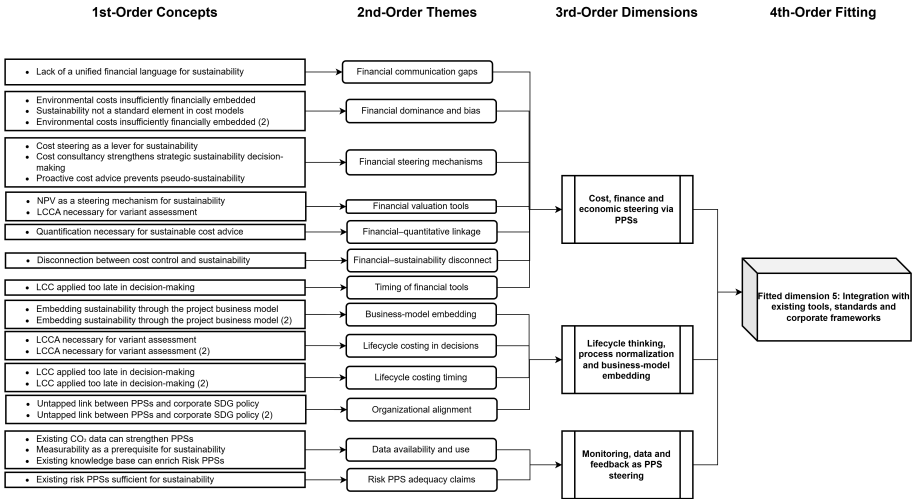


Figure 4.13: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q4 (source: Author)

Stakeholder interaction and participatory value of PPS-components show that sustainability only becomes dominant when it is explicitly driven by project objectives or stakeholder ambitions ***(FD6)***. In case these drivers are not available or present, then sustainability becomes secondary ([P16]). Highlighting that sustainability ambitions are not automatically embedded within projects, but are mainly dependent on how it is positioned and supported by both internal and external stakeholders. At W+B, it is the situation that what is considered acceptable by the environment determines how far sustainability ambitions can go. Not only is ambition setting an internal project activity, but also the result of negotiation within a social and political context ([P5],[P10]). The Ambitieweb session facilitates the dialogue in order to support this process by aligning on sustainability ambitions with the involved stakeholders at an early stage ([P13]). The value of each ambition depends on whether they are developed together (related to 'coupling opportunities') with stakeholders or are they applied solely ([P16]). Often, there also tends to be a lack of clear ownership when it comes to translating stakeholder input into concrete project decisions. This is related to collecting, processing and integrating stakeholder input responsibilities that are not always clearly defined and can lead to fragmentation and a weak connection between early ambition setting and scope definition ([P2]). Maintaining good relationship and constant stakeholder involvement throughout the entire project LC, it is essential to have continuous communication and transparency, which builds up trust. Techniques that are used and helpful in this are stakeholder engagement, dashboards (e.g. PI-matrix) and clear justification on decisions that are made which can help to sustain support over time ([P4],[P5],[P10]). This all proves that effective stakeholder participation is more than initial consultation, as it requires continuous dialogue, active involvement and integration into decision-making processes. Otherwise, the process risk becoming symbolic rather than being meaningful to the project development, which limits its contribution to sustainability integration.

The organization learning, development and missing elements ***(FD7-Organizational learning, developments and missing elements)*** are emphasized by the participants at W+B. The incentive structures are not used to its full potential as a governance mechanism within W+B. Sustainability performance could be straightened when reward and accountability mechanisms (e.g. RACI/RAM-matrix) are included through contractual incentives and penalties. By doing so, it can change behavior from a basic compliance towards a more performance-driven sustainability ([P5]). Besides that, apparently, there are financial resources available, but are not always used de to a lack of prioritization than actual scarcity. Showing that it is not about absence of tools, but how they are applied and utilized within governance structures. For example, the LCCA has a strong legitimizing power, as it can demonstrate that sustainable choices are also the most rational ones if properly quantified ([P7]). However, this method is not yet systematically integration into decision-making processes, which limits the influence of W+B in practice. Another aspect, is that project generate valuable sustainability insights that can be reused, but currently they are not consistently transferred to future projects or a central lessons learned repository to store them. This shows a lack of structural recording, storing and reusing knowledge, which is why continuous learning and improvement is limited ([P9]). Even existing knowledge is not always fully accessed or applied, while the more experience employees are often better and able at identifying sustainability opportunities ([P3],[P15]). The PPS-component LC thinking through LCCA is seen as valuable, as it is still not structurally anchored in standard project control and management workflows or SOPs ([P7]). This means that their potential remains underused within day-to-day project development at W+B. Furthermore, joint evaluation is reflected as an important part of ensuring that sustainability does not only remain a paper ambitions. Trough actively reviewing progress and implementation together helps to maintain focus and improve outcomes ([P18]). Providing feedback to stakeholders when their input has been

used also builds trust and strengthens engagement, which supports sustainability integration ([P2]). Altogether, the main challenges does not lie in availability of tools, but the consistent and structural integration into project processes. Sustainability learning and development is thus mostly dependent on anchoring these elements across projects and teams, instead of applying them in an irregular manner. The entire relationship of this paragraph with use of the extended Gioia methodology is shown in Figure 4.14. More about these fitted dimensions is discussed in Appendix C.

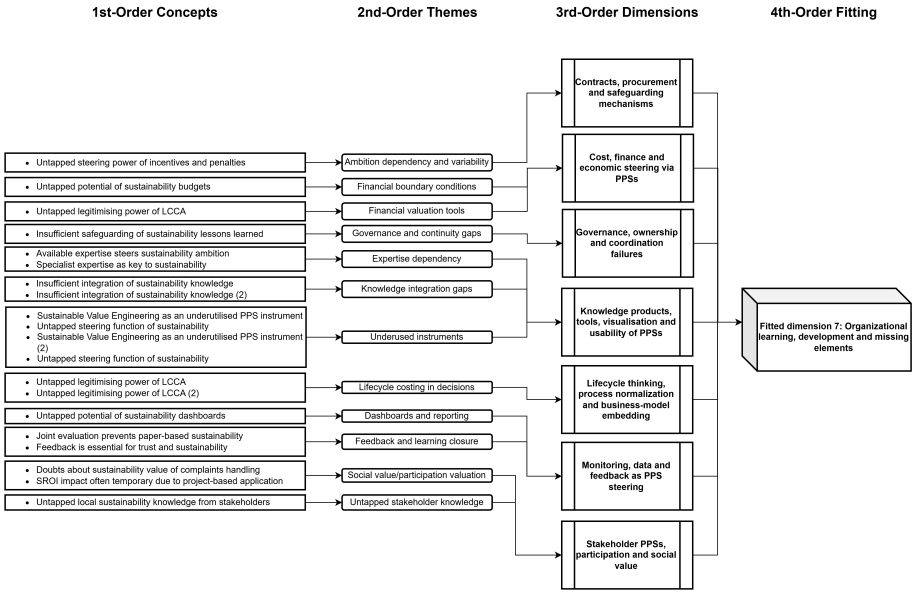


Figure 4.14: Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q4 (source: Author)

Conclusively, these findings indicate that PPS-components are broadly recognized as relevant and potentially effective instruments for sustainability integration within W+B, but their impact remains limited due to inconsistent application, weak integration into financial and governance structures, insufficient ownership and a lack of organizational learning mechanisms that connect ambitions to execution and evaluation across project phases.

FD	(SSIs-Q4)
1	Strategic positioning of sustainability within project scope and governance
2	Process-oriented embedding of sustainability
3	Role clarity, responsibilities and ownership
4	Practical applicability and usability of PPS components
5	Integration with existing tools, standards and corporate frameworks
6	Stakeholder interaction and participatory value of PPS components
7	Organizational learning, development and missing elements

FD = Fitted Dimension

Table 4.8: Overview of the Fitted Dimensions (FD) related to SSIs-Q4 (source: Author).

4.2.3. Opportunity matrix

Combining the findings from the table of opportunities from the Systematic Literature Review (SLR) with the results from practice from the exploratory research using the Semi-Structured Interview (SSIs). A new updated opportunity matrix is obtained by merging them both together and highlighting the ones from the participants of W+B. This is shown in Table 4.9 and Table 4.10.

Table 4.9: Overview of sustainability integration opportunities across PM-domains 1 to 5 and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017). These new items are identified opportunities from the SSIs interviews.

PM-domain	Product	Process	Service
1. Project Integration Management	• Update project charter with explicitly SMART-formulated sustainability objectives • Flag sustainability related conditions as a separate category in the assumption log • Embed sustainability in all project baselines within the PMP • Include sustainability changes, impacts and control within the change management plan • Include sustainability category within the lessons learned repository • Integrate sustainability metrics (e.g. MKI, MCI or CO_2) in deliverables • Include sustainability impact fields per change request within change log • Include sustainability benefit realization paragraph in the final report • Draft contractual sustainability frameworks **(CM)** • Deliver a 3D BIM model, clash-detection models and other visualizations **(BIM)** • Prepare a sustainability roadmap including indicators and a sustainability dashboard **(DA, MPB)** • Prepare an environmental report **(OM)** • Prepare an integrated assessment framework for sustainability principles, e.g. DOPs **(PA)** • Prepare an integrated project strategy, e.g. IPM model and decision-making documents **(PL)** • Prepare an integrated project execution strategy within the project team **(PM)** • Prepare technical design documentation, e.g. on IFD **(TM)** • Prepare integrated cost reporting **(CE)**	• Consider sustainability concepts during project charter development • Formulate SMART sustainability objectives before PMP baseline setting • Integrate sustainability milestones into the project timeline • Assess sustainability impact as part of integrated change control review (by CCB or PM) and performance monitoring • Capture and transfer sustainability lessons learned into OPAs and lessons learned repository • Integrate monitoring of sustainability metrics against baselines in PMP throughout the project LC • Identify sustainability opportunities within risk and change management cycles • Coordinate between design, market and policy **(CM)** • Integrate calculation models into realistic geometry **(BIM)** • Organize Ambition Web sessions and integrated sustainability sessions **(DA)** • Manage integrated processes across the project **(MPB)** • Support integrated decision-making **(OM)** • Apply iterative design processes **(PA)** • Coordinate disciplines and ensure integrated alignment **(PL)** • Coordinate contract, sustainability and execution integrally **(PM)** • Manage alignment between disciplines and interfaces **(TM)** • Align design, costs and sustainability **(CE)**	• Configure PMIS (e.g. Relatics) for sustainability requirements and tracking • Use +CD Tool for sustainability performance visualization on circularity • Organize Ambitieweb sessions as facilitator during project charter development • Make organizational knowledge base and lessons learned repository accessible • Expand CCB or PM review to include sustainability impact assessment • Align policy between design, market and policy domains **(CM)** • Integrate calculation models into realistic sustainable geometry **(BIM)** • Keep process development integrated in governance and decisions **(MPB, OM)** • Shape design processes iteratively **(PA)** • Integrally align and coordinate disciplines including interface management **(PL, PM, TM)** • Align design, costs and sustainability as an integrated advisory service **(CE)**
2. Project Scope Management	• Define explicitly sustainability requirements, constraints and acceptance criteria in scope statements • Include sustainability work packages in the WBS • Include sustainability scope descriptions per work package in the WBS dictionary • Include TBL or QBL performance in requirements documentation (KES) • Link sustainability requirements through a requirement traceability matrix (e.g. Relatics) • Include sustainability constraints as unnegotiable boundary conditions within scope baseline • Model the existing and new situation and visualize sustainability **(BIM)** • Define sustainability objectives, performance standards and sustainability indicators **(DA, PL)** • Record a scope document with scope description, including sustainability opportunities and agreements **(PM, MPB, PL)** • Prepare a KES document with sustainability objectives together with associated performance standards and sustainability indicators **(DA, MPB, OM)** • Define the problem statement and identify sustainability opportunities **(PA)** • Delineate technical scope including strengthening vs. replacement alternatives **(TM)** • Perform cost estimates for sustainability variants following variant study **(CE)**	• Collect sustainability requirements from client and regulatory context • Translate ambitions into a contractually grounded scope statement with explicit sustainability boundaries • Create decomposition of sustainability deliverables into assigned manageable work packages in WBS • Validate formally sustainability deliverables against acceptance criteria • Maintain and control scope to prevent elimination of sustainability work packages • Visualize, compare and control scope **(BIM, CE, MPB)** • Translate ambitions into concrete sustainable scope requirements and verify them **(DA, OM, PA)** • Monitor scope, manage change decisions and execute change control **(PM, PL)** • Assess residual capacity and alternatives **(TM)**	• Use Aanpak Duurzaam GWW, including Ambitieweb and Omgevingswijzer for scope definition • Use CO_2-Prestatieladder as external system for scope level sustainability commitments • Configure PMIS (e.g. Relatics) for sustainability requirements and tracking • Use +CD Tool for sustainability performance visualization on circularity • Use DuboCalc for MKI validation at product or project level • Automatically identify scope conflicts using updated models **(BIM)** • Advise on explicitly positioning sustainability as a scope component and choice **(DA, MPB, PL, CE)** • Advise on applicability and strategy of sustainability ambitions **(OM, PA)** • Advise on scope adjustment during the tender phase **(PM)** • Advise on the optimal technically sustainable solution direction **(TM)**
3. Project Time Management	• Plan sustainability review milestones at decision gates or handover moments • Create a list of contractually required sustainability milestones • Include sustainability activity durations and dependencies in the time baseline • Create specific sustainability activities as unique timeline items • Develop phase-based sustainability planning with sustainability milestones **(PL, DA)** • Produce deterministic sustainability planning **(MPB)** • Prepare phase-handover documentation with revision of sustainability aspects **(PM)** • Prepare research planning and inspection reports focused on sustainability **(TM)**	• Define sustainability activities as unique schedule items • Sequence sustainability task dependencies • Estimate realistic durations for sustainability processes • Integrate sustainability milestones into critical path analysis • Monitor sustainability achievements alongside time performance • Facilitate early ambition sessions and embed and document sustainability wishes **(DA)** • Manage and monitor phase transitions in integrated sustainability planning **(PL, MPB)** • Safeguard sustainable choices during phase transitions **(PM)** • Plan technically sustainable analyses per design phase **(TM)**	• Use planning software such as MS Project or Project Plan 365 • Consider completion time of environmental permit advisors and other time-sensitive service providers • Ensure sustainability is not introduced too late in the process **(DA)** • Provide advice based on schedules and evaluate them for prioritization advice to the client **(MPB, PL, PM)** • Identify schedule risks arising from technical uncertainties related to sustainability integration **(TM)**
4. Project Cost Management	• Include sustainability cost items as explicit cost baseline budget lines • Estimate costs per work package involved in SCBA/MKBA • Perform CBA, potentially expanded to SCBA/MKBA • Separate CAPEX, OPEX and total LC cost • Document cost estimates for sustainable solutions and assessments based on BPKV criteria **(CM, CE)** • Perform MKI calculations, LCA analyses and LCC substantiations for each sustainable design **(TM, DA, CE)** • Research budget reporting for possible sustainability subsidies **(MPB, PL, PM)** • Perform and document MKBA/SCBA analyses **(PA)** • Conduct variant studies comparing strengthening vs. replacement options **(TM)**	• Include LC methodology, e.g. LCCA, in cost estimation • Allocate sustainability budget lines in the approved baseline • Monitor sustainability cost performance and MKI targets • Expand EVM with sustainability performance metrics • Make trade-offs for each sustainable solution based on budget, financial monitoring, progress control and LCC **(MPB, CM, PA, PL, PM)** • Integrate MKI into variant studies **(DA)** • Substantiate costs from a technical perspective **(TM)** • Prepare deterministic and probabilistic cost estimates for variants using Monte Carlo simulations **(CE)**	• Use DuboCalc as primary MKI calculation service • Use consultancy services for LCCA • Use advisory services for MKBA/SCBA • Use CO_2-Prestatieladder for cost-performance verification • Provide financial and strategic advice on the implications of sustainability **(CM, DA, MPB, PA, PL, CE)** • Provide financial accountability to the client **(PM)** • Provide advice on cost-effective technical choices **(TM)**
5. Project Quality Management	• Include sustainability acceptance criteria in the Quality Management Plan • Integrate sustainability metrics into quality metrics • Document sustainability performance at phase gates or handovers • Provide quality reports containing sustainability performance • Test and evaluate sustainability verification evidence • Prepare detailed models and verification models of sustainable solutions **(PM, BIM)** • Create dashboards for sustainability integration and related indicators **(DA)** • Verify requirements to realize quality products in accordance with the KES, e.g. using Relatics **(PM, OM)** • Record assessment frameworks and acceptance criteria in the PMP **(PA, MPB)** • Prepare standard templates for quality plans and review documents **(PL)** • Prepare standard templates for verification calculations, inspection reports and quality dossiers **(TM)**	• Define sustainability requirements as quality criteria • Define measurement methods such as DuboCalc, +CD Tool and CO_2-Prestatieladder • Execute sustainability quality assurance throughout the project LC • Verify sustainability deliverables at phase gates or handovers • Test and check the constructability of sustainable alternatives **(CE, BIM)** • Safeguard sustainability integration and quality through monitoring of indicators and progress reports **(DA)** • Perform verification and validation of requirements from the KES **(MPB)** • Prioritize and safeguard hard requirements using a PMIS such as Relatics **(OM)** • Conduct design revision rounds to achieve the most optimal and sustainable design **(PA)** • Organize quality assurance processes and share them with the project team **(PL)** • Check whether sustainability measures are being complied with within the project **(PM)** • Perform quality assurance through testing and recalculations of sustainable alternatives **(TM)**	• Use DuboCalc as primary MKI calculation service • Obtain company certification for CO_2-Prestatieladder usage • Use CO_2-Prestatieladder as audit and certification service • Use third-party verification of sustainability workflow processes • Provide visual models and other project products for validation, quality monitoring and testing **(BIM, PA)** • Check whether sustainability ambitions are actually being realized **(DA)** • Provide advice regarding quality assurance **(MPB)** • Restructure the project through Systems Engineering to prevent conflicts and discussions **(OM)** • Safeguard integrated quality within the project team at both organizational and project level **(PL)** • Provide compliance- and audit-oriented supervision by a third party on project progress **(PM)** • Monitor the technical reliability and safety of sustainability solutions **(TM)** • Identify critical conditions within project development: duty to warn **(CE)**

Table 4.10: Overview of sustainability integration opportunities across PM-domains 6 to 10 and PPS-components based on the 6th edition of PMBoK (Project Management Institute, 2017). These new items are identified opportunities from the SSIs interviews.

PM-domain	Product	Process	Service
6. Project Resource Management	• Include sustainability expertise in the Resource Management Plan • Include sustainability specialists in the RBS • Define sustainability responsibilities in the team charter • Document sustainability competencies and gaps • Include sustainability tasks in a RAM/RACI • Prepare and share guidance on internal guidelines related to sustainability **(DA)** • Prepare team structure and task allocations for sustainability and other disciplines within the project team **(PL, PM, TM)** • Include estimated advisory hours for sustainable solutions in the project planning **(CE)**	• Identify sustainability expertise requirements per phase and work package • Obtain internal or external sustainability specialists • Develop sustainability competencies through training and workshops • Include sustainability task delivery in performance management • Monitor availability and deployment of sustainability experts • Direct, deploy and connect the project team based on specialist expertise and contractual obligations **(PM, DA, TM, PL)** • Estimate hours per phase in the project timeline **(CE)**	• Maintain internal sustainability knowledge networks • Use sustainability experts as contracted service providers • Obtain certification for CO_2-Prestatieladder usage • Use CO_2-Prestatieladder as audit and certification service • Provide support to project teams with sustainability expertise **(DA)** • Provide coaching and enable team development and knowledge transfer **(PL, TM)** • Assign or take on a leadership role and allocate tasks to project team members **(PM)** • Provide budget advice to keep resources manageable and choices under control **(CE)**
7. Project Communications Management	• Specify sustainability reporting requirements in the Communications Management Plan • Standardize sustainability sections in work performance reports • Visualize sustainability through dashboards or Sankey diagrams • Use stakeholder-specific sustainability communication channels • Prepare 3D visualizations for discussions about both the existing and new situation **(BIM)** • Prepare sustainability statistics through dashboards and opportunity lists for discussions **(DA)** • Prepare documentation for responses to public submissions as a communication tool for public accountability **(OM)** • Prepare reports as evidence for discussions about project progress **(MPB)** • Prepare a stakeholder analysis, PI matrix and participation plan on stakeholder interaction **(PL)** • Prepare technical explanatory documents to account for technical issues **(TM)**	• Map sustainability information flows • Share sustainability progress periodically through defined channels • Monitor whether sustainability information is received, understood and acted upon • Translate technical sustainability data for non-technical stakeholders • Facilitate design discussions on sustainable designs **(BIM)** • Facilitate stakeholder dialogue through Ambition Web sessions for stakeholder alignment **(DA, MPB)** • Conduct the public-submission process initiated by stakeholder submissions **(OM)** • Organize participation sessions **(PL)** • Conduct discussions about sustainability with the client **(PM)** • Translate technical analyses to decision-making level **(TM)**	• Use +CD Tool for sustainability visualization and reporting • Use BIM platforms such as Revit or AutoCAD • Use environmental management expertise for public communication • Use SharePoint or Teams with sustainability reporting templates • Provide visual communication through model imagery **(BIM)** • Make sustainability discussable and understandable **(DA)** • Coordinate through a communication advisor **(OM)** • Visualize dashboard results using Power BI software **(MPB)** • Maintain relationship management and administrative communication **(PL)** • Maintain relationship management and strategic alignment **(PM)** • Provide substantive verbal justification to the client **(TM)**
8. Project Risk Management	• Add sustainability risks as a separate category in the risk register • Include sustainability risk exposure in the risk report • Include sustainability opportunities as positive risks • Prepare a risk dossier including risk allocation tables, decision notes and sustainability risks **(CM, MPB, PL, PM)** • Prepare MKI and CO_2 impact reporting **(DA)** • Prepare a problem analysis **(OM)** • Prepare a trade-off analysis **(PA)** • Document residual service life with safety reporting **(TM)** • Prepare a probabilistic cost analysis **(CE)**	• Identify sustainability risks through workshops and pre-surveys • Assess probability and impact of sustainability risks • Perform quantitative analysis for sustainability-related risks • Define responses for sustainability risks and opportunities • Integrate sustainability risk responses into project execution • Monitor sustainability risk triggers throughout the project LC • Include risk analysis in procurement **(CE, CM, MPB)** • Integrate risk assessment into decision-making **(PL, TM)** • Integrate sustainability impact into risk assessment **(DA)** • Manage conflicts between involved stakeholders **(OM)** • Record sustainable choices and associated risks **(PM)**	• Use ecological field survey services • Use environmental permit advisors and omgevingsdiensten • Use legal advice regarding Omgevingswet-related risks • Use RISMAN-based risk software with sustainability risk categories • Provide advice on risk allocation and risk assurance **(CM, MPB, PM, TM)** • Identify risks and opportunities relating to sustainability **(DA)** • Identify emerging critical situations **(OM)** • Identify unintended impact **(PA)** • Provide administrative risk advice **(PL)** • Make financial risk assessments **(CE)**
9. Project Procurement Management	• Specify sustainability requirements in the Procurement Management Plan • Use sustainability-weighted selection criteria • Include sustainability obligations in procurement statements of work • Record supplier and contractor sustainability performance • Include sustainability metrics as binding contract obligations • Prepare contract documents and tender documents with strategies and award criteria **(CM, MPB, PL)** • Prepare contractual sustainability requirements and MKI award models **(OM, DA)** • Prepare tender submission documents with sustainability elements including indicators **(PM)** • Document technical specifications and design criteria **(TM)** • Prepare a contract cost estimate **(CE)**	• Define sustainability requirements per procurement category • Include sustainability criteria in tender assessment • Monitor contractor and supplier sustainability performance • Verify sustainability performance at contract closure • Share the approach and align on procurement strategy, risk allocation and tender procedure **(CM, PL)** • Integrate sustainability into tender documents and strategy using embedded requirements **(DA, OM, PM)** • Manage the contract with a focus on sustainability **(MPB)** • Provide input on contract requirements from a technical perspective and standardization **(TM)** • Review contractor calculations and check MKI-based award decisions **(CE)**	• Use CO_2-Prestatieladder as procurement audit and certification service • Use DuboCalc for MKI verification • Use circular procurement market engagement platforms • Use chain analysis services for supplier CO_2 and circularity performance • Use PIANOo as advisory service or knowledge base • Advise on procurement strategy and performance criteria in technology and sustainability **(DA, TM, MPB)** • Provide strategic advice on contract type and market approach **(CM, PL, OM)** • Proactively provide unsolicited sustainability advice during procurement **(PM)** • Advise on procurement strategy: price vs. MKI **(CE)**
10. Project Stakeholder Management	• Extend the stakeholder register with sustainability interest dimensions • Include targeted sustainability engagement strategies • Use stakeholder-specific sustainability communication materials • Prepare participation plans with associated communication requirements for all stakeholders **(CM)** • Create visualizations for participation sessions to be discussed with stakeholders **(BIM)** • Document Ambition Web results and monitor results from stakeholder communication **(DA)** • Prepare participation plans, participation reports and stakeholder analysis reports **(OM)** • Prepare stakeholder strategy and decision documents **(PL)** • Document stakeholder ambitions and monitor results from stakeholder participation **(PM)** • Document technical substantiation for the asset manager and other stakeholders **(TM)** • Document the MKI substantiation for discussion with stakeholders **(CE)**	• Identify sustainability-relevant stakeholders beyond the traditional project triangle • Define sustainability strategies per stakeholder type • Manage active sustainability dialogue through participatory processes • Monitor stakeholder satisfaction and sustainability concerns • Align expectations between client and market **(CM)** • Support and facilitate stakeholder dialogues through visualization **(BIM)** • Facilitate participatory sustainability processes such as Ambition Web **(DA)** • Provide opportunities to participate in participation processes **(OM)** • Strengthen chain collaboration with a focus on sustainability **(PA)** • Structure stakeholder dialogue through preparation **(PL)** • Align with the client on organizational and project ambitions **(PM)** • Align with asset managers on sustainability **(TM)** • Provide transparency in cost trade-offs **(CE)**	• Use environmental management services • Use public consultation portals as digital engagement services • Use independent sustainability mediators or environmental services • Provide strategic advice to the client **(CM)** • Clarify design choices through details **(BIM)** • Guide the strategic sustainability dialogue **(DA)** • Manage relationships **(OM, PA)** • Balance public and private interests **(PL)** • Provide administrative accountability **(PM)** • Explain and clarify technical choices **(TM)** • Provide accountability to the client **(CE)**

SRQ1 - Discover (diverge)

What is the current state of sustainability integration within the PM-domains at the PPS-level during the planning and design phase of a Dutch infrastructure project?

Answering ***SRQ1***, the current state of sustainability integration in the planning and design phase (FEDP) of Dutch infrastructure at projects at PPS-level can be described as *increasingly recognized, but structurally fragmented* in practice at W+B. Both, the findings of the SLR and the 18 conducted SSIs with employees of W+B basically converge to 4 main characteristics that together summarize and explain this formulated state of sustainability integration, in particular fragmentation across PM-domains and PMC's (disciplines) (1), dependent on individual roles and intrinsic motivation (2), implicit sustainability ambitions (3) and W+B's bounded contextual conditions and advisory constraints (4).

1. Fragmentation across PM-domains and PMC's
Sustainability is present within the planning and design phase and is even identifiable across all 10 PM-domains through the 305 collected PPS-components and corresponding opportunities, as shown in Table 4.9 and Table 4.10. However, in practice sustainability practices, remain inconsistent and scattered across roles and PMC's (disciplines) instead of being uniformly anchors in project management and control. As sustainability is not yet part of the GROTIK-equivalent control dimension within W+B's project control framework used in an IPM-model. Meaning that it competes with cost, scope, time, information and quality variables, rather than complementing them. In order to tackle this, it requires integrated project leadership, which requires proactive maintenance on the agenda through tools, sessions and progress monitoring. As this adds value by safeguarding sustainability (integration) across disciplines, project phases and handover moments. Not considering this, means risking sustainability to become deprioritized and fragmented within current management structures. Also, there is no need for a complete new PM-domain for sustainability, but instead a tool that integrates sustainability into existing PM-domains and supports decision-making processes. This confirms that the 305 PPS-components and corresponding opportunities are not yet completely used within W+B and that the position of W+B as advisory engineering consultancy with bounded conditions prevent this from happening.

2. Dependence on individual roles and intrinsic motivation
Sustainability progress at W+B appears to be highly dependent on personal commitment and motivation rather than an organizational setting (layer level). As professionals perceive sustainability as a 'nice to have' activity rather than a core mandate. Missing a clearly specified sustainability role or a specified role within each PMC weakens ownership. accountability and continuity of integration. This indicates that it remains secondary to to other traditional project drivers unless it is explicitly specified in project goals, scope and responsibilities. This proves the structural need for a sustainability role or manager that coordinates the continuity of integration and holds accountability for it across the project phases. Sustainability implementation at consultancy firms is shaped by resource constraints, client demands and the professional boundaries of consultants, which limits collective action.

3. Implicitness of sustainability ambitions
The sustainability objectives at W+B are often formulated at a high and abstract level, without any concrete targets expressed through quantitative metrics such as the MKI, MCI or CO_2 values. This non-SMART formulation creates a gap between the ambition and concrete practice, as sustainability considerations end up competing with established project control drivers (e.g. cost, scope and time), rather than serving as an integrated design parameter. The MKI is only gradually being integrated into analytical frameworks and is not yet a standard practice across roles and PMC's. Despite the fact that tools like DuboCalc, +CD Tool and CO_2 assessment are recognized as almost standard practice, they still lack standardization in their application which limits their effectiveness across project types and PMC's. In order to do so and standardize the use of it, it requires clear formulated sustainability ambitions during project initiation, so instead, it becomes specific in what each project needs. It must be done during project initiation and transferred across project phases to prevent 'watering down' sustainability goals. In case the transfer is not done properly, then the potential 'lock-in' effects of integration takes a hold. Causing the flexibility to influence sustainability outcomes in later phases to become constrained as the project moves towards execution. Whereas the options that were once available during the FEDP are now structurally constrained or unaffordable.

4. W+B's bounded contextual conditions and advisory constraints
Due to the advisory and non-decisive mandate of W+B as an engineering consultancy firm, limits the capability of sustainability integration outcomes. The main role of W+B in the planning and design phase is by signaling, raising and structuring information instead of having direct decision-making authority. The roles at W+B that are less engaged with direct design activities, mainly have a coordinating or signaling function indicating a risk of losing sight on sustainability integration (during phase transitions or handover moments). Adding to that, the timing of which role is involved at the FEDP is also critical. Roles that are mainly focused during the pre-planning and contract preparation can either 'lock-in' sustainability ambitions or allow them to disappear before it reaches formal project documents. Engineering consultancy companies face inherent constraints in sustainability integration that is driven by client buy-in, role-based impact and scope of influence. Altogether, these bounded conditions prevent the defined PPS-components from being optimally used to their full potential within the context of W+B.

In short, these four main characteristics prevent sustainability from becoming integrated and steerable as a project parameter during the FEDP. ***The main central gap in this phase is the absence of SMART-formulated sustainability objectives during project initiation***. This indicates that even where sustainability awareness exists, sustainability automatically lacks leverage to be formally anchored in project baselines, indicators and governance structures (control levels) that are needed to translate the ambitions into measurable project outcomes (layer level). Now that the status-quo is identified related to sustainability from SSIs-**Q1** and SSIs-**Q2**. The other findings from SSIs-**Q3 (opportunities)** and **Q4 (PPS-evaluation** serve as an empirical foundation on how sustainability integration gaps at W+B can be potentially close and what type of decision-support framework must be developed in order to do so.

Q3-FD1 proves evidence that less drastic, but performing alternatives provide bigger potential for sustainability integration. Strengthening a structure compared to a complete replacement of a structure (low and high CO_2 exposure), monitoring over time instead (service-life) of overdesigning (material overuse) and proof-loading or other tests to ensure performance requirements are met in the KES. These alternatives before key design decisions are made help to be sustainable but are currently overlook at W+B. On the other hand, design principle like the IFD or DOP remain underused as well, because of cultural resistance and preferences for conventional (safe) solutions. This is a choice which limits reuse potential (R-ladder strategy), scalability, circularity and thus sustainability integration. Related to choices, ***Q3-FD4*** proves that sustainability ambitions are systematically deprioritized when the budgets are right or when choices are perceived as 'non-essential' relative to core delivery of the project. This indicates why it is essential to predefine the ambitions that are critical for baseline setting (cost, time and scope) that is incorporated in the PMP, as it specifies the budget as well. Because, when sustainability is anchored in the PMP, contracts and permits, then it is hard to move towards another alternative. Regarding 'non-essential' thinking, it is a mindset issue, as this requires a shift from 'siloed thinking' to systems thinking, as sustainability generates collective value. However, the phenomenon of 'short-termism' (practice of prioritizing immediate gains at the expense of long-term value) is the main reason why sustainability is labeled as 'non-essential', in combination with missing LC value that accounts for procurement weakens the position within project governance even more. In general, at W+B, sustainability tends to be only realized and put effort in when it is requested by the client ('uitvraag') or when it is tied to MEAT criteria.

Q3-FD6 is the highest fitted dimension in the heatmap Table 4.4, which shows that sustainability knowledge as stated earlier is fragmented, difficult to access and insufficiently shared at W+B. A tunnel visioned perspective on sustainability, considering CO_2 mainly, while broader social and ecological impacts are overlooked makes this observation even worse. Weak feedback structures, limited cross-project evaluations and a missing open dialogue around failures in projects further limit organizational learning (layer-level). Not having a structured knowledge base and lessons learned repository, these gaps will continue to exist internally and across projects. ***Q3-FD7*** proves that the largest sustainability gain does not lie in individual project decisions (layer-level), but in cross-project coordination, chain collaboration and programmatic steering (e.g. HWBP for board authorities), which are all currently underdeveloped. Material reuse (part of the R-ladder strategy) is a 'neglected child' as methods, libraries and coordinating systems between (sustainable) demolition and new-built structures are still missing. Circular alternatives often score high on sustainability but low on short-term financial calculations (due to short-termism mindset).

Q4-FD1 confirms that sustainability must be formally anchored in the Project Start-Up (PSU) phase, both contractually as in accountability formats (e.g. RACI-RAM-matrices) to track the contribution of those that are involved, before the baselines are fixed. The PSU is a critical phase, because if it is closed, then ambitions erosion becomes difficult to reverse. This proves the strategic approach on integrating sustainability (control-level). ***Q4-FD2***, being the second highest fitted dimension together with ***FD5*** in Table 4.4 implies that sustainability does not require a new structure, it must be integrated in existing project management documents (e.g. PMP) (layer-level) and monitored with the same attention as is done for the timeline, budget and scope (baselines). An important note is that if it is not recorded, it will not be steered upon.

Furthermore, second highest ranked ***Q4-FD5*** reflects that sustainability only gains traction in project decision-making (layer-level), when it is expressed as in financial term. This can be done by expressing sustainability into monetary metrics through instruments like LCCA and NPV combined with linked CO_2 values and MKI-data directly to cost structures (e.g. currently done with C3 Project at W+B). In this way, attention and traction is gained during trade-off decisions. However, reality is that this is done often too late in projects, in order to influence key design decisions. ***Q4-FD7*** observes that incentive structures at W+B through accountability structures (control- and layer-level), are yet not integrated into standard project control and management practices (layer-level). Additionally, the insights gained on sustainability during projects are not consistently captured a central lesson learned repository, meaning that each project start from zero and thus the organizational learning remains limited.

Altogether, the findings from all fitted dimensions and especially from SSIs-***Q3*** and ***Q4*** form the basis for the next phase of this research. The results show that there is no need to introduce an entirely new PM-domain. However, there may be added value in explicitly considering a sustainability-focused domain within W+B, as this could provide more clarity in responsibilities and better align roles within a dedicated internal PMC. Building on these findings, the next step is to identify the most relevant and essential PM-domains, together with their corresponding PPS-components and opportunities, that can support the design of a framework for sustainability integration. To approach this systematically, all 305 PPS-components are evaluated using a MCDA, as presented in the following section.

As a result of the answers given on ***SRQ1***, sustainability often competes with established project objectives rather than being considered a shared responsibility across all PM-domains. This creates a central paradox in this research:

Central paradox

Despite the fact that the early planning and design phase (FEDP) offers the greatest leverage for influencing sustainability outcomes, this potential is only partially realized in practice due to limited institutionalization, fragmented ownership and the absence of standardized decision-support instruments.

Accordingly, the current state of sustainability integration does not only describe existing practices, but also implicitly exposes where opportunities are missed and where structural gaps exist. These observations form the analytical basis for the next sections, which moves beyond the status quo to examine the underutilized sustainability opportunities and key gaps identified by participants, focusing on where and why sustainability integration could be strengthened within existing PM-domains on PPS-level.

5

Framework and conceptual model

5.1. Multi-Criteria Decision Analysis (MCDA)

To determine how sustainability can be best integrated into project control and project management practices, this research applies a Multi-Criteria Decision Analysis (MCDA) to all (theoretical and practical) sustainability opportunities related to the 10 PM-domains as shown in Table 4.9 and Table 4.10. In general the results reflect that sustainability integration is distributed across multiple project roles, management domains and types instead of owned by a single actor. An MCDA was selected because the research problem involves comparing multiple sustainability integration options that differ in their contribution to measurable performance, decision support, governance and practical applicability. In such a case, MCDA offers a transparent way to structure trade-offs and compare alternatives across several criteria simultaneously.

The use of MCDA in this research is not intended to claim objective truth, but rather to provide a systematic and explicit analytical framework through which the relative strengths and weaknesses of different sustainability integration options can be assessed. However, as this research is focused on quantifying and measuring it, the following core idea is used:

1. (***MaQ***) Can the opportunity be measured? To what extent does the opportunity produce a number, indicator or verifiable output like MKI, CO_2 score, dashboard metric (MCI) or other result? Or does it only provided more 'soft' quantitative output related to the opportunity?
2. (***DL***) Does the opportunity drive a decision? Does acting upon this opportunity actually change what gets chosen, approved or contracted? Or does it just document something after the fact?
3. (***E***) Can it be embedded structurally? Is it anchored in a plan, contract, baseline or formal process so it survives personnel or project changes (reflecting vulnerability)? Or does it depend on mainly one motivated person?

5.1.1. Definition of alternatives

The alternatives are in this case all 305 found opportunities from practice (SSIs) and theory (PMBoK), as show in Table 4.9 and Table 4.10. An observation to the findings from practice is that those are more related to the workflow and organizational structure of an engineering consultancy firm (W+B). Regardless, the findings from theory are also relevant to take into account as it can be interesting from the perspective of another type of company for future research. These findings of opportunities, both theoretical and practical, are analyzed and assessed using the Weighted Sum Model (WSM) applied in this MCDA. The 10 PM-domains are examined individually using the same procedure, while the following decomposition of PPS-components associated with each opportunity is identified, as shown in Table 5.1:

Nr.	PM-domain	Product	Process	Service	Total
1	Project Integration Management	17	17	11	45
2	Project Scope Management	13	9	10	32
3	Project Time Management	8	9	5	22
4	Project Cost Management	9	8	7	24
5	Project Quality Management	11	12	12	35
6	Project Resource Management	8	7	8	23
7	Project Communications Management	10	10	11	31
8	Project Risk Management	9	11	10	30
9	Project Procurement Management	10	9	9	28
10	Project Stakeholder Management	11	13	11	35
	TOTAL	**106**	**105**	**94**	**305**

Table 5.1: Number of identified sustainability integration opportunities across the 10 PM-domains and corresponding division into PPS-components (source: Author)

5.1.2. Evaluation criteria

The alternatives (read opportunities) were evaluated using 3 criteria. These criteria were selected to reflect the core requirements of sustainability integration in project management, particularly in relation to measurability (MaQ), decision leverage (DL) and embeddability (E). Due to the complexity of the topic and the amount of opportunities found in this research, the amount of criteria are minimized due to risking an unclear analysis of different opportunities. Perhaps, the use of additional criteria of '*early-phase influence*', '*practical feasibility*' or '*cross-domain integration*' can be considered in future studies.

5.1.3. Criteria weighting

Because this thesis focuses on sustainability integration that is measurable and quantifiable, supports decision-making and is able to be embedded in project control and management. Each of these criteria are given a weight, with each one representing their relative importance to the context of this research. The weights are assigned as follows:

Table 5.2: Evaluation criteria and weights

Criterion	Weight
Measurability and Quantifiability (***MaQ***)	0.45
Decision Leverage (***DL***)	0.35
Embeddability (***E***)	0.20
Total	1.00

Measurability and Quantifiability (***MaQ***) carries the highest weight of 45% because, in order to integrate sustainability implicitly and experience its effects, it must be made tangible and understood through measurement. Decision Leverage (***DL***) carries 35% weight because it distinguishes whether an opportunity actually changes what is decided, as opposed to merely documenting a choice afterwards. Embeddability (***E***) carries 20% weight, reflecting the importance of anchoring sustainability in formal project structures (in case MaQ and DL are relevant enough to allow this) so that it survives personnel changes and remains a standard part of project control rather than depending on individual initiative.

5.1.4. Scoring and ranking

Each opportunity was scored on a 3-point scale for each criterion, where 1 indicates a weak contribution and 3 indicates a very strong contribution. The range is limited from 1 to 3 in order to prevent score inflation (tendency to rate inaccurate high ratings, resulting in a misrepresentation), reduce cognitive overload (breaking down complex evaluations into smaller, manageable parts) and keep the methodology intuitive given the large volume of opportunities assessed. However, Silva et al. (2016) used a similar linguistic scale fro software methodology selection, making the analysis more 'process friendly and cheap', but on the other hand 'this scale provokes a considerable loss of information the can compromise the robustness of the result'. This is a risk that comes with this scoring methodology. The scoring scale for this research is defined in Table 5.3:

Criterion	Score 1	Score 2	Score 3
MaQ	The opportunity is vague, qualitative or not verifiable.	The opportunity produces some indicators or partial evidence, but it is incomplete or hard to compare.	The opportunity produces clear, trackable and verifiable output such as a metric, calculation, audit result or dashboard value.
DL	The opportunity does not materially influence a choice, approval or contract decision.	The opportunity informs decisions indirectly or only occasionally.	The opportunity directly changes what is selected, approved, contracted or prioritized.
E	The opportunity depends on one person or remains an informal suggestion.	The opportunity is partly embedded, but not consistently anchored in formal processes or controls.	The opportunity is formally anchored in a plan, contract, baseline or governance process and is likely to survive personnel changes.

Score 1 = Low contribution; Score 2 = Moderate contribution; Score 3 = Strong contribution

Table 5.3: Scoring criteria used for evaluating sustainability integration opportunities (source: Author).

The opportunities initially identified through the SLR and following SSIs are now evaluated using the insights gained from both theoretical and practical perspectives. By applying the MCDA, all opportunities are rated, while acknowledging that this assessment involves subjectivity based on personal expertise gained from both theory and practice and that outcomes may depend on personal judgment. The actual heat map visualizations and scores of opportunities per domain can be found in Appendix D.

5.1.5. Weighted Sum Model

The total value of each opportunity was calculated using a Weighted Sum Model (WSM):

$$V(a) = \sum_{i=1}^{n} w_i \cdot s_i(a) \tag{5.1}$$

where:

- $V(a)$ = Total weighted score of sustainability integration potential of an opportunity a related to a corresponding PPS-component within a PM-domain
- w_i = Weight of criterion i
- $s_i(a)$ = Score assigned to opportunity a on criterion i
- Each criterion is scored on a 1–3 scale as shown in Table 5.3

The WSM was selected because it is transparent, easy to reproduce and suitable for exploratory comparative analysis in this research over other methods (e.g. AHP, TOPSIS). O'Shea et al. (2026) shows that this WSM method, produces results that are similar to complex methods, whereas it requires less pairwise judgments. This is especially preferred and advantageous when assessing 305 opportunities, as the large number of comparisons required by another complex method would have made its application impractical. The simplicity and reproducibility also makes it well suited to exploratory and large comparative analysis involving both objectives and subjective criteria. In addition, this method has been applied earlier on specifically early-stage sustainability assessment under conditions of uncertainty by Henderson and Peeling (2024), which is closely in parallel with the integration nature of this research. However, one of the main limitations of the WSM is its sensitivity to the assigned criteria weights, whereas future research could apply weight stability interval analysis (O'Shea et al., 2026) to test the robustness of the rankings presented in in this research.

5.2. Ranking and analysis of results

The results from this MCDA have been translated into a number of other relationships, including the distribution of $V(a)$ scores (1), PM-domain vs PPS-component score heatmap (2) and finally the average $V(a)$ score per PM-domain (3). This information provides an overview of the most essential PM-domain including the opportunities and associated PPS-component(s) for sustainability integration during the planning and design phase.

5.2.1. Distribution of $V(a)$ scores

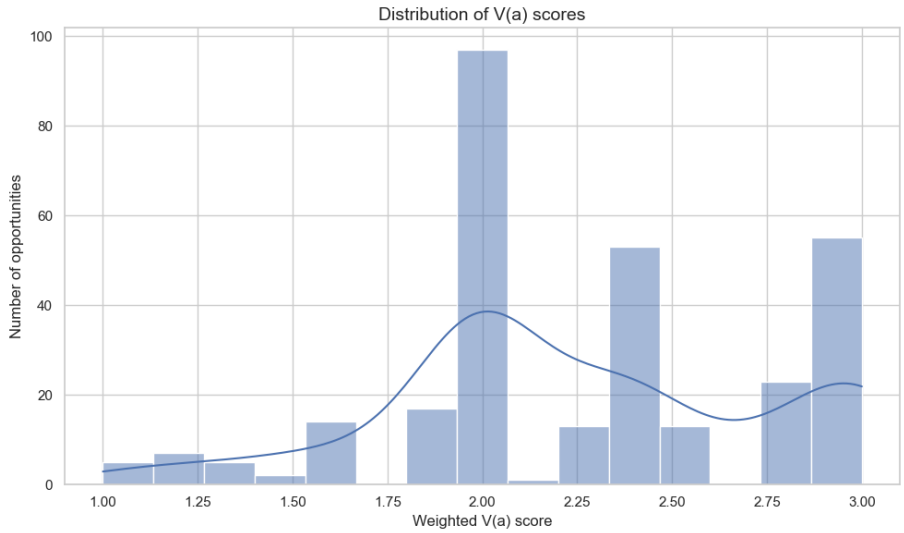


Figure 5.1: Score distribution of $V(a)$ scores for all opportunities across the 10 PM-domains and corresponding PPS-components (source: Author)

As show in Figure 5.1, it is clear that a lot of opportunities are clustered around **2.00**, whereas another two important groups are placed around **2.25 - 2.50** and **2.75 - 3.00**. The latter group is analyzed extensively, but before the first cluster around **2.00** indicates that many sustainability opportunities are relevant but are not completely measurable, decision-relevant or embedded currently within W+B. Matching with the statement that sustainability knowledge is often to access, insufficiently shared or hidden. Resulting in low visibility of both expertise and opportunities ([P3],[P4]). Meaning that many opportunities exist, but they have not yet been translated into standardized project management instruments. To standardize a developed method, it is essential to see what opportunities can assist in this, therefore the high scoring group (**2.75 - 3.00**) is important. As they are measurable, decision-relevant and are capable to be embedded in project workflows at W+B. Sustainability must be followed just as serious as planning and budget if it is to remain visible and steerable during projects ([P11],[P6]). These highest scoring opportunities are not directly the most visionary ideas, but are ideas that can be potentially converted into project control, design choices, dashboard, cost estimates, risk registers

and requirements which support decision-making.

The cluster around **2.00** should not be treated as middle tier as simply 'moderate' and moving on. Because, it is worth examining what separates a 2.00 scoring opportunity from a top opportunity, since in several cases the gap is not too big. Based on the current weighting structure in this approach, an opportunity scoring high on ***MaQ*** and ***DL*** but only moderate on ***E*** for example can still land on around $V(a) = 2.00$, while the same opportunity would approach $V(a) = 3.00$ if it got a suitable adjustment. This indicates that part of the **2.00** cluster may consist of 'low-hanging fruit', which opportunities that already exhibit strong potential but are not consistently incorporated into formal project control structures. As a result, their lower score is likely due to limited integration rather than poor performance on all three criteria. However, this distinction cannot be identified from the $V(a)$ score alone. A decomposition of the underlying ***MaQ***, ***DL*** and ***E*** sub-scores for the 2.00 cluster would provide greater insight into which opportunities possess strong inherent potential and require only a marginal improvement in one of the criteria to be elevated to a '*top opportunity*'.

5.2.2. Average $V(a)$ per PM-domain and PPS-component

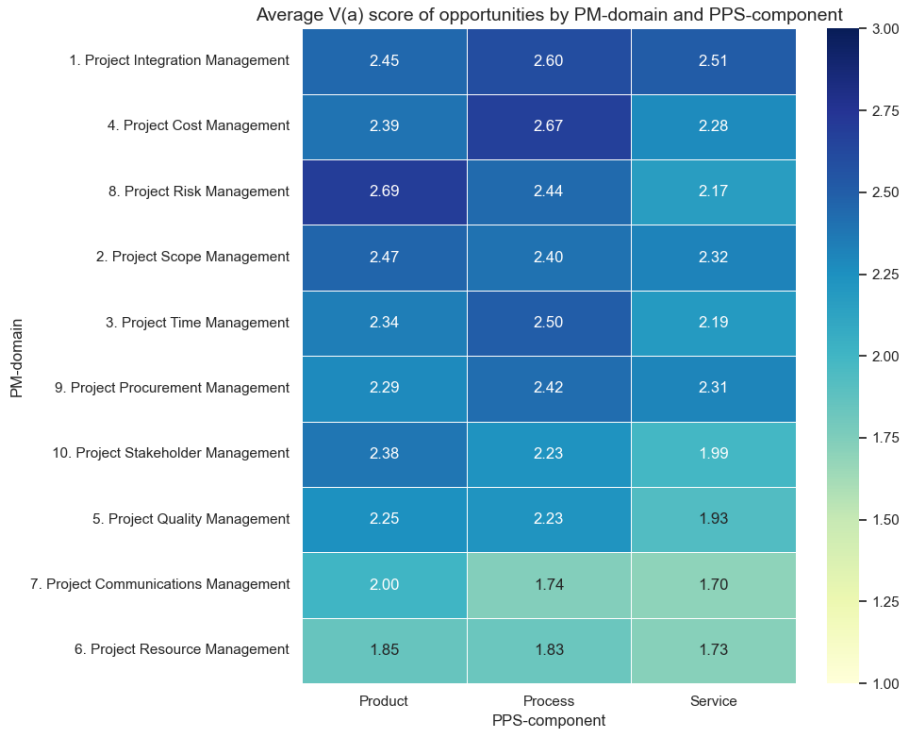


Figure 5.2: The average $V(a)$ score per PM-domain and PPS-component (source: Author)

In order to get a better understanding of this distribution a more zoomed approached is handled, by setting up a heatmap that visualizes the average $V(a)$ score per PM-domain and PPS-component. As shown in Figure 5.2, the top ranked PM-domains are visualized with each average score on each PPS-component. In this research, the top 5 PM-domains remain relevant as they are traditional project control and management domains that naturally contribute more to project development and result. **Project Integration Management** is **1st**, with a highest value in the Process-component at **2.60**. Meaning that the strongest integration potential lies in the way sustainability is anchored in project workflows, decision-making structures and coordination processes. As verified by a participant that sustainability should be anchored in existing management documents and control mechanisms ([P8],[P14]). For example, by including sustainability in the PMP as a dedicated section in larger projects ([P13]). Proving the interpretation that the Process-component is critical in Project Integration Management.

Additionally, the same component is the strongest for the **2nd** ranked **Project Cost Management** with a score of **2.67**. Representing the highest value in the heatmap, meaning that that main opportunities lies in the process of comparing alternatives, making trade-offs and integrating sustainability into cost decision-making. As sustainable alternatives gain traction, only when they become comparable within standard cost assessments ([P7]) and without integration into financial models, sustainability remains an additional consideration that is overridden when trade-offs are made ([P7]). The heatmap supports this as cost processes are crucial because they determine whether sustainability is treated as evidence or as a secondary preference.

The Product-component scores the highest for the **3rd** ranked **Project Risk Management** with **2.69**, having the highest score of the whole heatmap. Indicating that sustainability risk integration becomes impactful when it results in concrete outputs (e.g., risk reports or probabilistic cost analysis). Despite that it has been incorporated more and more within W+B as an additional sustainability risk category, it still remains weakly anchored in risk management overall ([P8],[P14]). Sus-

tainable risk management requires formal products and documentation to become visible and actionable during project development, without these sustainability remains implicit and can disappear from project control.

The **4th** ranked **Project Scope Management**, contains a balanced score across all three PPS-components, showing the stability of the PM-domain. Scope definition is not limited to one aspect or component, as it needs requirements, practical processes and technical advisory input. This is reflected by the fact that actors tend to deliver only what is contractually required, nothing more nothing less. Meaning that when sustainability is explicitly included in the assignment, it quickly disappears and becomes secondary ([P5],[P10]). This domain is key for formalizing sustainability (e.g. including sustainability objectives, indicators and requirements) in the project scope, where sustainability becomes part of what the project must deliver rather than something optional.

Again, the Process-component, scores the highest within the **5th** **Project Time Management** with **2.50**, confirming that timing is critical for sustainability integration. Sustainability considerations are often introduced too late in the project lifecycle, particularly in financial evaluations. Early stage decisions (during FEDP) largely determine sustainability outcomes, yet cost-benefit analyses (e.g. SCBA) of sustainable options are frequently postponed until later phases, when flexibility is already reduced ([P17]) due to embedding of a technical solution in contracts, permit and stakeholder communication. This supports the need for sustainability milestones, early variant studies, scheduled MKI/LCA/LCC calculations and design review moments before stage gates (or accelerate stage gates by integrated automation).

5.2.3. Average overall $V(a)$ score per PM-domain

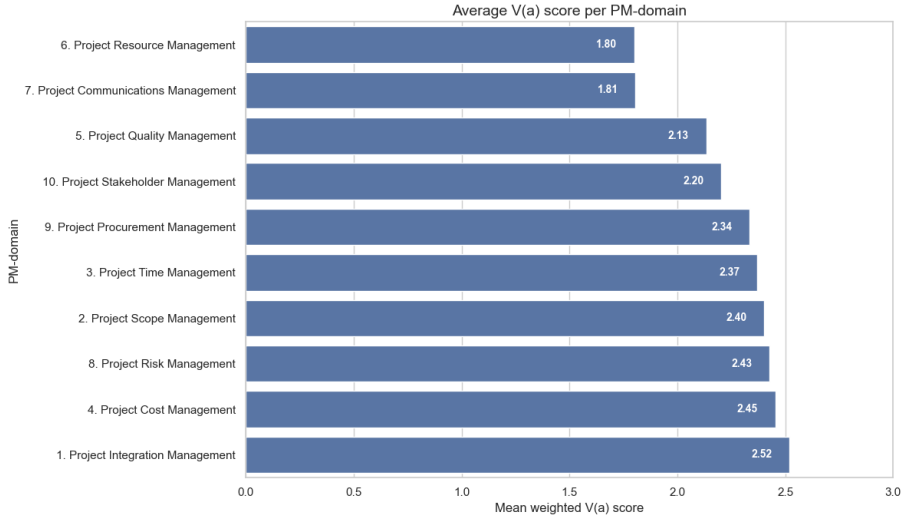


Figure 5.3: The average overall $V(a)$ score per PM-domain (source: Author)

The ranking could already be identified by the visualization of the heatmap in Figure 5.2. It is more interesting to know what the overall average $V(a)$ score is per PM-domain, in Figure 5.3, it shows the most prominent PM-domains for sustainability integration where project decisions are coordinated, quantified, risk-assessed, scoped and planned. **1st** ranked **Project Integration Management** obtains the highest average overall score of **2.52**, proving that sustainability inclusion is integrative by nature and should not be treated as a separate domain or advisory activity, but instead as an integrated project control task. Participants from W+B experience that sustainability still remains fragmented across roles and project structures and even across multiple PM-domains, which diminishes integration rather than strengthening it ([P09]). Conclusively, sustainability integration depends on clear role allocation, explicit ownership and continuous coordination across project processes. By not maintaining these elements, sustainability ambitions are vulnerable to (ambition) erosion, causing fragmentation and eventually loses its attention and priority. This explains why Project Integration Management ranks highest, as it is a central challenge not only to identify sustainable solutions, but to coordinate them across the PM-domains. Aside from this, sustainability is not always seen as a hard project constrained, remaining secondary to other priorities unless it is explicitly incorporated in project goals, scope and responsibilities ([P1],[P11]). This is relevant to interpret this figure, as the corresponding high score of this domain suggests that sustainability needs to be anchored in documents. Without this integration layer, sustainability can and will remain dependent on individual initiative instead of becoming a structure part of project steering.

Project Cost Management ranks **2nd** with an average overall score of **2.45**, as reflection of the statement that one dimensional financial metrics are dominant in decisions making. Meaning that if decisions are based on direct costs only, then the more sustainable option are often eliminated. Proving that metric choices shape outcomes, because what is not monetized or measured remains invisible in decision-making ([P12]). This statement reflects, why the weighting factor is so high for the criteria of Measurability and Quantifiability' as it is essential for outcomes. Sustainability is influential if it is translated into comparable metrics (e.g. MKI, MCI, LCA or CO_2). The ranking of this domains shows that sustainability integration requires more than ambition only, it requires financial and technical language to compete with conventional

solutions (and cost, time and scope arguments).

Project Risk Management ranks **3rd** with an average overall score of **2.43**, confirming that sustainability should be treated as an uncertainty and exposure issue (receiving sufficient attention). Sustainability is implicitly present in risk management, but barely treated as an explicit and structurally monitoring risk category on its own ([P8],[P14]). The findings suggest that sustainability is not completely absent from projects, but is still insufficient institutionalized, whereas it depends too much on personal initiative and is not completely anchored in project management and control practices. This supports the result of this MCDA, whereas risk management has a big potential for sustainability integration, containing several and different types of sustainability risks. Highlighting the importance of not assessing sustainability as a performance ambitions, but also as a risk category with ownership, probability, impact and mitigating measures.

Project Scope Management ranked **4th** and **Project Time Management** ranked **5th**, with scores of **2.40** and **2.37**, complete the top 5. Their position is particularly important for the planning and design phase, in regards to the sustainability ambitions that are often not sufficiently specified SMART at the start of an infrastructure project ([P5]). This causes the ambitions to remain formulated at a high level and missing targets using specific metrics (e.g. MKI, MCI or CO_2). This indicates why the scope domain is critical, as sustainability must be translated into requirements within the KES, (design) boundaries and performance indicates before the design becomes permanent and fixed. Similarly, the time domain should be considered equally important, because sustainability is often introduced too late in the project LC, when design flexibility is reduced and rigidity remains (less impact on changes). This supports the need to include sustainability milestones, calculation moments, variant studies and review points before formal design stage gates (or accelerate stage gates by integrated automation).

Project Procurement Management has a middle level average overall score of **2.34** on the **6th** place below the top five and is just a bit behind the 5th place, meaning that it is still relevant for sustainability integration. Specifically during the procurement phase, where sustainability ambitions are translated into contracts, tender criteria, supplier requirements an award systems. Based on Figure 5.2 the main opportunities lies in the Process-component (e.g. tender evaluation, contract conditions and market dialogue). However, it does not take place before the other top 5 domains, because the procurement often takes place after design choices have been made. Therefore, procurement is highly important for formalizing and enforcing sustainability requirements, but it is less suitable as the primary entry point for early design optimization.

Project Stakeholder Management at the **7th** place has an average overall $V(a)$ score of **2.20**, which has a meaningful but indirect role in sustainability integration within project management and project control (aside from the fact that at W+B the sustainability ambitions are identified during stakeholder Ambitieweb and Omgevingswijzer sessions). Again, within the Product-component Figure 5.2 shows that stakeholder related sustainability integration is realized more concrete when the results are tangible outputs (e.g. stakeholder analysis, participation reports or decision justification). Gaining a 'goodwill' factors is due to good 'stakeholder management' which is important in realizing the sustainability objectives in infrastructure projects. However, stakeholder management and engagement alone does not directly imply sustainability integration or whether sustainable alternatives are selected. Stakeholders can influence priorities and acceptance depending on their power and interests (PI-matrix), regardless, some of them still needs to be translated into the project context (e.g. scope requirements, design criteria en cost estimates) related to other domains.

Project Quality Management has an average overall $V(a)$ score of **2.13**, which ranks **8th** position. Figure 5.2 indicates that this domain is mainly contributing through Product- and Process-components (e.g. quality criteria, verification procedures, design checks or review moments). The domain is relevant for sustainability integration as well, because products need to be delivered within agreed acceptance criteria and expectation of the client and other stakeholders and should be checked during project development. However, this domain is more evaluative rather than generative, so it checks whether requirements are met (on quality) rather than defining or proposing sustainable solutions or ideas. It can help ensure that sustainability indicators are consistently reviewed, validated and documented, but it should support rather than replace the earlier integration, design optimization and decision-making processes. Therefore it scores relatively low compared to the other domains.

Project Communications Management has a an average $V(a)$ overall score of **1.81** ranking **9th** and **Project Resource Management** has an average $V(a)$ overall score of **1.80** ranking **10th**. Based on Figure 5.2 it is shown that their PPS-components do not perform well and reach the thresholds required to be considered a '*top opportunity*' cluster. The low ranking does not directly imply that resources and communication are irrelevant for sustainability integration, but within the defined boundary conditions of the MCDA they have less direct leverage on sustainability integration compared to the other PM-domains. Resource management domains mainly involves about the availability, allocation, coordination of people and knowledge capacity. They help in providing room to assist sustainability integration, but these domains do not automatically produce measurable sustainability outcomes. An example is that a sustainability advisor or allocating design capacity can support sustainability, but the real impact depends on whether it is translated into tangible project management or control deliverable and documents (e.g. KES, MKI or cost estimates). This explains why **Project Resource Management** scores lower on measurability (***MaQ***) and decision leverage (***DL***). As the findings from the SSIs indicate that sustainability depends on individual awareness, expertise and intrinsic motivation instead of being a part of

standard role responsibilities and workflows ([P12], [P18]). This highlights that if it only depends on motivated individual then this domains functions more as a supporting condition rather than as a strong direct decision mechanism. Additionally, sustainability knowledge tends to be difficult to access, insufficiently shared or hidden, resulting in low visibility of both expertise and opportunities ([P3],[P4]). Highlighting that not the challenge not only lies in people within this domain, but also the structural organization of knowledge, responsibilities and capacity.

Project Communication Management does lack '*top opportunities*' as well, because again this domain is mainly an enabling and supporting domain, which creates awareness, alignment and stakeholder understanding. Furthermore, communication alone does not guarantee that sustainability will be anchored in the design, budget, timeline or scope. Within W+B the advisory role whereas signaling, raising awareness and structuring information are more contributory to sustainability rather than direct authority to integrate. The signaling acts more as a safeguard to sustainability consideration, reflecting a proactive behavior ([P7],[P12],[P14]). This shows why this domain scores relatively low, as it can support sustainability integration, but its effect is indirect unless it is connected to direct decision-making. Communication can help maintain alignment through Ambitieweb sessions, stakeholder dialogue, dashboards and decision justifications but it does not by itself determine whether a sustainable alternative is selected.

In conclusion, **Project Resource Management** and **Project Communications Management** should be seen as supporting domains rather than primary methodological domains for sustainability integration. They are and still remain necessary parallel with the order more essential domains to realize sustainability integration, but as the MCDA results proof, the main foundation on sustainability integration is built on the opportunities of the top 5 PM-domains:

1. Project Integration Management
2. Project Cost Management
3. Project Risk Management
4. Project Scope Management
5. Project Time Management

These domains offer stronger direct potential to make sustainability measurable, decision-relevant and embedded in the project control and management processes of an infrastructural project during the planning and design phase within W+B. As this is an expected result, due to the fact that multidisciplinary projects are integrated by nature and therefore the other 4 traditional project control and management domains (cost, risk, scope and time) come together eventually in project integration management. A wider, more systematic adoption, especially in integration, time, quality and risks allows for a transparent and traceable process aligned with sustainability objectives.

SRQ2 - Define (converge)

What is the highest PPS-based project management domain(s) and component(s) that offer highest potential for (semi-)-quantitative sustainability integration, considering the effort required within existing workflows and the reproducibility of the method across different Dutch projects?

Building on ***SRQ1*** and answering ***SRQ2***, based on the MCDA results, **Project Integration Management** scored the highest with an overall $V(a)$ score of **2.52** across the evaluated sustainability integration opportunities integration opportunities. This shows that sustainability integration has the strongest overall potential in case its anchored in the coordinating and steering mechanisms of the project, rather than being treated as a separate activity or advisory task. This is also emphasized by the participants from the qualitative findings of the SSIs and answer of ***SRQ1*** where sustainability was described as fragmented across roles and project phases. Therefore, the main challenge is not only to identify sustainable solutions, but to make sure that these solutions are coordinated, assigned, monitored and protected throughout the planning and design phase. The Process-component shows the highest potential when looking at its average score of **2.60** in Figure 5.2. Meaning that the strongest opportunities lies in the way sustainability is anchored into existing project controls, workflows, decision-making moments (e.g. SMART sustainability objectives before the PMP baselines are fixed or integrating sustainability milestones into the project timeline). These opportunities are essential since they are connected to existing project management procedures within W+B without requiring a complete new sustainability system. This improves practical feasibility and makes the approach more reproducible across different Dutch infrastructure projects.

As **Project Integration Management** is the primary domain, the MCDA results proof that the **Project Cost, Risk, Scope and Time Management** domains are relevant too for sustainability integration. As is expected, since they come together within **Project Integration Management** because these domain are traditional project control and management mechanisms. The final selection of **Project Integration Management** is therefore not based only on the highest numerical score, but on its strategic position within project management. This domain connects the other PM-domains and determines whether sustainability objectives are translated into project documents, responsibilities, baselines, monitoring mechanisms and decision-making procedures. Therefore, to reproduce a methodology for sustainability integration, **Project Integration Management** is the most logical point to start. Because if sustainability is anchored in this PM-domain, then it indirectly influences project decisions made on cost, risk, scope and time.

In summary, the Process-component of **Project Integration Management** offers the biggest potential to integrate sustainability in a semi-quantitative manner within the scope of this research, using the '*top-opportunities*' as shown in Table 5.4. The relevant supporting domains are **Project Cost, Risk, Scope and Time Management** as they represent the main project control mechanisms through which sustainability can become measurable, actionable and reproducible during the planning and design phase of Dutch infrastructure projects. However, **Project Integration Management** should be selected as the primary domain for further method development, because it provides the coordination structure needed to prevent sustainability ambitions from remaining fragmented, informal or dependent on individual initiatives.

5.3. Overview of all top PPS-components

Based on the analysis, Table 5.4 presents a comprehensive overview of all highest-scoring sustainability integration opportunities ($V(a) = 3.00$) across the examined PM-domains. Being from now on introduced as '*top-opportunities*' within these 5 PM-domains.

Table 5.4: Overview of the highest scoring sustainability integration opportunities across the examined PM-domains based on the MCDA analysis (source: Author).

PM-domain	PPS	Origin	Top opportunity	Score
Project Integration Management	Process	PMBoK-based	Formulate SMART sustainability objectives before PMP baseline setting	3.00
Project Integration Management	Process	PMBoK-based	Integrate sustainability milestones into the project timeline	3.00
Project Integration Management	Process	SSI-based; PA	Apply iterative design processes	3.00
Project Integration Management	Process	SSI-based; CE	Align design, costs and sustainability	3.00
Project Integration Management	Product	PMBoK-based	Integrate sustainability metrics, e.g. MKI, MCI or CO_2, in deliverables	3.00
Project Integration Management	Product	SSI-based; BIM	Deliver a 3D BIM model, clash-detection models and other visualizations	3.00
Project Integration Management	Product	SSI-based; DA, MPB	Prepare a sustainability roadmap including indicators and a sustainability dashboard	3.00
Project Integration Management	Product	SSI-based; PL	Prepare an integrated project strategy, e.g. IPM-model and decision-making documents	3.00
Project Integration Management	Product	SSI-based; TM	Prepare technical design documentation, e.g. on IFD	3.00
Project Integration Management	Product	SSI-based; CE	Prepare integrated cost reporting	3.00
Project Integration Management	Service	SSI-based; BIM	Integrate calculation models into realistic sustainable geometry	3.00
Project Integration Management	Service	SSI-based; PA	Shape design processes iteratively	3.00
Project Integration Management	Service	SSI-based; CE	Align design, costs and sustainability as an integrated advisory service	3.00
Project Scope Management	Process	SSI-based; TM	Assess residual capacity and alternatives	3.00
Project Scope Management	Product	PMBoK-based	Include TBL or QBL performance in requirements documentation, KES	3.00
Project Scope Management	Product	SSI-based; DA, MPB, OM	Prepare a KES document with sustainability objectives together with associated performance standards and sustainability requirements	3.00
Project Scope Management	Product	SSI-based; TM	Delineate technical scope including strengthening vs. replacement alternatives	3.00
Project Scope Management	Product	SSI-based; CE	Perform cost estimates for sustainability variants following variant study	3.00
Project Scope Management	Service	PMBoK-based	Use DuboCalc for MKI validation at product or project level	3.00
Project Scope Management	Service	SSI-based; TM	Advise on the optimal technically sustainable solution direction	3.00
Project Time Management	Process	PMBoK-based	Integrate sustainability milestones into critical path analysis	3.00
Project Time Management	Process	SSI-based; TM	Plan technically sustainable analyses per design phase	3.00
Project Time Management	Product	SSI-based; MPB	Produce deterministic sustainability planning	3.00
Project Cost Management	Process	SSI-based; MPB, CM, PA, PL, PM	Make trade-offs for each sustainable solution based on budget, financial monitoring, progress control and LCC	3.00
Project Cost Management	Process	SSI-based; DA	Integrate MKI into variant studies	3.00
Project Cost Management	Process	SSI-based; TM	Substantiate costs from a technical perspective	3.00
Project Cost Management	Process	SSI-based; CE	Prepare deterministic and probabilistic cost estimates for variants using Monte Carlo simulations	3.00
Project Cost Management	Product	SSI-based; TM, DA, CE	Perform MKI calculations, LCA analyses and LCC substantiations for each sustainable design	3.00
Project Cost Management	Product	SSI-based; TM	Conduct variant studies comparing strengthening vs. replacement options	3.00
Project Cost Management	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00
Project Cost Management	Service	SSI-based; TM	Provide advice on cost-effective technical choices	3.00
Project Quality Management	Process	SSI-based; CE, BIM	Test and check the constructability of sustainable alternatives	3.00
Project Quality Management	Process	SSI-based; PA	Conduct design revision rounds to achieve the most optimal and sustainable design	3.00
Project Quality Management	Process	SSI-based; TM	Perform quality assurance through testing and recalculations of sustainable alternatives	3.00
Project Quality Management	Product	SSI-based; PM, BIM	Prepare detailed models and verification models of sustainable solutions	3.00
Project Quality Management	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00
Project Risk Management	Process	SSI-based; CE, CM, MPB	Include risk analysis in procurement	3.00
Project Risk Management	Process	SSI-based; PL, TM	Integrate risk assessment into decision-making	3.00
Project Risk Management	Process	SSI-based; DA	Integrate sustainability impact into risk assessment	3.00
Project Risk Management	Product	PMBoK-based	Include sustainability risk exposure in the risk report	3.00
Project Risk Management	Product	SSI-based; PA	Prepare a trade-off analysis	3.00
Project Risk Management	Product	SSI-based; TM	Document residual service life with safety reporting	3.00
Project Risk Management	Product	SSI-based; CE	Prepare a probabilistic cost analysis	3.00
Project Risk Management	Service	SSI-based; CE	Make financial risk assessments	3.00
Project Procurement Management	Process	PMBoK-based	Include sustainability criteria in tender assessment	3.00
Project Procurement Management	Process	SSI-based; DA, OM, PM	Integrate sustainability into tender documents and strategy using embedded requirements	3.00
Project Procurement Management	Process	SSI-based; TM	Provide input on contract requirements from a technical perspective and standardization	3.00
Project Procurement Management	Process	SSI-based; CE	Review contractor calculations and check MKI-based award decisions	3.00
Project Procurement Management	Product	PMBoK-based	Use sustainability-weighted selection criteria	3.00
Project Procurement Management	Product	SSI-based; OM, DA	Prepare contractual sustainability requirements and MKI award models	3.00
Project Procurement Management	Product	SSI-based; TM	Document technical specifications and design criteria	3.00
Project Procurement Management	Service	PMBoK-based	Use CO_2-Prestatieladder as procurement audit and certification service	3.00
Project Procurement Management	Service	PMBoK-based	Use DuboCalc for MKI verification	3.00
Project Stakeholder Management	Product	SSI-based; BIM	Create visualizations for participation sessions to be discussed with stakeholders	3.00
Project Stakeholder Management	Service	SSI-based; BIM	Clarify design choices through details	3.00

5.4. PPS-SIME Framework

Based on the results of the MCDA, with input from both theoretical (SLR) and practical (SSIs) opportunities for sustainability integration, a framework has been developed to ensure that an opportunity becomes immediately clearly visible, resulting in a Standardized Measure Card (SMC). This can be seen as a theoretical measurement card for a sustainability opportunity, which can be used in practice as a memory aid during project control and project management. In this research, one or more of the 'top opportunities' within the Project Integration Management domain will be examined using this framework, introduced as the 'Product–Process–Service Sustainability Integration and Measurability Embedding Framework' (PPS-SIME Framework), as shown on the next page.

© 2026 Shahram Omary

1 Theoretical findings on PPS-components related to sustainability integration within PM-domains of sector or company

*PMBoK for example

2 Practical findings (from SSIs) on PPS-components related to sustainability integration within PM-domains of sector or company

*Engineering consultancy firm (W+B) for example

Collect

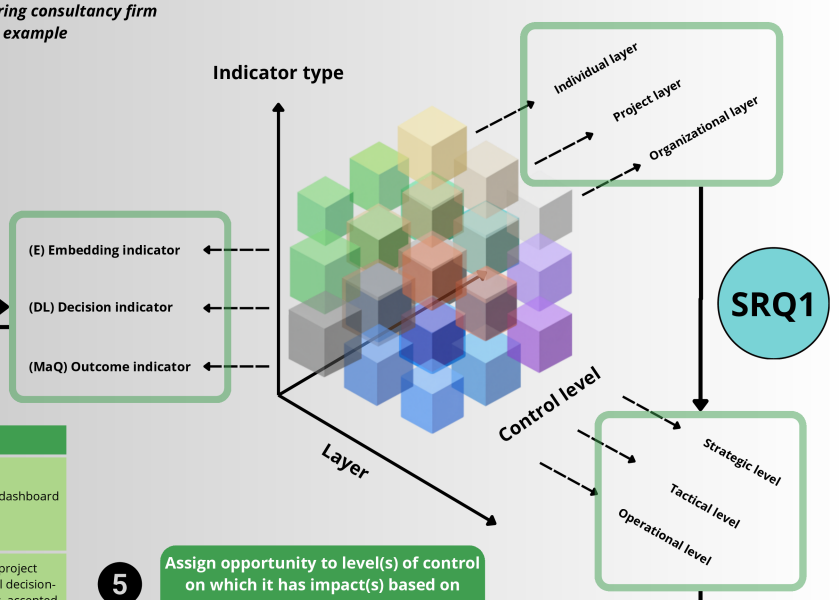
SRQ1

3 Integrated opportunity register (theory + practice)

SRQ2

Assess

4 Assess opportunities and corresponding PPS-components on indicators



SRQ1

Indicator type	Purpose	Examples	Evidence
1. **Outcome indicator**	Measures (in)direct sustainability effects if sufficient data are available or 'soft' observations	MKI, CO_2 emissions, MCI, material quantities, LCA/LCC or residual service life	MKI-report (DuboCalc) or MCI-dashboard (+CD Tool), LCA/LCC reports
2. **Decision indicator**	Measures whether sustainability influenced choices	Number of alternatives assessed, number of trade-off analyses, accepted/rejected sustainable alternatives, number of client decisions with sustainability justification	Documented record of all key project decisions, MCDA tables, formal decision-making checkpoint documents, accepted or rejected design choices, procurement asesement notes
3. **Embedding indicator**	Measures whether sustainability was structurally anchored in project control and management practices	Number of sustainability requirements in KES/Relatics, number of sustainability work packages in WBS, number of sustainability risks/opportunities in registers, number of assigned actions, number of sustainability milestones	PMP, WBS, RACI/RAM, risk register, schedule, quality plan, stakeholder engagement plan, procurement documents

5 Assign opportunity to level(s) of control on which it has impact(s) based on assessment results

6 Determine in which layer(s) the opportunity should be utilized within the company based on assessment results

Control level / Layer	Individual layer	Project layer	Organizational layer
1. **Strategic level**	The individual is responsible for leveraging their own capacity to achieve sustainability integration. Clear role definitions, responsibilities, and decision-making authority are essential to ensure who is empowered to set sustainability requirements towards the client and act on opportunities. **Quantification focus**: number of sustainability responsibilities (assigned and role-based), competency level (junior, medior, senior) and level of decision-making authority.	At the strategic project level, sustainability ambitions are translated into objectives, scope, and decision-making criteria. Embedding these ensures smoother integration of sustainability into project setup, including the charter, description, procurement strategy, and governance (aligned with EEFs and OPAs). **Quantification focus**: number of sustainability objectives, decision-making criteria, targets, ambition levels and formal decision-making thresholds.	At the strategic organizational level, sustainability must be translated into the organization's policy (related to EEFs and OPAs), standard operating procedures, reusable methodologies, and project portfolio priorities. This includes, among other things, a library of sustainability measurement tools (see tactical level - project level), standard templates and learning structures within the organization. **Quantification focus**: frequency of use of measurement tool, project portfolio indicators, number of standard templates, number of validated lessons learned from lessons learned repository or register.
2. **Tactical level**	The individual gets sustainability responsibilities assigned based on the project role and corresponding work packages (WBS). These are defined in a clear RACI/RAM matrix, linking ownership to KES requirements. The tasks are integrated into the project planning, with support from a sustainability specialist where needed. **Quantification focus**: number of assigned actions, completed tasks, open sustainability responsibilities and planned vs actual specialist hours.	At the tactical project level, sustainability is embedded in project control instruments such as the PMP, WBS, KES (Relatics), project baselines, risk register, planning, quality plan and stakeholder engagement plan. **Quantification focus**: number of sustainability requirements, work packages, risks and opportunities, milestones, and sustainability-related trade-offs.	At the tactical organizational level, sustainability must be translated into supporting mechanisms such as standard PMIS configurations (e.g. Relatics for the KES), EMVI templates for tender submissions, tender results, reusable dashboards (for example, the MCI dashboard from +CD Tool, via Power BI) and knowledge bases. **Quantification focus**: number of reusable dashboards, projects that have applied a method, templates used, and complete evidence.
3. **Operational level**	The individual must realize sustainability integration through concrete actions. This includes preparing calculations, reporting design choices, challenging established sustainability requirements, facilitating sessions to engage in dialogue (e.g., Amibtieweb and Omgevingswijzer sessions) and documenting sustainability evidence. **Quantification focus**: Number and type of calculations, challenged sustainability requirements, report sustainable alternatives, sustainability actions from meetings and completed sustainability tasks.	At operational project level, sustainability is determined by evidence. Examples include estimates of MKI, MCI, and LCA/LCC through calculations, probabilistic cost analysis, or stakeholder feedback. **Quantification focus**: MKI score (DuboCalc), CO2 emissions (database), MCI score (+CD Tool), number of tested alternatives, accepted or rejected alternatives, and definitively documented sustainability decisions.	At the operational organizational level, evidence regarding sustainability must be recorded and reused after the execution of the project or the completion of a phase. This includes lessons learned, validated EMVI measures, organizational benchmark data and dashboards. **Quantification focus**: number of validated measures, benchmarking opportunities, repeated measures, audit results and improvements in projects

Collect, setup and define

Opportunity ID: A unique identifier

PM-domain link: Determine which PM-domain this opportunity belongs to

PPS-component: What component doest this opportunity belong to?

Name: Plain language of opportunity

Description: What does the opportunity mean in practice?

Evidence type: What does the opportunity mean in practice?

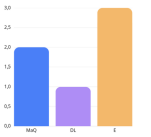
Indicator elaboration: What does the scores mean exactly?

Indicators

Outcome (MaQ):
How is it measured?

Decision (DL):
What is its impact on project decisions?

Embeddability (E):
How easy can it be integrated into existing project structures?



Control level	Application
Strategic	...
Tactical	...
Operational	...

Layer level	Application
Individual	...
Project	...
Organizational	...

Control level(s):
What does the opportunity mean on each control level based on the above?

Layer(s):
What does the opportunity mean on layer level based on the above?

SRQ3 + SRQ4

STANDARDIZED MEASURE CARD (SMC)

The PPS-SIME Framework is a three-dimensional model structured along three axes, layer (x-direction), control level (y-direction) and indicator type (z-direction). Each dimension consists of three categories, resulting in a total of 27 possible combinations (3×3×3) in which a '*top opportunity*' can be positioned.

The framework starts, as a starting point, with the development of an integrated opportunities register, based on both theoretical and practical insights within a sector or organization. This register is then evaluated using indicators through subjective, objective, or combined assessments. In this research, these indicators serve as the evaluation criteria within the MCDA. Following the MCDA, the '*top opportunities*' are identified. These can later be positioned within the appropriate layer (where the opportunity is applied) and the corresponding control level (where the opportunity is utilized), if these have not already been clearly defined. The overall structure of the PPS-SIME Framework follows a six-step process:

1. Collect theoretical findings on PPS-components related to sustainability integration within PM-domains of the sector or company (e.g. PMBoK).
2. Collect practical findings (from SSIs) on PPS-components related to sustainability integration within PM-domains of the sector or company (e.g. an engineering consultancy firm such as W+B).
3. Develop an integrated opportunity register that combines both theoretical and practical findings.
4. Assess opportunities and their corresponding PPS-components on the (three) indicator types (e.g. ***MaQ***, ***DL*** and ***E***).
5. Assign each opportunity to the level(s) of control on which it has impact, based on the assessment results.
6. Determine in which layer(s) the opportunity should be utilized within the company, based on the assessment results.

The final output of steps 4, 5 and 6 for each *top opportunity* is consolidated into a **Standardized Measure Card (SMC)**, as explained in Subsection 5.4.4.

5.4.1. Indicator type

The indicator type represents the *z-axis* of the PPS-SIME Framework and describes *how* a sustainability opportunity can be measured and evidenced. 3 indicator types are distinguished, each reflecting a different dimension of measurability:

Indicator type	Purpose	Examples	Evidence
1. Outcome indicator (*MaQ*)	Measures direct sustainability effects if sufficient data are available.	MKI, CO_2 emissions, MCI, material quantities, LCA/LCC, biodiversity score, residual service life.	MKI-report (DuboCalc), MCI-dashboard (+CD Tool), LCA/LCC reports.
2. Decision indicator (*DL*)	Measures whether sustainability influenced choices, approvals or trade-offs.	Number of alternatives assessed, trade-off analyses performed, accepted/rejected sustainable alternatives, client decisions supported by sustainability justification.	Documented record of all key project decisions, MCDA tables, formal decision-making checkpoint documents, accepted or rejected design choices, procurement assessment notes.
3. Embedding indicator (*E*)	Measures whether sustainability was structurally anchored in project management practice.	Number of sustainability requirements in KES/Relatics, sustainability work packages in the WBS, sustainability risks/opportunities, assigned actions, sustainability milestones.	PMP, WBS, RACI/RAM, risk register, schedule, quality plan, stakeholder engagement plan, procurement documents.

Table 5.5: Indicator types used within the PPS-SIME Framework, including their purpose, examples and corresponding evidence (source: Author).

The used indicators in this framework are aligned with the 3 MCDA criteria, outcome indicator (***MaQ*** = Measurability and Quantifiability), decision indicator (***DL*** = Decision Leverage) and embeddability indicator (***E*** = Embeddability). This indicates that each opportunity is not only scored in abstract, since it is connected to a concrete and verifiable form of evidence in practice. The opportunities that score high on all three indicators, are simultaneously measurable in output, traceable in decisions and embedded in formal existing project control and management processes.

5.4.2. Control level

The control level represents the *y-axis* of the PPS-SIME Framework and describes *where* within the organizational hierarchy a sustainability opportunity has its primary impact. 3 control levels are distinguished as follows:

Control level	Individual layer	Project layer	Organizational layer
1. Strategic level	The individual is responsible for leveraging their own capacity to achieve sustainability integration. Clear role definitions, responsibilities and decision-making authority are essential to ensure who is empowered to set sustainability requirements towards the client and act on opportunities. **Quantification focus:** number of sustainability responsibilities (assigned and role-based), competency level (junior, medior or senior) and level of decision-making authority.	At the strategic project level, sustainability ambitions are translated into objectives, scope and decision-making criteria. Embedding these ensures smoother integration of sustainability into project setup, including the project charter, project description, procurement strategy and project governance (aligned with EEFss and OPAss). **Quantification focus:** number of sustainability objectives, decision-making criteria, targets, ambition levels and formal decision-making thresholds.	At the strategic organizational level, sustainability must be translated into organizational policy (related to EEFs and OPAs), standard operating procedures, reusable methodologies and project portfolio priorities. This includes, among other things, a library of sustainability measurement tools (see Tactical level – Project layer), standard templates and organizational learning structures. **Quantification focus:** frequency of use of sustainability measurement tools, project portfolio indicators, number of standard templates and number of validated lessons learned from the lessons-learned repository or register.
2. Tactical level	The individual receives sustainability responsibilities based on the project role and corresponding work packages (WBS). These are defined in a clear RACI/RAM matrix, linking ownership to sustainability requirements documented in the KES. The tasks are integrated into project planning, with support from a sustainability specialist where needed. **Quantification focus:** number of assigned actions, completed tasks, open sustainability responsibilities and planned versus actual specialist hours.	At the tactical project level, sustainability is embedded into project control instruments such as the PMP, WBS, KES (Relatics), project baselines, risk register, schedule, quality plan and stakeholder engagement plan. **Quantification focus:** number of sustainability requirements, work packages, risks and opportunities, milestones and sustainability-related trade-offs.	At the tactical organizational level, sustainability must be translated into supporting mechanisms such as standard PMIS configurations (e.g. Relatics for the KES), MEAT templates for tender submissions, tender results, reusable dashboards (e.g. the MCI dashboard from +CD Tool via Power BI) and organizational knowledge repositories. **Quantification focus:** number of reusable dashboards, number of projects applying the method, template adoption rate and evidence completeness.
3. Operational level	The individual realizes sustainability integration through concrete actions. This includes preparing calculations, documenting design choices, challenging established sustainability requirements, facilitating dialogue sessions (e.g. Ambitieweb and Omgevingswijzer sessions) and recording sustainability evidence. **Quantification focus:** number and type of calculations, challenged sustainability requirements, reported sustainable alternatives, sustainability actions resulting from meetings and completed sustainability tasks.	At the operational project level, sustainability is determined through evidence. Examples include estimates of MKI, CO_2, MCI and LCA/LCC through calculations, probabilistic cost analyses and stakeholder feedback. **Quantification focus:** MKI score (DuboCalc), CO_2 emissions, MCI score (+CD Tool), number of tested alternatives, accepted or rejected alternatives and definitively documented sustainability decisions.	At the operational organizational level, sustainability evidence must be captured and reused after project execution or phase completion. This includes lessons learned, validated MEAT measures, organizational benchmark data and dashboards. **Quantification focus:** number of validated measures, benchmarking opportunities, repeated measures, audit results and improvements across projects.

Table 5.6: Control levels and their application across the three layers in the PPS-SIME Framework (source: Author).

5.4.3. Layer level

The layer level represents the *x-axis* of the PPS-SIME Framework and describes *where within the organizational structure* a sustainability opportunity is applied and utilized. 3 layers are distinguished as follows:

Layer	Description
Individual layer	The opportunity has been applied and is being utilized at an individual level. The degree of sustainability integration depends on the knowledge, expertise and awareness (e.g., systems thinking or silo thinking) of a specific person. A designer, sustainability advisor or cost estimator should each contribute within their capacity to influence and act within their profession (chain collaboration).
Project layer	The opportunity is anchored in the structure and context of a specific project. The potential for sustainability integration can be realized by using tools and documents at the project level that are relevant to project control and project management (e.g. PMP, WBS, KES and risk register). The opportunity remains available to all team members within the project until final decisions are formally recorded and tasks are assigned (ownership) and managed.
Organizational layer	The opportunity is standardized at the company or organizational level. Meaning that sustainability integration becomes part of standard operating procedures (SOPs) or standard working methods within the company. By using standardized templates, PMIS configurations and transferring knowledge and expertise between PMC's using a standardized organizational learning system for projects and teams.

Table 5.7: Layer definitions in the PPS-SIME Framework (source: Author).

The distinction between layers is important because it directly relates to the vulnerability of sustainability integration. An opportunity that only exists at the individual layer is highly dependent on a single motivated person and risks disappearing when that person leaves or changes role. This connects back to the finding from the SSIs that sustainability at W+B currently depends too much on individual initiative and intrinsic motivation ([P12],[P18]). Moving an opportunity from the individual layer to the project layer and ultimately to the organizational layer is the key mechanism through which the PPS-SIME Framework operationalizes structural sustainability integration.

5.4.4. Standardized Measure Card (SMC)

The final output of the PPS-SIME Framework is the **Standardized Measure Card (SMC)**, see Table 5.8 and earlier image of the framework, Each SMC describes a single *top opportunity* in a standardized, structured format that makes the opportunity immediately understandable and actionable for both project managers, sustainability advisors and other individuals within W+B. The SMC is designed to function as a memory aid and reference tool during project control and project management, making sure that sustainability is not only identified but also made measurable, decision-relevant and embedded in project workflows. Each SMC contains the following fields:

Field	Description
Opportunity ID	A unique identifier that links the opportunity to the integrated opportunity register, its PM-domain and its PPS-component
PM-domain link	Specifies which PM-domain this opportunity primarily belongs to (e.g. Project Integration Management, Project Cost Management)
PPS-component	Specifies which component of the PPSs the opportunity belongs to
Name	A plain language description of the opportunity
Description	What the opportunity means in practice and what action or output it requires
Evidence type	What the opportunity produces in practice, the tangible deliverable, document or data that serves as proof of execution
Indicator elaboration	A detailed explanation of what the scores mean exactly for this specific opportunity, elaborating on the three indicator types Outcome (***MaQ***), Decision (***DL***) and Embedding (***E***)
Indicators (*MaQ*, *DL*, *E*)	The MCDA scores on the three criteria, shown as a bar chart, with the total $V(a)$ score also reported
Control level(s)	Which control level(s) the opportunity applies to, shown per layer
Layer(s)	Which layer(s) the opportunity applies to

Table 5.8: Structure of the Standardized Measure Card (SMC) in the PPS-SIME Framework (source: Author).

Together, the SMC fields translate the abstract MCDA scoring into a practical and communicable format. The combination of indicator scores, control levels and layers allows a project team to immediately understand not only *what* the opportunity is, but also *how* it should be measured, *where* in the project governance it should be anchored and *at which organizational level* it can be standardized. This is precisely the gap identified in the SSIs, sustainability opportunities exist but have not yet been translated into standardized project management instruments ([P3],[P4]). The SMC is the primary instrument through which the PPS-SIME Framework addresses this gap.

6

Analysis and validation

6.1. Application of the PPS-SIME Framework

The framework is kept modular and transferrable to other context intentionally, as it can be reused and modified to the context of another company or sector whereas opportunities related to PM-domains can be identified from both theoretical and practical perspectives. In this research the framework is applied to the context of W+B (an engineering consultancy firm) and the Dutch infrastructure sector (GWW). The main structure and red thread can be applied to any engineering consultancy firm, project management organization or companies that use project management and that want to systematically anchor sustainability into their day-to-day project control and management practices.

The PPS-SIME Framework is applied in this research to the *top opportunities*, identified within Project Integration Management, which is the highest-ranked PM-domain in the MCDA with an average overall $V(a)$ score of **2.52** see Table 6.1. This domain is selected as the primary application domain, because sustainability integration is by nature an integrative task, thus it must be coordinated across all PM-domains rather than being siloed within a single domain. Project Integration Management therefore serves as the logical starting point for developing and validating SMCs.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	PMBoK-based	Formulate SMART sustainability objectives before PMP baseline setting	3.00
2	Process	PMBoK-based	Integrate sustainability milestones into the project timeline	3.00
3	Process	SSI-based; (PA)	Apply iterative design processes	3.00
4	Process	SSI-based'(CE)	Align design, costs and sustainability	3.00
5	Product	PMBoK-based	Integrate sustainability metrics, e.g. MKI, MCI or CO_2, in deliverables	3.00
6	Product	SSI-based; (BIM)	Deliver a 3D BIM model, clash-detection models and other visualizations	3.00
7	Product	SSI-based; (DA, MPB)	Prepare a sustainability roadmap including indicators and a sustainability dashboard	3.00
8	Product	SSI-based (PL)	Prepare an integrated project strategy, e.g. IPM-model and decision-making documents	3.00
9	Product	SSI-based (TM)	Prepare technical design documentation, e.g. on IFD	3.00
10	Product	SSI-based (CE)	Prepare integrated cost reporting	3.00
11	Service	SSI-based (BIM)	Integrate calculation models into realistic sustainable geometry	3.00
12	Service	SSI-based; (PA)	Shape design processes iteratively	3.00
13	Service	SSI-based; (CE)	Align design, costs and sustainability as an integrated advisory service	3.00

Table 6.1: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Integration Management based on the MCDA analysis (source: Author).

6.1.1. Redesigned MARK-method

After development of the PPS-SIME Framework in Chapter 5, the framework is applied to the first *top opportunity* of Project Integration Management. The opportunity that is used is: '***Formulate SMART sustainability objectives before PMP baseline setting***'. To structure the application and validation of this opportunity, the so called MARK-method (Meerkleurig Argumentatief ReferentieKader) analogy is used, which is based on the MRVO (Maatregel = Measure, Resultaat = Result, Verklaring = Explanation and Onderbouwing = Substantiation) that is developed by the RWS as a transparent assessment methodology that assesses biddings in an objective, structured and transparent manner (House of Tenders, 2025). In this research, the method is not used as a tender evaluation method, but is redesigned as a sustainability integration logic. The adjusted MARK-method is used to test whether the top opportunity is sufficient concrete enough, result-oriented, explainable and substantiated before it is anchored into project management workflows. The differences between the original method and redesigned one is show in Table 6.2.

MARK element	Original function	Application in this research
Measure	Describes what intervention or action will be carried out.	Defines the concrete sustainability action that must be implemented in the project management workflow.
Result	Describes what the measure delivers in relation to the objective.	Defines the expected sustainability and project management result, including the required evidence.
Explanation	Explains why the measure leads to the result.	Explains the causal link between the project management intervention and improved sustainability integration.
Substantiation	Shows why the proposed measure is realistic and credible.	Provides the evidence base, including MCDA results, project documents, expert input, available tools and lessons learned.

Table 6.2: Redesigned MARK-method for validating sustainability integration opportunities within the PPS-SIME Framework

The added value of this redesigned MARK-method is that it prevents sustainability top opportunities to remain abstract. A sustainability opportunity is only considered valuable and sufficiently developed when it is clear:

1. What are we going to do?
2. What does it deliver?
3. Why does it work?
4. Why should we trust that it will work in practice?

Especially for a top opportunity, because sustainability objectives that remain abstract without any clear ownership and link to project baselines, the top opportunity becomes irrelevant. As a result, sustainability ambitions end up becoming symbolic rather than steering mechanisms for project decisions. Therefore, the following main logic has been proposed for each related 'MRVO' (in English, 'MRES') aspect for each sustainable '*top opportunity*':

- **Measure - what are we going to do?**
  Establish a sustainability team consisting of a maximum of 5 experienced employees, all of whom have a connection to this specific '*top opportunity*' through their direct role or responsibility. This team ensures that this opportunity is prepared, monitored during phase transitions throughout the project (in the planning and design phases) and integrated into the entire project. Each one of them is responsible for a specific action related to the implementation of the opportunity.
- **Result - what does it deliver?**
  This sustainability team monitors the likelihood of any risks or negative external influences that could cause this '*top opportunity*' to be eliminated or become secondary. Beyond progress on the implementation of this sustainability opportunity, all observed influences are documented and shared within this team to ensure they can be monitored. Furthermore, it is essential that all other (partial) projects taking precedence over the monitoring and implementation process are communicated early on so that preparations can be made.
- **Explanation - why does it work?**
  Given the diversity within the team, which includes various disciplines, it is essential to schedule a central coordination meeting. These 5 experienced employees within the team are permanent staff members and possess knowledge at the strategic, tactical and operational levels within projects. They analyze every opportunity comprehensively and monitor the planning and capacity to ensure smooth realization and integration of the opportunity. This is achieved by scheduling structured consultations and feedback sessions.
- **Substantiation - why should we trust that it will work in practice?**
  The successful implementation of this '*top opportunity*' will be recorded in a lessons learned register, so that it can be structurally and potentially applied within projects of the same size and context. Apart from the implementation procedure, the team capacity (role, years of experience expertise and contribution) is also included in this.

This method has been redesigned for the context of this research and applied to further elaborate the *top opportunity* in detail based on the developed PPS-SIME Framework. This methodology helps with the issues identified in **SRQ1** as sustainability integration is fragmented, remains inconsistent in application and depends largely on individual roles and is insufficiently anchored within formal project objectives, baselines and performance indicators. Due to the main reason (being directly a top opportunity to do so), of missing SMART-formulated sustainability objectives during project initiation. Regardless of W+B having an advisory role.

6.1.2. Top opportunity implementation and validation

The *top opportunity* selected for analysis is positioned within the **Project Integration Management** domain, because the baseline setting is related to the cost, scope and time baselines within the project, documented in the PMP. These baseline settings are all defined base on the overall project purpose, objectives, assumptions and constraints. In case sustainability is not explicitly included within these sub-variables that define these baselines, then it is inherently not considered and consistently translated into the PMP. Therefore, updating the PMP (through these sub-variables) with

SMART-formulated sustainability objectives is a logical starting point for anchoring sustainability in the planning and design phase. In this research, the opportunity is applied through the redesigned MARK-method. This method is used as the validation bridge between the MCDA results, the PPS-SIME Framework and the practical implementation of the opportunity within W+B project control and management workflows. Before this is done, more context on a workshop (validation) session at W+B is given to elaborate extensively on the integration of this opportunity.

On Wednesday 3 July 2026 a workshop session was held internally at W+B, whereas two PMC's were preparing, attending and presenting ('Construction Management' and 'Circular Net Zero Solutions') that day with the main topic being sustainability. There was an opportunity to validate some opportunities related to this research and got some more additional information related to 'decision structures' at W+B around sustainability and beyond. These decision structures are highly dependent (as expected and concluded from the SSIs findings) on roles and responsibilities. The team structure that exists during the definition phase of a project with several roles are shown in Figure 6.1.

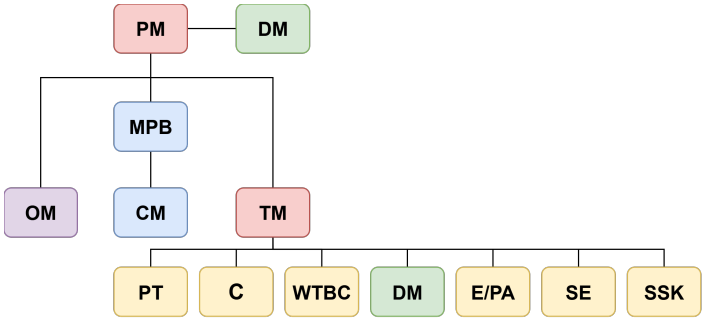


Figure 6.1: Sustainability in team composition within W+B (source: Author)

Based on the explanation of this team composition, the following was shared:

1. The Project Manager (PM) and Technical Manager (TM) (in **red**) are primarily responsible for ensuring that sustainability-related conditions and requirements are implemented.
    - PM is process-oriented, whereas this individual is responsible for structuring and defining the process steps in each project phase, maintaining contact with the client's sustainability team and approaching the trajectory from a top-down perspective.
    - TM is content-oriented, where as this individual acts as the primary point of contact within design teams, engages directly in design decision-making, is embedded in the overarching process and approaches the trajectory from a bottom-up perspective.
2. The Environmental Manager (OM) (in **purple**) interprets the MKI reporting as part of the EIA review process.
3. The Sustainability Manager (DA or SM) (in **green**) is an integral part of the overall process and project team, working closely with the Project Manager and contributing to the overarching governance led by the TM. In collaboration with the TM and PM, the Sustainability Manager (DA or SM) safeguards the process of sustainability integration and is responsible for conducting MKI calculations and identifying associated opportunities.
4. All TM disciplines (in **yellow**) provide input and act as sparring partners in the identification and evaluation of (sustainability) opportunities, helping to ensure a comprehensive and integrated overview of these opportunities.

The overall conclusion during this validation session of the PPS-SIME Framework, is that for sustainability integration it is essential to use the output (the SMC) with clear practical definition, therefore it is essential to do the following:

- Think through and clearly explain what you want to accomplish and specify exactly who or what is affected, as well as when, how, where and for what reason it will have an impact.
- Define the appropriate decision-making structure, who is authorized to provide input and/or make decisions regarding sustainability.
- Preconditions must be properly in place and not simply an MEAT commitment, but a genuine intention to address sustainability within the project.
- Ensure involvement of all stakeholders, as sustainability affects all aspects of a project:
    1. Project management
    2. Project control
    3. Environmental management
    4. Technical management
    5. Procurement and contract management

Measure - what are we going to do?
The implementation of this *top opportunity* '(***Formulate SMART sustainability objectives before PMP baseline setting***)' is carried out in a structured and process-driven manner. Prior to implementation, a dedicated *sustainability team* is established, responsible for executing the implementation first at the project level, subsequently within the organization and ultimately across the broader project ecosystem and supply chain. Each project in which a top opportunity and its corresponding SMCs have been identified is assigned to a sustainability team to ensure the effective implementation and operationalization of the opportunity. This process is governed through a defined *decision-making structure*, as visualized in the project management team hierarchy in Figure 6.1. This hierarchy shows which role carries the highest level of responsibility, depending on the nature of the identified sustainability opportunity.

For the sustainability *top opportunity* elaborated in this report, the team consists of a Technical Manager (TM), Project Manager (PM), Cost Engineer (CE) and Sustainability Manager (DA or DM). The Sustainability Manager (DA or DM) acts as the primary responsible role and leads the team. Once the team composition has been established, a *kick-off session* is organized for the sustainability team. During this session, the *group capacity* is defined and assessed based on the following aspects:

1. Introduction of team members
2. Years of experience (junior, medior, or senior level)
3. Expertise and responsibilities within each role
4. Expected contribution of each team member, based on points (2) and (3), to the realization of the top sustainability opportunity
5. Identification and resolution of conflicting contributions and recognition of reinforcing factors to ensure efficient sustainability integration
6. Documentation of the group capacity session. If the Sustainability Manager (DA or DM), in alignment with the team, considers the team capacity sufficient, the process proceeds to step 7. If not, a revised team composition must be established at the project or organizational level to ensure the feasibility of implementing the identified top opportunity
7. Development of a plan of approach within the sustainability team, focusing on the following 3 aspects

1. Support within organization
During the initial project meeting in the initiation phase (2–3 hours), involving the client and key primary stakeholders, the Sustainability Manager (DA or DM) is present to emphasize sustainability ambitions at both the project and organizational levels. This demonstrates that W+B attaches significant importance to sustainability within its projects. To strengthen this positioning, success stories and practical examples of sustainability integration are presented to the client, thereby supporting the process of **Evaluation** and actively convincing the client of the added value.

Following this initial meeting, the sustainability team conducts an internal session (+/- 1 hour) to assess and confirm the applicability of lessons learned. The key question addressed is whether, in the context of the identified top opportunity (derived from the SMCs), the project primarily utilizes existing lessons, generates new lessons or combines both. This step corresponds to the **Establishment** phase. If more lessons are learned than applied, this requires increased attention, as it may indicate higher levels of uncertainty and associated risks. Alternatively, if more lessons are reused than generated, this strengthens confidence within the sustainability team regarding the feasibility and successful implementation of the opportunity.

Regardless of the implementation outcome, all knowledge gained throughout this process is systematically documented and stored in a centralized lessons learned repository for use in future projects. This relates to the **Transfer** phase. By adopting this approach, no valuable knowledge is lost and all roles within the sustainability team are explicitly engaged in safeguarding the sustainability opportunity. In addition, new insights and experiences related to sustainability integration are continuously documented and centrally archived, ensuring ongoing organizational learning and improvement.

2. Encourage within the organization
The Sustainability Manager (DA or DM), as the primary responsible role, appoints together with the team, a suitable (internal or external) sparring partner to the project. This sparring partner is selected based on the identified sustainability opportunities linked to the SMCs derived from the PPS-SIME Framework. The sparring partner supports the team in exploring these opportunities and facilitates well-informed decision-making, with the objective of ensuring effective integration within the project. In addition to organizing Ambitieweb sessions, this partner serves as a practical knowledge source, sharing real-world expertise. Examples include knowledge institutes such as TNO and 3TU or specialists such as sustainability advisors in project management.

3. Challenge the chain collaboration
The SMC obtained from the identified top opportunity are, in addition to the previously described steps, translated into practice through the following n

1. **Collaboration with external sustainability actors**
   Partnerships are established with sustainability-focused organizations in project management, as well as with students conducting research on sustainability integration within the sector. The Technical Manager (TM) facilitates these collaborations from a commercial perspective.
2. **Participation in chain innovations**
   W+B, through its sustainability teams, actively participates in market-wide chain innovations and contributes insights on their impact on the engineering sector (e.g. green concrete or timber bridges). The Sustainability Manager (DA or DM) coordinates these activities.
3. **Application of research outcomes**
   Research results from knowledge institutes and students are actively applied in practice to strengthen sustainability integration. For example with HNN (Het Nieuwe Normaal, (Het Nieuwe Normaal / Cirkelstad, 2026)) This keeps the W+B innovative and up-to-date. This process is coordinated by the Sustainability Manager (DA or DM) together with company supervisors.

Based on a recent development within W+B (the C3 Project), a SMART-formulated sustainability objective is proposed in relation to the identified top opportunity:

'*The Carbon Cost Calculator (C3) is integrated into the cost estimation process to achieve at least 80% MKI coverage, define a project-specific MKI reduction target and enable quantitative comparison of at least 2 design alternatives, with results explicitly incorporated into decision-making during the preliminary design phase.*'

To make sure this opportunity is integrated, it is essential to include a dedicated sustainability section within the PMP. This ensures that such sustainability objectives are formally embedded during the project start-up phase (PSU phase) and prior to the finalization of the PMP baseline. A decomposition of this objective in each SMART component is provided in Table 6.3. Do note, that these SMART objective formulations can be created easier in case of mutual demand and agreement on the sustainability objectives throughout Ambitieweb sessions for example. If a mutual agreement is achieved between client and stakeholders, the baselines are easier to agree upon as well.

SMART criterion	Description
Specific	Integrate the Carbon Cost Calculator (C3) into the project cost estimation process to define project-specific MKI targets, ensure broad MKI coverage across cost items and enable quantitative comparison of design alternatives during the preliminary design phase.
Measurable	Achieve at least 80% MKI coverage of all cost items, define a clear MKI reduction target (e.g. $\geq$ 20% compared to a reference design) and perform a quantitative comparison of at least two design alternatives based on MKI values.
Achievable	The objective builds on existing cost estimation processes, where a direct match between cost items and MKI data is feasible for the majority (approximately 80%) of elements, supported by C3 automation and available datasets.
Relevant	The objective directly supports data-driven sustainability integration in early project stages, strengthens decision-making and contributes to regulatory developments such as increasing MKI requirements and sustainable procurement practices.
Time-bound	The C3 integration, MKI target definition and alternatives comparison must be completed before PMP baseline approval and applied during the preliminary design phase.

Table 6.3: Example of a SMART sustainability objective for integrating the Carbon Cost Calculator (C3) into project cost estimation (source: Author).

Result - what does it deliver?
Now that the criteria for the sustainability objective have been established, a structured approach, implemented by this sustainability team operating in a process-oriented manner, improves the feasibility of integrating this top sustainability opportunity. This approach enables well-informed decision-making and the execution of targeted actions, with team members acting according to their defined roles and responsibilities. The sustainability team therefore, monitors whether other conflicting objectives from stakeholders or client arise that could harm this sustainability objective. The report on this is shared by the Sustainability Manager (DA or SM) within the sustainability team. The DA or SM is also responsible to clearly identify and measure whether the other team members are available and have no other urgent project that could undermine their contribution in realizing this opportunity.

Transparent communication and effective collaboration form the foundation of this process and are essential for achieving integration of the opportunity. In addition, this supports the further development and strengthening of the sustainability DNA of W+B. The associated tasks and responsibilities are documented in Table 6.4. Based on this table, the indicators of the SMC can be assessed, providing insight into the extent to which this opportunity contributes to sustainability.

SMART criterion	Responsible role	Assigned task(s)
Specific	Cost Engineer (CE) + Sustainability Manager (DA/SM)	• **WP-01:** Define the project-specific sustainability objective • **WP-04:** Identify which cost item(s) can be linked to MKI data • **WP-05:** Configure and integrate the C3 methodology into the cost estimation process • **WP-07:** Determine which design alternatives will be included in the sustainability assessment
Measurable	Cost Engineer (CE)	• **WP-06:** Calculate the percentage of cost item(s) covered by MKI data • **WP-08:** Define the MKI reduction target • **WP-09:** Perform a quantitative comparison of at least 2 design alternatives • **WP-16:** Document all results, assumptions and calculation outcomes
Achievable	Technical Manager (TM) + Cost Engineer (CE)	• **WP-02:** Verify the technical feasibility of the proposed alternatives • **WP-03:** Assess the availability and reliability of MKI datasets • **WP-10:** Confirm that the required calculations can be executed within project constraints • **WP-11:** Validate whether the intended MKI coverage level is realistically achievable
Relevant	Project Manager (PM) + Sustainability Manager (DA/SM)	• **WP-12:** Align the sustainability objective with client ambitions and project goals • **WP-13:** Ensure sustainability criteria are included in project decision-making processes • **WP-14:** Integrate the objective into the PMP (**ACHIEVED!**) • **WP-15:** Communicate the sustainability objective and expected contribution to stakeholders and project team members
Time-bound	Project Manager (PM)	• **WP-17:** Define deadlines for C3 implementation and MKI calculations • **WP-18:** Incorporate sustainability milestones into the project schedule • **WP-19:** Verify completion of all sustainability deliverables before PMP baseline approval • **WP-20:** Monitor progress and escalate delays within the sustainability team

Table 6.4: Assigned responsibilities and sequential work packages for implementing the SMART sustainability objective related to the Carbon Cost Calculator (C3) within the sustainability team (source: Author).

Once a SMART sustainability objective is integrated into the PMP, its impact on the three project baselines becomes clear. First, the **scope baseline** includes sustainability as a mandatory requirement rather than just an ambition from the *initial project meeting in the initiation phase*. This means that sustainability directly influences design decisions. Second, the **time baseline** shifts more effort to early project phases, ensuring that sustainability is considered from the start and reducing the need for costly redesigns later on in the project. Lastly, the third **cost baseline** moves away from focusing only on lowest initial costs and instead considers LC value. Sustainability-related activities are explicitly included in the WBS, as shown in Table 6.4. Based on the tasks coupled to a role that is related to each criterion, the *top opportunity* '(***Formulate SMART sustainability objectives before PMP baseline setting***)' scores a 3.00 across all indicators/criteria, resulting in $V(a) = 3.00$, because:

- (***MaQ***) - Outcome
  The sustainability objective is SMART defined with explicit sustainability aspects, MKI coverage percentage of 80% and reduction targets with a quantitative comparison of two alternative designs. This is carried out through **WP-06**, **WP-08** and **WP-09** in Table 6.4. These indicators prove they are verifiable outputs that can be monitored and tracked throughout project LC. A more 'soft' outcome indicator could be the amount of changed decisions made due to the integration of this *top opportunity*.
- (***DL***) - Decision leverage
  The sustainability objective directly impacts project decisions (besides the fact that it is a project 'integration' component that results into this naturally). The integration of this objective into the PMP baselines through **WP-14**, automatically results into a formal decisions criterion during decision-making through **WP-12** and **WP-13**. Therefore, trade-offs and alternative assessments and project approvals are already considering the boundary conditions, shaped by these baselines, during decision-making. So, any decisions that impact sustainability must be clearly explained and recorded.
- (***E***) - Embedding
  The integration of objective depends on the rate of resistance or mutual agreement from the client and stakeholder for example. However, including a formal sustainable objective in the PMP baselines through **WP-14** on itself is not a hard task. The involvement of the roles (e.g. PM, TM, CE and DA or DM) in this sustainability team makes sure and proves that it is not dependent on individual motivation. As a matter of fact, it is anchored within project management structures that is supported through project planning, work package from the WBS and accountability instruments using a RACI/RAM-matrix through **WP-17** and **WP-18**. As a result of this, the sustainability opportunity remains traceable and resilient throughout the planning and design phase.

Explanation - why does it work?
In practice the added value of sustainability opportunities are often fragmented or even lost during transfer, gate reviews or handover moments, whereas the implementation of these opportunities stand still. Furthermore, without alignment within the internal 'sustainability team', client, involved stakeholders and research institutions, the success of sustainability integration remains uncertain. Often, the client is looking for a partner or collaboration who strengthen sustainability integration by actively supporting, encouraging and challenging, which is only established through a culture of continuous learning, collaboration and trust. The goal is to anchor sustainability in project control and management practices, where knowledge transfer is secured, collaboration on equal terms is established and continuous innovation and talent development are encouraged (through e.g., research institutions).

Therefore, central coordination meetings (1 time a week for 1 hour) with the 'sustainability team' is organized to define the right control level (strategic, tactical and operational) with the corresponding layer (individual, project and organizational) iteratively per meeting and understand what progress the opportunity makes and how to ensure alignment between everyone. To enforce this, there are voluntarily consultation session on fixed timeframes (2 times per week for 30 min) to ask question combined with feedback sessions (2 times per week for 30 min). The total amount of meetings and sessions is realistic, as was found by Stray (2018) that large-scale project employees spend 13.5 hours per week in meetings total, this in total not even 50% of the that amount of hours.

To realize the '**integration of SMART sustainability objectives before PMP baseline setting**' opportunity, alignment within the control level and layer must be established. This alignment ensures that sustainability objectives are not only defined, but consistently translated into decision-making, deliverables and individual actions. For this *top opportunity* the implementation is achieved through:

1. **Tactical project level - core implementation**
   In this level-layer combination it is about core implementation since the sustainability objective needs to be translated into concrete project management instruments. This is the most critical level for this *top opportunity*, because of the fact that the objective must be embedded before the PMP baselines are permanently fixed. The Project Manager (PM) is responsible for assuring that the objective is formally included in the PMP, as this is a verification for the project ambitions. Whereas the Sustainability Manager (DA or DM) safeguards that the sustainability part remains explicit and measurable. The Cost Engineer (CE) helps in this by linking the cost items to the MKI data an by preparing the required quantitative comparison.

   - The CE and DA/DM are both contributing to the definition of project-specific sustainability objective and link it to the cost estimation process (**WP-01, WP-04 and WP-05**). This process contributes mainly to the *MaQ* indicator, as it makes the objective measurable through the set MKI coverage and calculation approach.
   - The CE is calculates the MKI coverage, defines the reduction target and compares at least two design alternative (**WP-06, WP-08 and WP-09**). This also strongly contributes to the ***MaQ*** indicator, because it produces a verifiable quantitative result.
   - The PM and the DA/DM integrate the SMART sustainability objective into the PMP and guarantees that it becomes part of formal project decision-making (**WP-13 and WP-14**). This contributes mainly to the ***DL*** indicator, as the objectives evolved from an informal ambition to a formal decision criterion in the project.
   - The PM makes sure that the sustainability milestones are incorporated in the timeline and verifies completion before the PMP baselines are permanently fixed and approved (**WP-18 and WP-19**). By doing so, it contributes to the ***E*** indicator, because the opportunity becomes structurally anchored in project planning and (time) baseline control.

2. **Strategic organizational level - enabling conditions**
   In this level-layer combination the organization (W+B) creates and allows a condition in which repetitive application of this opportunity is possible across projects. It is not the level and layer where the objective is executed immediately, it is where standardization takes place such as templates and organizational learning structures are defined. The TM, PM and DA/DM all have a crucial role in translating lessons learned from this application into reusable project management and sustainability practices.

   - The TM and DA/DM assess if the required MKI datasets, calculation methods and technical assumptions are available and reliable (**WP-02, WP-03 and WP-10**) with a review of the CE as he is the one providing the results. This also contributes to the ***MaQ*** indicator as it determines whether the method is technically and practically possible.
   - The TM and CE validate together whether the intended MKI coverage level is realistic and feasible within the project context (**WP-11**). Again, this contributes to the ***MaQ*** indicator and the ***E*** indicator, because it checks both the measurability and practical feasibility.
   - The PM and DA/DM align the objective with the client ambitions, organizational sustainability goals and project management structures (**WP-12**), this mainly contributes to the ***DL*** indicator as it ensures that the objective is relevant for the project and client decisions.

- The DA/DM record and document the approach used, assumptions and outcomes so that this approach can be reused in (identical) future projects and incorporated in templates, lessons learned repositories or (adjusted) workflows or SOPs (**WP-16**). This mainly contributes to the ***E*** indicator, because it strengthens the organization learning and reduces dependency on individual motivation. Which is why the sustainability team is recommended in the first place, to gain a 'team' feeling.

3. **Operational individual level - execution and monitoring**
   In this level-layer combination the objective is translated into concrete tasks, actions by the involved project roles from the sustainability team. By doing so, sustainability integration is made sure not to remain a management intention, but it is reflected in calculations, design choices, reporting and (stakeholder) communication. The PM, TM, CE and DA/DM, each individual contribute from their own role (as was mentioned to encourage more and more regarding chain collaboration).

   - The TM verifies whether the proposed (minimum of 2) design alternatives are technically feasible (considering the technical requirements from the KES) and whether they can be properly compared from a sustainability perspective (**WP-02 and WP-07**). Again, this contributes to the ***DL*** indicator, as it ensures that the alternative choices are valid and relevant.
   - The CE makes the calculations and documents the assumptions, results and limitations of the MKI-based comparison (**WP-06, WP-09 and WP-16**). This contributes mainly to the ***MaQ*** indicator, because it creates measurable and verifiable evidence (type).
   - The DA/DM communicates the objective and (expected) contribution to the project team and stakeholders (**WP-15**). This contributes to the ***DL*** indicator, as it improves understanding of how sustainability should influence decisions.
   - The PM monitors progress, defines deadlines and escalates delays within the sustainability team with the others if necessary (**WP-17 and WP-20**). This contributes to the ***E*** indicator as it secures continuity, accountability and follows-ups during the planning and design phase.

This multi-(control) level and -layer approach combined, enables a strong interaction between levels and layers. Allowing the *top opportunity* to be effectively anchored in the PMP baseline setting, which as a consequence is safeguarded during project execution and strengthened through organizational learning. This proves that sustainability integration touches down on several levels and confirms the integrality nature. However, the most essential part for this opportunity is establishment of the tactical project level as this is where the core implementation of the opportunity takes place, but the combination of these levels and layers leads to acknowledgment of the opportunity, adoption and adjustment of current existing project management and control workflows or SOPs within the W+B. The 'sustainability team' is responsible that needs create an overview of this and determine which combination is the most critical dependent on the structure of the opportunity.

The moment **SMART formulated objectives are included in the PMP baselines**, that is where formal direction to the project and influences later planning, scope, cost, risk and other PM-domain related decisions. As this is also the moment the Project Manager (PM) receives a mandate to steer on sustainability as well. Once these baselines are fixed, any other drastic change or suggestion becomes difficult to implement. At that stage, sustainability often has to compete with already established objectives for time, cost and scope. Therefore, the earlier sustainability is translated into SMART project objectives, the greater the chance that it will influence actual project decisions (*DL*-indicator). So, the PMP is not only an administrative document, but a steering instrument that can reduce ambition erosion and improve sustainability integration during the planning and design phase.

Substantiation - why should we trust that it will work in practice?
The *top opportunity* '(***Formulate SMART sustainability objectives before PMP baseline setting***)' is in this research substantiated through 4 complementary perspectives that are basically performed in this research; theoretical (1) (through the SLR), empirical (2) (through the SSIs), organizational (3) (through findings of this report) and practical (4) (through findings of this report). Altogether, these perspectives provide proof to what rate this opportunity and methodology is realistic, feasible and reusable for other future projects.

1. **Theoretical**
   Theoretically, the used *top opportunity* is supported by both PMBoK and sustainability integration literature. **Project Integration Management** puts the essence on alignment of objective, baselines, governance structures and decision-making processes throughout the project LC. Sustainability objectives influence scope, cost, time, risk and quality decisions simultaneously, which implies that **Project Integration Management** is the most logical domain to anchor sustainability. Besides this, the SMART formulation of objectives is a main management principle to translate sustainable ambitions into measurable and actionable project outcomes.
2. **Empirical**
   Empirically, the *top opportunity* is supported by the findings from the SSIs and validated during the workshop session held within W+B. Often, it was stated by participants that sustainability integration depends on individual interpretation, timing and project context and circumstances. However, the workshop validated and confirmed

that sustainability must be anchored through clear decision-structures, role definitions and project management instruments. These finding directly support the need for SMART sustainability objective that are formally integrated into the PMP baseline approval.

3. **Organizational**
   Organizationally, the *top opportunity* builds upon existing existing structures within W+B. A proposed sustainability team for this opportunity consists of a PM, TM, CE and DA/DM, which reflects how decisions are actually made in the organization, as seen and validated during the workshop. Additionally, the opportunity does not require new management processes, but instead builds on existing instruments and tools like the PMP, WBS, RACI/RAM-matrix, planning and lessons learned repository. This indicates that the described approach can be implemented by adjusting current workflows or SOPs rather than changing the organization its structure.
4. **Practical**
   Practically, the *top opportunity* extensively treated in this research is supported by existing sustainability tools and methods (e.g. DuboCalc, the currently under development tool for C3 Projects, Ambitieweb and +CD Tool). These are already used at W+B to produce sustainability data that can be turned into SMART objectives and included in project deliverables for next projects. Furthermore, the work packages in Table 6.4 show that tasks, outputs and decision points can be assigned to current project roles. This means that *top opportunity* is not only feasible, but can also be reused in similar projects.

Combining all 4 types of evidence and elaborations, this *top opportunity* is not just theoretical based, but also supported by research, confirmed and validated by participants during a workshop, fits within existing W+B's organizational structure and can be implemented using current tools and expertise. However, it must be made clear that one run of assessing a *top opportunity* is not representative for all the others and the framework itself. Therefore, it must be performed for all the other opportunities too, before it can be considered reliable and mature enough to be applied in project management workflows through the PPS-SIME Framework and its corresponding SMCs for W+B (as an engineering consultancy company).

Standardized Measure Card (SMC) for the selected top opportunity

Based on the PPS-SIME Framework and redesigned MARK-method, the selected opportunity can be translated into the following Standardized Measure Card (SMC).

SMC field	Application to selected opportunity
Opportunity ID	SMC-01
PM-domain	Project Integration Management
PPS-component	Process
Name	Formulate SMART sustainability objectives before PMP baseline setting
Description	The PMP is updated with a dedicated sustainability section that defines SMART sustainability objectives, including sustainability indicators, target values, evidence methods (verification and validation), responsible roles, work packages and decision moments during the planning and design phase.
Evidence type	Approved PMP, SMART sustainability objective table, sustainability team meeting records, KES/Relatics requirements, project schedule, decision log, MCDA results, RACI/RAM matrix, sustainability calculations (MKI, CO_2, MCI, LCA/LCC) and lessons learned documentation.
Outcome indicator (MaQ)	Number of SMART sustainability objectives defined; percentage of MKI coverage across cost items; MKI reduction target achieved; number of alternatives quantitatively assessed; resulting sustainability performance indicators such as MKI, CO_2, MCI, LCA or LCC.
Decision indicator (DL)	Number of project decisions, trade-offs, design reviews, MCDA sessions, client approvals and alternative assessments in which SMART sustainability objectives were explicitly used as decision criteria.
Embedding indicator (E)	Number of SMART sustainability objectives embedded within the PMP, project baselines, KES, WBS, project schedule, risk register, decision log and RACI/RAM matrix; number of assigned sustainability work packages completed.
Level-layer combination	**Tactical – Project layer (primary):** sustainability objectives are translated into the PMP, project baselines, planning, requirements and project control instruments. **Strategic – Organizational layer (supporting):** organizational templates, sustainability guidelines, lessons learned and governance structures support consistent application across projects. **Operational – Individual layer (execution):** project roles execute calculations, document evidence, challenge requirements, assess alternatives and monitor progress against sustainability objectives.

Table 6.5: Standardized Measure Card (SMC) for integrating SMART sustainability objectives before PMP baseline setting.

Validation procedure and outcome

The *top opportunity* is validated using a practical, application-focused approach rather than a traditional project validation. The goal of implementation was not to demonstrate actual sustainability improvements in a completed infrastructure, as

this would require historical and relevant data across multiple phases. Instead, the validation assessed whether the opportunity is practical, logical, measurable, relevant for decision-making and if it fits in W+B's existing project management structures.

During the validation, the redesigned MARK-method (Measure, Result, Explanation, Substantiation) was followed in four steps for the *top opportunity*:

1. A proposal was made on the practical approach on how to integrate the *top opportunity* within the organization, whereas this *top opportunity* was check against SMART criteria given a current development about the C3 Project at W+B as an example.
2. The opportunity was evaluated using the PPS-SIME Framework criteria as indicators with assigned responsibilities per decomposed SMART aspect including work packages from the WBS:
    - Outcome - (***MaQ***)
    - Decision leverage - (***DL***)
    - Embeddability - (***E***)
3. The opportunity was reviewed from the point of view of the roles from the sustainability team on layer-level combinations.
4. The procedure of integration is reviewed in terms of theoretical, empirical, organizational and practical perspective.

The validation shows that the opportunity is suitable for use in Dutch infrastructure projects, as it can be tracked on from an outcome perspective during the planning and design phase. Proved by the use of MKI target and quantitative comparisons between design alternatives. From a decision-making perspective the opportunity allows to include objectives in the PMP, which ensures that sustainability becomes part of core decision-making processes. Same counts from the embedding perspective, because the responsibilities, work packages, documentation and accountability are assigned and linked to existing project management instruments or tools like the WBS, RACI/RAM-matrix, planning and the KES.

However, a limitation of this validation is that it does not demonstrate actual sustainability performance improvements of a current or completed infrastructure project. The validation provides evidence regarding the applicability and feasibility of the method rather than its long-term environmental, social or economic (TBL) effectiveness. To measure this, it would require a demonstration of the framework within a real infrastructure project and monitoring across multiple project phase transitions. This might be interesting for future research. In summary, the validation verifies that the selected *top opportunity* is sufficiently concrete, explainable and evidence based to serve as a first application of the PPS-SIME Framework. By defining SMART sustainability objectives before the PMP baseline is approved, sustainability becomes part of the project governance. This increases the chance that sustainability goals are reflected in scope, costs, risks, planning and design decisions during the planning and design phase. All previous sections and paragraphs now provide sufficient information to answer ***SRQ3*** and ***SRQ4***.

SRQ3 - Develop (diverge)

How can a (semi-)quantitative decision-support method or framework be designed from the selected PM-domain(s) in order to evaluate the effort and outcome of sustainability integration during the planning and design of Dutch infrastructure projects?

After the final findings of the application and validation, including the ones from the SLR, SSIs and the MCDA used to answers ***SRQ1*** and ***SRQ2***. The method developed is not one that should be only used as a separate sustainability assessment tool, it should be embedded as a in project management instrument. The methodology used under the analogy of the MARK-method, translates sustainability opportunities into measurable indicators, decision moments, responsibilities and project control documents (as evidence). Therefore, this research developed the PPS-SIME Framework, supported by the Standardized Measure Card (SMC) as a result and validated through the redesigned MARK-method.

In this research a *top opportunity* from the Project Integration Management domain is used as a starting point for the method, as it was the best scoring domain, reflecting the highest potential, from the MCDA result. Even more important, is that this PM-domain is integrative and connects project objectives, the PMP, baselines, decision-making and many other facets together, making this domain most essential for anchoring sustainability before it becomes fragmented, as it allows connection to other PM-domains. In essence the method is designed, using 4 connected building blocks:

1. Identify both theoretical (e.g. PMBoK) and practical (e.g. SSIs) sustainability integration opportunities (on PPS-level). Creating an integrated opportunity register.
2. Evaluate and assess the opportunities from the opportunity register using an MCDA on the relevant criteria (e.g. Quantifiability (MaQ), Decision Leverage (DL) and Embeddability (E)). These are also used as indicators in the PPS-SIME Framework:
    - **Outcome indicator** (***MaQ***)
      Direct sustainability outcomes that are measured through MKI, CO_2, MCI, LCA/LCC or even other project specific indicators from 'softer' measurements instead of hard numerical evidence.
    - **Decision indicator** (***DL***)
      The extent of impact of the sustainability opportunity on project choices that are selected, accepted, prioritized or rejected on trade-off analysis, design alternatives or client decisions for example.
    - **Embedding** (***E***)
      The extent of how anchored the sustainability has become in project management and control practices and instruments through the PMP, WBS or KES using Relatics as PMIS for example.
3. Collect all *top opportunities* that rank the highest and position them in the PPS-SIME Framework using 3 dimensions; indicator type (1), control level (2) and layer (3).
4. Translate and create this into a Standardized Measure Card (SMC) that can be used in practice conform the redesigned MARK-method.

The semi-quantitative part of this method is created through the MCDA scoring model, also the Weighted Sum Model (WSM) as elaborated earlier. In this research the (***MaQ***) contains the highest weight because the main goal in this research is to make sustainability tangible before it can be influence (in)directly any project decisions. Therefore, the decision leverage indicator (***DL***) is weighted second because any opportunity is only relevant if it can impact what is selected, accepted, prioritized or rejected. As last, the indicator embeddability (***E***) is weighted third, because as it works from the earlier two indicators than the implementation should be no issue, since it is evidence (from (***MaQ***)) and practical (from (***DL***) based, becoming easier to anchor this into project management or control structures if it is to survive personnel changes, time pressure and shifting priorities.

The distinction of these indicators within the PPS-SIME Framework is essential because not all sustainability opportunities that contribute can be measured as a direct numerical environmental or financial outcome during the planning and design phase. Some of them are more process- or decision-based and are measured in more practical 'softer' observations instead of hard numerical evidence. The opportunity of '**Formulation SMART sustainability objectives before PMP baseline setting**' may not directly reduce the MKI or CO_2-emissions, but in project control and management this improves decision quality and prevents sustainability ambitions from disappearing later in the project. This is worth notifying as the evidence might differ in this sense.

The effort of sustainability integration is also included in this method, not as calculated in hours, cost or staffing levels as this would require more real project and organizational data that is not incorporated in this research. Instead, effort is represented as through which control level and layer the opportunity must be applied for successful adoption and integration. The control level shows whether the opportunity affects strategic, tactical or organizational project management (within the company of W+B in this research). The layer shows whether the opportunity depends on an individual level, is anchored at project level or can be standardized at organizational level. This makes it possible to assess whether the opportunity is relatively easy to implement within an existing project workflow, or whether it requires broader organizational standardization. Parallel to this, the importance and urgency of the opportunity can be identified to some extent. An opportunity on organizational level that is strategically oriented is more important than one on individual level that is operational oriented, however both are essential to be integrated to reach full potential as a company.

The SMC is the output of this method with PPS-SIME Framework as a basis, which prevents the MCDA from to remain a 'lonely and abstract' raking exercise. Regardless of the fact that it was a subjective approach with relatively low amount of criteria and corresponding scores for some reason, this is discussed in Chapter 7. Each opportunity that leads to a SMC records the opportunity ID, PM-domain, PPS-component, description, evidence type, indicator elaboration, MCDA score, control- and layer level. This allows the SMC to be used for practical implementation, as a project manager (PM) or sustainability advisor (DA), can use the card to understand what the opportunity means, what evidence is required and where it should be embedded and how it can be monitoring during the planning and design phase. The real reason on how this should be be executed is depending on the redesigned MARK-method for this sustainability integration context, this should be utilized as a validation logic for the selected opportunity. The (MRVO, also MRES in English) logic is that the opportunity should describe very clearly on what it Measures (change), what it produces as a Result (outcome), Explain what the actual implementation implies (elaboration) and Substantiate by finding evidence or proof and explain this (evidence). This validation logic makes the opportunity more robust because it requires a clear causal argument between the proposed measure and the expected sustainability integration outcome.

In conclusion the semi-quantitative decision-support method is designed by combining the MCDA prioritization of opportunities with the PPS-SIME Framework resulting into the assisting SMC. The MCDA determines which (theoretical or practical) opportunities have the highest potential. The PPS-SIME Framework determines how the opportunities can be measured, where they should be controlled and at which layer they should be anchored. The SMC translates this into an actionable project management instrument using the redesigned MARK-method. This method tests whether the selected opportunity is sufficiently concrete, result-oriented, explainable and substantiated. Together, these elements create a decision-support method that evaluates both the expected outcome of sustainability integration and the effort required to embed it in existing project management workflows during the planning and design phase of Dutch infrastructure projects. However, it should be mentioned that the method must be critically reviewed and interpreted as it does not yet prove actual sustainability impact in complete projects. Instead, it evaluates the integration potential, decisions relevance and evidence structure of sustainability opportunities. Real actual impact, requires application in real time projects over time with a comparison of (soft) indicators (e.g. MKI, CO_2 or 'a new internal sustainable workflow') before and after the project, elaborated in Chapter 7. Within the scope of this research, the method therefore functions as a structured and semi-quantitative decision-support framework for making sustainability measurable, actionable and embedded, rather than as a final proof of sustainability performance.

SRQ4 - Deliver (converge)

How does the developed method (or potential framework) perform in a real-life infrastructural project and which lessons learned enable reproducibility of the approach for other PM-domain processes and organizations?

The developed PPS-SIME Framework can be used as a structured, semi-quantitative and application-oriented decisions-support instrument for making sustainability opportunities measurable, actionable and embedded within existing project management workflows or SOPs. As this is applied to one of the '*top opportunity*' within the **Project Integration Management**, which is '***Formulate SMART sustainability objectives before PMP baseline setting***'. The framework proves that it can translate a MCDA prioritized opportunity into a complete MARK-validated SMC that is internally consistent, measurable in terms of outcomes, decision and embedding indicators besides that fact that it is reproducible across comparable Dutch infrastructure projects within Dutch planning and design phase. However, the following lessons learned are obtained from the application:

1. **Governance comes first**
   A precondition for successful implementation is the establishment of a well-structured sustainability team with clear defined roles, responsibilities and contribution depending on the opportunity. This identifies the overall team capacity. No having this, even well defined SMART objectives are risk being deprioritized and lose attention during phase transitions or handover moments.
2. **Timing is critical**
   The sustainability objectives must be applied and included early in the PMP, before the project baselines (cost, scope and time baselines) are fixed. Because, after this point, any new sustainability idea, request or solution often face resistance, as the opportunity to influence decisions has passed.
3. **Adjust existing tools instead of adding new ones**
   The PPS-SIME Framework is intuitive and easy to apply when it is build on existing project management documents (e.g. PMP), rather than introducing separate new sustainability procedures. This lowers effort, time and increases the chances of adoption.
4. **Measurability requires a baseline or reference level**
   (Soft) quantified sustainability targets or measures (e.g. 'X' MKI reduction or 'Y'% reuse of material) can only be defined when a reference design or baseline is available. If this is not the case, then the initial objective should focus on comparing alternatives and documenting trade-offs, with quantitative targets added later on as the design develops.
5. **Capture lessons learned systematically**
   The long-term value of the PPS-SIME Framework depends on consistent documentation of results, team setups, challenges and success in a central (lessons learned) repository or register. If not done, then each project starts from scratch and the framework becomes harder to use won't be optimized iteratively.
6. **Collaboration across chain increases impact**
   The PPS-SIME Framework is most effective when the sustainability objectives are developed and monitored together with clients, contractors and partners. This shown under the '*3. Challenge the chain collaboration*' within the **Measure** element of the MARK-method and provides the opportunity to benchmark, innovate and share learnings and lessons.

In summary, the redesigned MARK-method applied on the PPS-SIME Framework shows that the *top opportunity* is clear, explainable and well supported which makes it a strong first application of the PPS-SIME Framework. Hence, by embedding SMART sustainability objectives in the PMP before the baselines are set, sustainability becomes part of the project's core decision-making. This increases the chance that sustainability is reflected in scope, cost, risk and planning decisions rather than remaining an informal ambition that might phase over time due to ambition erosion.

7

Discussion and limitations

7.1. Discussion

7.1.1. Overview of main findings

This research addresses a persistent and practical relevant gap in Dutch infrastructure project management, which continuous to be the limited measurability of sustainability efforts at the level of PPS within the 10 PM-domains during the planning and design phase. In this report the research is guides by a DSRM, structured through a Double Diamond lens. This research produced 4 interconnected results as it is corresponding to the 4 sub-research questions (***SRQs***). The SLR that is completed during the Discover phase showed that sustainability integration within PM-domains remains fragmented in practice. Despite the growing regulatory pressure in the Netherlands and constitutional commitment to sustainability in Dutch infrastructure sector, the current state of sustainability (integration) is best summarized as increasingly recognized and important, yet insufficiently standardized and adopted. Sustainability is visible across the 10 PM-domains through specific PPS-components in Table 4.9 and Table 4.10, but its application depends mostly on individual roles and (intrinsic) motivation rather than on formal project instruments, baselines or performance indicators. The absence of SMART formulated sustainability objectives as a process, at project initiation, is identified as one of the central structural gaps.

The MCDA completed in the Define phase proved that, across 305 identified sustainability integration opportunities, the **Project Integration Management** domain ranks highest with an average weighted score of $V(a)$ is **2.52**, followed by Project Cost Management with **2.45**, Project Risk Management with **2.43**, Project Scope Management with **2.40** and Project Time Management **2.37**. On an important note, the Process-component of the **Project Integration Management** had the highest average component score of $V(a)_{component}$ is **2.60**, showing that the strongest integration potential does not lie in individual tools, but in the way sustainability is anchored in existing project workflows, coordination and decision-making structures. Building up on these results, the Develop phase produced the PPS-SIME Framework, which stands for 'Product–Process–Service Sustainability Integration and Measurability Embedding Framework' that is eventually supported by a SMC. This framework translates sustainable '*top opportunities*' into measurable (soft) outcome, decision and embedding indicators that are structured across 3 control levels (strategic, tactical and operational) and 3 organizational layers (individual, project and organizational). This framework is validated by using a redesigned MARK-method (Measure, Result, Explanation and Substantiation, by House of Tenders (2025)), applied to the '*top opportunity*': '***Formulate SMART sustainability objectives before PMP baseline setting***'. The last phase, the Deliver phase confirmed that this opportunity is practically feasible, consistent and reproducible within the organizational context of W+B, as was affirmed during an internal workshop and validation session 3 June 2026, involving key project roles and PMC's related to sustainability.

7.1.2. Interpretation of results

The results show that making sustainability measurable within infrastructure project is not mainly a technical shortcoming, but also a structural and governance problem (within an engineering consultancy firm like W+B). The **1st** ranked **Project Integration Management** domain proves that sustainability is inherently integrative as it touches all project management domains at the same time. Therefore, it is also the most vulnerable to fragmentation when no overarching coordinating person or team takes ownership of it. This is confirmed by the fact that the Process-component outperforms the Product- and Service-component across the top 5 PM-domains. This implies that sustainability is not absent from project outputs, but from the processes and decision logics that determine which outputs are produced and on what terms. This verifies the identification of a '*central paradox*' in Chapter 4. The early planning and design phase (FEDP) is acknowledged as the phase with the biggest potential and moment of leverage over long-term sustainability outcomes because of relatively low design rigidity and high decision flexibility (Bragança et al, 2014). But at the same time, it is exactly in this phase that sustainability ambitions are most vulnerable to erosion (Veen, 2023). The findings from the SSIs proof and simultaneously confirm this 'central paradox' whereas, according to the participants, that sustainability objectives formulated at a high and abstract-level tend to disappear over time as project baselines are fixed and cost, time and scope constraints become dominant and urgent. This phenomenon, referred to in this research as 'ambition erosion', appears to be directly related to the absence of formal SMART-formulated sustainability objectives in the PMP prior to baseline setting. Additionally,

it appears that the natural advisory role of engineering consultancy firms like W+B creates a tension. Despite the fact that sustainability expertise is available within the organization, the authority to push sustainability requirements through belongs mainly to the client and the contract. Without any explicit SMART formulation of sustainability objectives in the project, the position of W+B remains as a sustainability signaler rather than a steerer.

7.1.3. Positioning with existing literature

The observation that sustainability integration in infrastructure project management remains fragmented and role dependent, aligns with earlier studies from A. G. Silvius and Schipper (2014) who noted that sustainability considerations are barely embedded in formal project management tools and tend to depend on commitment of individual project managers. As well as Ahn et al. (2013), who identified a persistent gap between sustainability intentions and the instruments available to operationalize them at project level. This research extends these findings by proving that the gap is not only about the tools availability, but the structural anchoring. Ambitieweb, DuboCalc or CO_2-Prestatieladder are available and used, but still remain disconnected from the formal project control and management instruments or documents that steer decision-making. Besides this, the prioritization of **Project Integration Management** corresponds to the conclusion drawn by Keleş et al. (2025) who argues that a more 'systematic adoption of sustainability', particularly in integration management, allows a transparent and traceable process aligned with sustainability objectives. This research demonstrates that especially the Process-components of **Project Integration Management** is the domain where the highest quantity of measurable, decision-relevant and embeddable sustainability opportunities is found. The emphasis on *SMART-formulated sustainability objectives before baseline setting* fits with the findings by Bragança et al (2014) who argued that early-stage design decisions are the basis of LC sustainability performance. The developed PPS-SIME Framework and its associated SMC can therefore be seen and understood as a methodological approach to the structural gap identified in the SLR in infrastructure practice. Namely, the absence of a project management instrument that translates abstract sustainability ambitions into binding, verifiable and decision-relevant project requirements before cost, time and scope baselines are fixed.

The MCDA used as an underlying framework to prioritize sustainability integration opportunities is consistent with the current broader methodological trend in sustainability assessment research. By doing so, transparency and replicability of multi-criteria approaches are valued in context of competing priorities and limited data availability (Bueno Cadena et al., 2015). However, the 3-criterion structure used in this research (***MaQ*** - ***DL*** - (***E***)) represent a significant simplification relative to more detailed MCDA frameworks found in the literature. On the other hand, this choice was made with the intention to improve analytical clarity given the volume of 305 opportunities being assessed. Although this volume does carry the risk of information loss, as acknowledged by Silva et al. (2016).

Project Risk Management - W. Wong

The findings of this research are consistent and have an interface with earlier work conducted within W+B context on the integration of sustainability into project risk management. Wong (2024) proposes that sustainability should be included into risk management through 3 methods, namely by defining sustainability ambition (1), expanding risk classification (2) and including sustainability indicators in risk evaluation (3). This is relevant to this research, because it proves that sustainability can be translated into existing project management and control instruments rather than being treated as a separate and individual advisory activity. A main distinction is that Wong (2024)'s work focuses specifically on the **Project Risk Management** domain, whereas the developed PPS-SIME Framework developed in this research takes a broader PPS-level perspective across the 10 PM-domains and applies the first validation to **1st** ranked **Project Integration Management**. Therefore, Wong (2024) should not be interpreted as a validation of PPS-SIME Framework, but as a complementary domain-specific example that could support future development of SMC for sustainability in risk management.

7.1.4. Implications

The findings of this research contain several values for practice, methodology and theory. From a practical (1) point of view, the PPS-SIME Framework provides a practical, structures and semi-quantitative instrument for identifying, prioritizing and embedding sustainability integration opportunities within existing project management and control workflows or SOPs at W+B and comparable Dutch engineering consultancy companies. The SMC offers a project level instrument that can reduce ambitions erosion as it translated top opportunities into actionable structures, defined responsibilities and decision moment. The example '*Formulate SMART sustainability objectives before PMP baseline setting*' proves direct actionable recommendations including standardization in existing project documents. From a methodological (2) point of view, the redesigned MARK-method proves that sustainability opportunities can be validated in terms of internal logic, measurability and reproducibility without requiring real-time or historical project data. This approach provides a practical way to evaluate methods based on their design and application, rather than relying solely on end results. This is useful, especially for projects that span multiple years and where relationship are harder to determine and identify. Perhaps this might be a validation process that could be build on in future research, by monitoring SMC implementation across different project phases.

From a theoretical (3) point of view, the developed PPS-SIME Framework adds value to the growing body of research at the intersection of sustainability science and project management, by proposing a framework through which the documented gap between sustainability intention and sustainability performance can be addressed (in this example at opera-

tional level). However, the framework's 3-dimension structure (indicators, control levels and layers) offer a transferable conceptual model for examining how sustainability governance can be operationalized within complex multidisciplinary projects. Finally, the findings indicate that measurability of sustainability in infrastructure project is a necessary pre-condition for sustainability steering. However, without measurable objectives, sustainability cannot be monitoring or strengthened. The PPS-SIME Framework is therefore not only a decision-support tool, but also a steering instrument that creates the condition under which sustainability can compete on equal terms with traditional project control drivers (cost, time and scope) in project decision-making.

7.2. Limitations

Despite all the contribution as described above, this research is also subject to a couple of methodological, contextual and scope related limitations that must be recognized and mentioned in order to support a properly balance interpretation of the findings.

7.2.1. Single organization context and limited transferability

The most significant and clear limitation of this research is its isolated approach within a single engineering consultancy firm, W+B. All 18 SSIs were conducted with employees of W+B, as well as the application and validation of the PPS-SIME Framework were conducted within W+B's organizational workflows and project context. As the research design does explicitly state this boundary condition, it implies that the findings reflect only the sustainability integration challenges, organizational culture and decision-making structure of one specific firm. Namely, an engineering consultancy firm with an advisory, rather than a contracting role that operates in Dutch regulatory environment. As a consequence, the generalizability of the results to other organizational type (e.g. public clients, main and subcontractor or governmental bodies like RWS or ProRail), to other national regulatory contexts or to infrastructure projects beyond the planning and design phase still remain uncertain. However, this might be an opportunity for future researchers to conduct comparative studies across different organizations, to test whether the MCDA ranking and the PPS-SIME Framework still holds under different organizational context and logics.

7.2.2. Subjectivity of the MCDA scoring

The MCDA performed during this research relies on a 3-point scoring scale that is applied across 305 sustainability integration opportunities. Besides the fact that the scoring criteria were defined and the assessment was informed by both the SLR in Chapter 3 and practical findings in Chapter 4 from the SSIs, the scoring process involved expert judgment and was done subjectively indicating some bias. As Silva et al. (2016) states that when the scoring range is too limited, the method cannot clearly distinguish between better and worse options, which may hide important differences between them. Additionally, the weighting of the 3 criteria (***MaQ*** (0.45) - ***DL*** (0.35) - ***E*** (0.20)) reflects that this research mainly focused on making sustainability tangible (hence measurable) and decision-relevant during the planning and design phase. As these weights are not universal, using a different emphasis (e.g. stakeholder engagement or long-term asset performance) the analysis would likely lead to different results. Future research could address this by testing alternative weighting schemes or by involving independent experts to assess consistency in the scoring, perhaps through a sensitivity analysis. More elaborated on in Chapter 9.

7.2.3. Scope restriction to planning and design phase

This research is scoped only to the planning and design phase (FEDP) of Dutch infrastructure projects and does not address sustainability integration during project execution, operation and maintenance phase. Aside from the fact that this was intentionally bounded due to the active role in these phases by W+B and methodologically justified (given that most leverage is in this phase related to sustainability outcomes). However, this does give a blind sport for feedback, as the long-term effectiveness of *SMART sustainability objectives being formulated during the PMP baseline* can only be assessed by tracking their progress and development in the phases afterwards. This falls outside the scope of this research. Future research should apply the PPS-SIME Framework throughout the entire project LC and assess whether SMART sustainability objectives defined early on are actually maintained in later project stages. Tracking projects long term on sustainability ambitions from project initiation to asset could provide evidence on whether sustainability ambitions result in real performance improvements, instead of only demonstrating their potential for integration, as done in this research.

7.2.4. Application-focused validation approach

The PPS-SIME Framework and the redesigned MARK-method is conducted as an application-oriented validation, which implies that the method was assessed against criteria of internal consistency, measurability and reproducibility. Instead of against observed improvements in sustainability performance within a (completed) infrastructure project, as is stated in Chapter 6. This limitation arises from the practical constraints of the research timeline, (multi-)year duration of projects and participant availability. The causal claim that embedding '*SMART sustainability objectives in the PMP before baseline setting*' remains theoretically grounded but empirically unverified in a real project setting. Future research could address this gap by applying the SMC within an ongoing Dutch infrastructure projects and track how often *top opportunities* are used, as well as how sustainability (indicators) result changes over time.

7.2.5. Generalizability of the framework

Lastly, the PPS-SIME Framework proposed concerns the generalizability beyond the specific context in which it is developed. Most of the identified opportunities came from the SSIs conducted within a single engineering consultancy firm (W+B) as noted in Chapter 5, meaning that the findings are inherently shaped by the organization's workflows, project types, client base and internal governance structures. Whereas the opportunities derived from the PMBoK are theoretical and therefore more transferable across organizations, the practical opportunities and their MCDA scores reflect the priorities and working practices of single company in a specific sector. As a result of this, the identified '*top opportunities*' may not apply in the same way to other organizational contexts (e.g. contractors, public sector clients or companies in other industries) where the importance and weighing of criteria (***MaQ*** - ***DL*** - ***E***) may vary. This limits the generalizability of the resulting rankings. Future research should replicate the SSIs and MCDA process across a wider range of organizations, project types and sectors to determine which opportunities (within the chain collaboration) consistently rank highly across contexts and which are context-specific. Perhaps it even might require adjustment of the initial PPS-SIME Framework for applicability of the framework. By approaching it in such a way, then it would allows for comparison of criteria weightings between practitioner groups, providing insight into whether the relative importance of the criteria remains stable or varies across organizational settings.

8

Conclusion

This research was motivated by a structural gap in Dutch infrastructure project management, namely the difficulty of translating sustainability ambitions into measurable and decision-relevant requirements during the early planning and design phase. Projects such as the Betuweroute and the Amelisweerd A27 for example, demonstrate the consequences of weak sustainability integration at this stage, where the potential to influence long-term outcomes is greatest due to 'lock-in' effects, but the mechanisms to act on that potential remain underdeveloped. Against this background, this research addressed the following main research question below

Main research question

How can the measurability of sustainability efforts of products, processes and services (PPSs) within the PM-domains be improved to enhance sustainable decision-making in Dutch infrastructure projects during the planning and design phase?

In this research the answer to this main research question was developed through a structured DSRM that was approached using a Double Diamond model, as shown in Figure 2.2. The process was follows through 4 phases: Discover, Define, Develop and Deliver. Each of the phases contained a sub-research question (***SRQ***), with each answer to the question building directly on the one before. In this chapter, each sections summarizes the answers to each ***SRQ1–4*** before formulating a comprehensive and complete answer to the main research question as stated above.

Answer to SRQ1

SRQ1 - Discover (diverge)

What is the current state of sustainability integration within the PM-domains at the PPS-level during the planning and design phase of a Dutch infrastructure project?

To conclude for sub-research question 1 (***SRQ1***), the current state of sustainability integration in the planning and design phase of Dutch infrastructure projects at PPS-level can be described as increasingly *recognized but still fragmented in practice*. Based on the SLR and 18 SSIs with employees from and at W+B, sustainability is visible across all 10 PM-domains, through different PPSs. However, it s not yet consistently anchored in formal project management practices and routines (SOPs). The rate of integration is strongly dependent on individual roles, (intrinsic) motivation, client demand instead being reliant on standardized project instruments, baselines responsibilities or performance indicators. The biggest pain point and central gap identified is the '***Lack of SMART formulated sustainability objectives in the PMP before baseline setting***'. Not formulating these objectives, sustainability ambitions remain abstract ('non-essential') and vulnerable ('hard to steer upon, if not measured'), due to *ambition erosion* whereas cost, time and scope become dominant during later stage decision-making. Another reason that increases the fragmentation problem is limited standardization of tools (e.g. DuboCalc, +CD Tool and CO_2 assessment) besides the fact that W+B has an advisory mandate, which can structure, advise and signal sustainability opportunities. They do not have the authority for final project decisions after the FEDP. Therefore, the main issue is not the absence of sustainability awareness, but the lack of systematic anchoring in project governance, decision-support systems and PPS-level project management and control.

The central paradox identified in ***SRQ1*** directly raises the question of *where* within the PM-domains the leverage to break this fragmentation is highest. This is addressed in ***SRQ2***, which identifies the PM-domain and PPS-component that offer the strongest potential for structured and reproducible sustainability integration.

Answer to SRQ2

SRQ2 - Define (converge)

What is the highest PPS-based project management domain(s) and component(s) that offer the highest potential for (semi-)quantitative sustainability integration, considering the effort required within existing workflows and the reproducibility of the method across different Dutch projects?

The answer to ***SRQ2*** is conclusively provided by the answer obtained from the MCDA that is applied to all 305 found (theoretical and practical) sustainability integration opportunities across 10 PM-domain. **Project Integration Management** is identified as the highest potential PM-domain, with an average weighted overall score of $V(a)$ of 2.60. This indicates that sustainability integration is most promising if it is anchored within the coordinating and steering instruments of the project (or PPS-components). Instead of treating sustainability (integration) as a separate advisory activity. This is follows the finding on ***SRQ1***, which identified that in case sustainability is not anchored in project governance (management and control), it still remains vulnerable by being dependent on individual motivation, client demand ('uitvraag') and phase specific interpretation. The Process-component is the highest scoring component in **Project Integration Management**, with an average of **2.60** showing that the best opportunities are in anchoring sustainability into existing workflows or SOPs. For example, the outlined *top opportunity* '***Formulate SMART sustainability objectives before PMP baseline setting***'.

Besides the **Project Integration Management**, the following top 4 domains are **Project Cost, Risk, Scope and Time Management** and show strong relevance, as they serve as supporting control domains through which sustainability can be measurable and actionable in practice. This means that these domains are important for operationalizing sustainability, but do not primarily drive its integration within projects as much as **Project Integration Management**. Therefore, this domain is selected in this research as the primary domain for further method development. This is not only because of its highest score, but also because it connects and aligns the other PM-domains inherently. In practice, this domain maintains coherence within a project as is proven by the IPM-model used at W+B (Rijkswaterstaat, 2026c). As a result of this, starting sustainability integration within this domain, it benefits potentially spreads out to the other domains, as it influences formal project documents, baselines, monitoring structures and responsibilities.

After knowing *where* the highest potential lies out of the 10 PM-domains are corresponding PPS-components with opportunities. The next logical step is to address *how* this potential can be translated in a structure, semi-quantitative decision-support method. ***SRQ3*** answers this by developing the PPS-SIME Framework and the SMC as an operational end product or instrument that converts the MCDA rankings to a (theoretical) actionable project management instrument.

Answer to SRQ3

SRQ3 - Develop (diverge)

How can a (semi-)quantitative decision-support method or framework be designed from the selected PM-domain(s) in order to evaluate the effort and outcome of sustainability integration during the planning and design of Dutch infrastructure projects?

Building on the findings fragmentation in ***SRQ1*** and prioritization determined in ***SRQ2***, this research developed the PPS-SIME Framework as a semi-quantitative decision-support method for anchoring sustainability into project management and control practices as an answer to ***SRQ3***. This method is not designed as a separate sustainability assessment (SA) tool, but it served as a project management method that translates sustainability opportunities into measurable indicators, decision moments, responsibilities of roles and provided project control evidence. The method consists of 4 main and connected steps:

1. Sustainability integration opportunities are identified at PPS-level both from theoretical and practical sources
2. The opportunities are evaluated and prioritized through a (subjective) MCDA with the necessary criteria, weights and scoring scale (e.g. (***MaQ***-0.45), (***DL***-0.35), (***E***-0.20) with scores from 1-3)
3. The *top opportunities* are positioned within the PPS-SIME Framework including their indicator type and elaboration (based on criteria score), evidence type, control- and layer-level elaboration.
4. Each selected *top opportunity* is translated into a SMC using the redesigned MARK-method (Measure, Result, Explanation and Substantiation).

By doing so, each opportunity is made concrete, focused on results, explainable and evidence-based before it is anchored in project workflows or SOPs. In this developed method, the expected outcome of sustainability integration is evaluated through the type of evidence that is linked to the opportunity, so both hard (quantitative) evidence (e.g. MKI-reduction or 'X'% reused material) and soft evidence (qualitative) (e.g. 'Z' number of adjusted decisions due to integration of opportunity 'A'). This confirms the semi-quantitative naming. The required effort to realize the actual SMC related to the opportunity, is not calculated in hours, costs of staffing levels, as this would require additional historical or real project data, which is beyond the scope of this research. Therefore as an alternative, the effort is represented through the control- and layer level at which the opportunity must be anchored. This positions the opportunity at the exact level of where it belongs to for implementation and this creates clusters, groups or batches between opportunities. Distinguishing whether an opportunity needs to be implemented through an operational project level document or require broader organizational treatment. Conclusively, the PPS-SIME Framework evaluates the integration potential, decision relevance and evidence type(s) of sustainability opportunities. It should not be interpreted as final proof of actual sustainability performance, but as a structured and semi-quantitative decision-support method for making sustainability more measurable, actionable and embedded during the planning and design phase of Dutch infrastructure projects.

Using the developed method through the PPS-SIME Framework in ***SRQ3*** the final and last step is to test how it performs when it is applied to the opportunity within W+B's project management context. The lessons learned allow its reproducibility beyond the first application as it will provide answers to ***SRQ4***.

Answer to SRQ4

SRQ4 - Deliver (converge)

How does the developed method (or potential framework) perform in a real-life infrastructural project and which lessons learned enable reproducibility of the approach for other PM-domain processes and organizations?

Providing an answer to ***SRQ4***, based on the application of the PPS-SIME Framework through the *top opportunity* '***Formulate SMART sustainability objectives before PMP baseline setting*** of the **Project Integration Management** domain. The framework shows that it can function as a structured, semi-quantitative and application oriented decision-support instrument within the planning and design phase of Dutch infrastructure projects. The framework translates an MCDA *top opportunity* into a SMC through the redesigned MARK-method. However, this is done by defining a sustainability team based on W+B's 'decision-structure'. This makes the opportunity concrete by specifying what are we (the team) going to do (1), what does it deliver (2), why does it work (3) and why should we (the team) trust that it will work in practice? The application indicates that the method is practically feasible because it builds on an existing project management document, the PMP, rather than another new separate procedure or document. Furthermore, it is also decision-relevant because sustainability objectives formulated before baseline setting can influence later decisions on cost, scope, time and time.

The main lessons learned proof that successful application of this methodology depends on a few conditions (based on all 3 layer levels; individual, project and organizational). It is preferred to have a clear governance, early integration within the project (initiation phase), alignment with existing tools (compatible), use of a reference baseline for quantification (historical data), systematic documentation of lessons learned and collaboration across the project chain (central knowledge base and lessons learned repository). This means that the method should not be applied as a fixed template, but instead it should adapt to the relevant PM-domain, PPS-component, project phase and organization structure to make sure it remains applicable and relevant in practice. At the same time, the current validation remains focused on application rather than outcomes, besides the fact that it is done for just one *top opportunity*. Meaning that it should not be interpreted as proof of actual sustainability performance improvement in completed projects. Instead, the PPS-SIME Framework demonstrates that sustainability opportunities can be made measurable, actionable and anchored within existing project workflows or SOPs. But in the end, actual impact on soft and hard indicators such as MKI, CO_2 or MCI or long term project value, still requires validation through long-term studies with real data across multiple projects and phases.

Now that all 4 sub-research questions (***SRQs1-4***) are answered, the building block are established in order to answer the main research question.

Answer to the Main Research Question

Main research question

How can the measurability of sustainability efforts of products, processes and services (PPSs) within the PM-domains be improved to enhance sustainable decision-making in Dutch infrastructure projects during the planning and design phase?

The measurability of sustainability efforts of PPSs within the 10 PM-domains can be improved by anchoring sustainability systematically into project management structures, that steer early project decisions. A main finding of this research is that sustainability in Dutch infrastructure projects, is already recognized and supported by several reliable tools, like DuboCalc, +CD Tool CO_2 assessments, Ambitieweb and the Omgevingswijzer. However, these instruments do not automatically make sure that sustainability becomes part of daily project management, control and decision-making. Therefore, the problem is not primarily that sustainability awareness or technical instruments are missing. What is missing is a standardized method that translates sustainability ambitions into measurable, decision-relevant and anchored project requirements during the planning and design phase (FEDP). As a result of this missing element in project development, sustainability remains dependent on individual motivation, client demand ('uitvraag') or advisory input. This makes it vulnerable and prone to fragmentation and *ambition erosion*.

This research addresses this gap through the development of the PPS-SIME Framework. This framework improves measurability by linking sustainability integration opportunities to concrete PPS-components, prioritizing these opportunities through a MCDA and translating them into actionable project management instruments. The **Project Integration Management** domain has the strongest overall potential for sustainability integration, with a weighted average score of $V(a)$ of 2.52 and highest Process-component score of 2.60. This indicates that the greatest leverage lies in the way sustainability is anchored into project workflow or SOPs, responsibilities, baselines and decision moments. This is expected and a logical result, because **Project Integration Management** connects the other PM-domains and determines whether sustainability objectives are formally translated into the PMP, project baselines, work packages, monitoring systems and responsibilities.

A practical improvement in measurability found, being central to sustainability integration is translating sustainability ambitions into '***Formulate SMART sustainability objectives in the PMP before baseline setting***'. This is the central integration point being emphasized and found. The reason being, when sustainability objectives are formulated before cost, time and scope baselines are fixed, they still influence (design) alternative, cost estimations, planning decisions and more. Once these baselines are fixed, any sustainability proposal or change, becomes hard to introduce, because they must compete with already established project constraints. Therefore, measurability must be built into project management structures at moment when decisions are still flexible enough to be influenced. This implies how important timing is and that measurability (from sustainability integration) is not something that can be added after (design) decisions have been made. Because of this, it must be anchored in project instruments that steer early-phase (FEDP) decision-making.

The PPS-SIME Framework allows to do so, through three indicator types. First, the *Outcome indicator* (***MaQ***), which evaluates whether sustainability efforts can be linked to measurable hard or soft evidence (e.g. MKI, CO_2 or 'Z' number of adjusted decisions due to integration of opportunity 'A or other specific indicators). Second, the *Decision indicator* (***DL***), which evaluates whether sustainability efforts impact actual project decisions, like selection of design alternatives, client approvals or procurement choices. Third, *Embedding indicator* (***E***), which evaluates whether the effort is anchored in project management instruments like PMP, WBS, KES or others. Altogether, these indicators ensure that sustainability is not only measured as an environmental outcome, but assessed based on it influence on decision-making and anchoring within internal project governance structures.

The SMC is the operational end result of the PPS-SIME Framework. This prevents that the MCDA remains an abstract ranking exercise, by turning each opportunity into a (theoretical) project management card, that can be used in practice to become practical. Every SMC described the opportunity and links it to the relevant PM-domain and PPS-component, combined with the definition of its corresponding type of evidence, indicator elaboration, control- and layer level. This proves that sustainability is not only identified, but also structured and made applicable within project practice. The redesigned MARK-method strengthens this by requiring each opportunity to specify what is measure, what result is expected, why the intervention should work and what evidence is needed to support it. The operationalization of this can be done, by defining a sustainability team, with clear task and responsibilities through a 'decision-structure'. This guarantees that each opportunity is not only described, but also justified and traceable (e.g. using a RACI/RAM-matrix). The evidence provide can either be a hard or soft evidence as mentioned earlier, this makes the method semi-quantitative.

This shows that the developed method improves sustainable decision-making by making sustainability visible, comparable and steerable within existing project management workflows or SOPs. It does not require the introduction of a completely new PM-domain or a separate sustainability procedure, but contradictory, it builds on existing project management instruments and strengthens them. Especially the PMP, so that sustainability becomes part of the same steering logic as done for cost, scope, time, risk and quality. Treating it like this, make sustainability more likely to be treated as a formal (traditional) project parameter, rather than an informal ambitions or advisory addition. At the same this, its position increases in decision-making and reduces the risk that it is overlooked in practice. The developed method also supports reproducibility, as the same logical can be applied across other PM-domains and corresponding PPS-components and opportunities. As long as the opportunity, evidence type, control- and layer level are adapted to the specific project context. Showing the adaptability of the method, while still providing a clear format for sustainability integration.

However, the contribution of this research should be interpreted with care, the PPS-SIME Framework does not yet demonstrate actual and real sustainability performance improvement in completed infrastructure projects. The method shows that sustainability opportunities can be identified, prioritized, structured and anchored in a potential way that makes them more measurable and relevant for decision-making during the planning and design phase (FEDP). Meaning that the framework improves how sustainability is handled within projects, but it does not yet prove final impact or outcomes. Actual improvements on hard evidence, like lower MKI, reduced CO_2-emissions or increasing social value still need to be investigated in practice. This can only be done if historical or real time data is available for multiple projects across different project phases. Showing that this research provides a solid foundation, to continue upon, but not yet a full empirical proof of sustainability performance improvement. As outlined within the scope of this research, the developed framework should therefore be understood as a structured and semi-quantitative decision-support method that improves the conditions for sustainable decision-making, rather than as final evidence of sustainability outcomes.

In conclusion, the measurability of sustainability efforts within PPSs and PM-domains can be improved by shifting sustainability from a separate assessment activity to an integrated project management practice. Meaning that it should not be seen and treated as an addition or afterthought, but anchored within existing project processes and decision-making structures. In practice at W+B, this is achieved by finding relevant (both theoretical and practical) integration opportunities through PPS-components. Prioritized them through the MCDA and structured one of the *top opportunities*; '*Formulate SMART sustainability objectives in the PMP before baseline setting*' by using the PPS-SIME Framework and eventually turned it into a practical SMC using the redesigned MARK-method. Following this method, sustainability becomes measurable not only through final environmental indicators, but also because of influence on project decisions and its anchoring in project control. This shows that sustainability can be made visible and steerable throughout the project, rather than only evaluated afterwards. The main contribution of this research is therefore that it provides a structured approach to make sustainability efforts more measurable, actionable and governable during the phase in which infrastructure projects still have the greatest influence on long-term sustainability outcomes.

9

Recommendation and future research

This chapter translates the conclusions drawn in Chapter 8 and the limitations identified in Chapter 7 into concrete, actionable recommendations directed at 3 different audiences; W+B and identical engineering consultancy firms that operate during the planning and design phase of Dutch infrastructure projects (1), public owners and governmental bodies (e.g. Rijkswaterstaat or ProRail) (2) and the academic research community that are engaging with sustainability integration in project management. Following the participants recommendations, this chapter closes with a structured agenda for future research that directly responds to the methodological gaps and scope restrictions identified in this research.

9.1. Recommendations for practice

Integrate sustainability in the PMP before baseline setting

Based on the immediate, important and actionable recommendation of this research, engineering consultancy firms should always formally include sustainability objectives in the PMP, before the (cost, time and scope) baselines are fixed. As this is proven to be one of the *top opportunities* as many others that are subjectively assessed using an MCDA. These *top opportunities* commonly have an average $V(a)$ overall score of 3.00 for the criteria (***MaQ***), (***DL***) and (***E***). The *top opportunity* that is extensively worked out using a validation through the redesigned MARK-method suggests that adding a mandatory sustainability section to the PMP template used for W+B for medium and large projects. The section should include; a sustainable ambition for at least one TBL dimension, corresponding indicator(s) to track the progress, a project role responsible for monitoring and a formal moment to review sustainability against the baseline. This is a recommendation that does not not need any new type of software or drastic changes within the organization (speaking from W+B's perspective). This only connects with the existing management tools that extends the project management structure.

Establish a sustainability team on complex projects

The empirical findings of this research, prove that sustainability integration at W+B is depending on motivation and initiative of individual professionals, rather than on a shared and structured responsibility (Scanlon & Davis, 2011). As introduced through the redesigned MARK-method, it is recommended to create a formal 'sustainability team' at the start of each infrastructure project that exceeds a certain level of complexity. Smaller projects perhaps have relatively lower ambitions or do organize sustainability integration within the regular project team. A potential sustainability team based on the decision structure of W+B can exist of a PM, TM, CE and DA/DM. This is not a fixed and only team structure, but for the assessed *top opportunity* this team composition was determined to be the most useful based on their roles, responsibility, influence and mandates.

This sustainability team should follow the suggested management structure emphasized during the application of the MARK-method that defines the following:

- Who is responsible for what part of integrating the sustainability *top opportunity* identified through the PPS-SIME Framework
- How are (performance) issues escalated when targets and thus the *top opportunity* is at risk
- How are decisions documented and justified that trade-off the *top opportunity* again cost, time or scope

Not including this structure, even the best defined sustainability objectives can lose priority during project phases or design changes. The sustainability team is not a separate structure, but a steering project team within the existing project project organization, assuring project sustainability is considered equally alongside tradition project drivers like cost, time and scope.

Apply framework across all priority domains

This research developed and validated the PPS-SIME Framework using only the highest ranked opportunity within the 1st ranked PM-domain, namely **Project Integration Management**. This limitation was due to the scope and time constraint

of this research. However, looking at this from a practical point of view, the framework delivers full (potential) value when it is applied systematically across the *top opportunities* in all top 5 PM-domains, including their corresponding PPS-components. Besides the fact, that **Project Integration Management** inherently impacts the other 4 subsequent domains; **Project Cost, Risk, Scope and Time Management**, the full integration potential can be obtained when 'coupling opportunities' can be identified that benefits multiple PM-domains perhaps. This is a recommendation that be considered and perhaps used in the near future in practice within W+B, whereas a phased implementation programme using the integrated opportunity register from this research as a starting point and assesses this in practice with the SMCs following the structured application (through the redesigned MARK-method) approach. Practices makes perfect and learned lessons can be fed back into the lessons learned repository at W+B,

Include the SMC into existing digital project management information systems

The from of the Standardized Measure Card (SMC) is now used as a structured document instrument. However, a potential added value is when it get integrated into digital tools that project teams already use daily at W+B. Therefore, it might be beneficial to explore the opportunity of anchoring the SMC data structure into existing Project Management Information Systems (PMIS), like Relatics for the KES, that is used to track requirements and maintain scope changes in Dutch infrastructure projects. In essence, this means that each identified *top opportunity* resulting in a SMC is stored as an object in a similar environment like Relatics. Linked to the relevant WBS elements and other documents or instruments used during project development that are important to integrate and realize this opportunity. By doing so, a clear and traceable chain of sustainability evidence within the existing project system is created, instead of treating sustainability as a separate process. Over time, this digital SMC systematic allows to compare projects in sustainability integration, which helps W+B understand which opportunities are applied most often, which indicators are measures and what challenges occur.

Develop an organizational sustainability knowledge base

A main and repetitive finding from the SSIs is that sustainability knowledge at W+B is hare to access, not shared well and often remains within individual project teams or specialist (due to 'siloed thinking'). As a consequence, repeated reinvention of solutions are defined, learning opportunities between projects are missed and sustainability integration relies continuously on personal initiatives. Therefore, a central managed '*sustainability knowledge base*' is recommended that includes the following:

1. Complete SMCs (3rd level) from past and ongoing projects
2. Lessons learned register that is structured by PM-domain (1st level), PPS-components (2nd level)
3. Reference values for both soft and hard sustainability indicators (e.g. MKI values per infrastructure project or 'number of decision changes based on opportunity integration like formulation of SMART objectives')
4. Providing links to relevant Dutch guidelines (e.g. Duurzaam Aanpak GWW) for context and information

This knowlege base tackles the structural gap that was identified in the **FD** 6 for SSIs-Q1, Q2 and Q3 in Table 4.3 and serves as a memory needed to scale PPS-SIME Framework

Standardize a proactive sustainability approach in client relationships

The findings of this research reveal a systematic underused potential of the advisory role at W+B in client relationships (Scanlon & Davis, 2011). Participants emphasized, during the SSIs, that more sustainable alternatives were not discussed with the client, because of the concerns that the agreed project direction would be at risk or disrupted. This points to a structural governance issue, where the W+B operates within a limited and bounded play field than its expertise would allow. Therefore, it is recommended that W+B develops and formalizes a proactive sustainability advisory approach. Including a clear instruction on how sustainability alternative must be documented and presented to the client at key decision moments (at least before the KES programme and scope baseline are fixed). This approach should be supported by a discussion format similar to an Ambitieweb session, where discussion can openly take place with the client and relevant stakeholders. By making sustainability an explicit agenda topic from the start of the project, W+B can more consistently turn its expertise into clear, agreed and contractually embedded sustainability requirements.

9.2. Recommendations for public sector

The developed PPS-SIME Framework is developed in the context of an engineering consultancy firm (e.g. W+B), but several findings in this research are also relevant for the public sector and wide Dutch infrastructure sector. For public clients like RWS and ProRail, it is recommended to include a basic set of SMART sustainability requirements in their project briefs and tender documents before market consultation. This helps with maintaining sustainability objectives as formal project requirements, instead of general ambitions. By doing so, it creates a contractual basis that requires the application of frameworks like PPS-SIME Framework. Lastly, standardizing sustainability indicators across the sector, would help reduce the current differences and variety in calculation methods. This would allow for comparable results across projects and organizations.

9.3. Recommendations for future research

Long-term framework validation

The main limitation of this research does not lie in the the fact that it does not yet show actual result in practice. The PPS-SIME Framework and SMC output were tested on how it would be executed in practice (1), what it could measure in the decision-structure from the perspective of an engineering consultancy like W+B and whether it is repeatable (useful in other context (3). However, the real impact on sustainability performance is not proven yet, since it is unclear whether the implementation of the *top opportunity* leads to improvement on the indicators like the MKI. Future research could perhaps focus on long-term case studies where the framework is applied from the start of a project to its completion. This provide more insight on the comparison between projects that use SMCs and those that do not. A best case scenario would be to compar similar projects that are compared side by side, whereas one uses the framework and the other uses standard project management, to better understand the actual impact on sustainability outcomes.

Application of framework across full project lifecycle

The focus of this research was mainly on the planning and design phase (FEDP). However, the overall sustainability performance is determined over the entire project LC. Therefore, future research should therefore extend the PPS-SIME Framework to the stages beyond (construction, delivery, operation and maintenance). It should be examined whether SMART sustainability objectives defined in the PMP are actually carried through in the tender documents, construction monitoring and asset management plans.

Compare application across multiple stakeholder and organizations

This research was mainly executed with all 18 interview participants that were employees at W+B. This means that the results reflect the perspective on one main stakeholder, namely the engineering consultancy firm in an advisory role. Future research should include other relevant parties which would allows to test whether the MCDA results found in this research also apply in different roles and context or whether the priorities change. Adding to that, if more stakeholders are included it would help to identify under which conditions the PPS-SIME Framework can be applied beyond and advisory organizations. This is important, because clients and contractors have different levels of authority to include and apply sustainability requirements in contracts and project decisions. Besides that, this addition in a future research would allow boundary conditions evaluation under which the PPS-SIME Framework that can be transferred from an advisory organization like W+B to a contracting or client organization.

Strengthen the MCDA model

The MCDA scoring approach used in this research is based on 3 criteria with fixed weights and a 3-point scoring scale. This was practical and simplifying the analysis due to the large number of 305 opportunities. However, it also brings some subjectivity and limits the reliability of the the ranking. In future research this can be done better by:

1. Using a more detailed scoring scale (e.g. 1 to 5) for a better distinction between the options
2. Testing different weight combinations to see how stable the ranking is under different assumptions (sensitivity analysis)
3. Adding more criteria (e.g early phase impact or potential of linking PM-domains) to better assess the opportunities

Integration with digital systems and automation

The process of obtaining the SMC is manual, which makes it hard to scale. A potential future research could be to explore whether parts of the PPS-SIME Framework can be automated within existing project systems (e.g. Relatics as a PMIS) or within other digital tools. Including sustainability data like the MKI or other indicators, in case it is related to the opportunity, could be directly linked to the SMC field, which would allow automatic alerts in case the target and thus the opportunity is at risk at project phases or milestones. This automation would reduce the administrative effort and turn sustainability monitoring in a continuous and real-time activity instead of a periodic task.

Expand and apply sustainability dimensions

A final direction for future research, is about how sustainability is measure. The current findings indicate and as the development of the PPS-SIME Framework is based on, only considered the CO_2, MKI or MCI indicators as the main ones used in infrastructure projects. However, these are mainly environmental and economic indicators, but the social and economic aspects receive less attention in this research. A future research could be the exploration on social indicators (e.g. stakeholder impact) that can be added to the MCDA framework alongside the environmental and economic dimensions. Automatically, this insists on expansion of the current PPS-SIME Framework and developing a way to assess social impact, which is more a qualitative and harder measure. That build upon work of Ahn et al. (2013) and Bueno Cadena et al. (2015) who have explored mixed-method approaches to sustainability assessment in infrastructure contexts.

References

Journal articles

AbdelHaffez, A. G., Kaloop, M. R., Eldessouki, M., & Issa, U. (2025). Identification and assessment of risk factors in green building projects: A multi-dimensional approach for sustainable infrastructure. *Sustainability*. https://doi.org/10.3390/su172210178

Abdi, A., Taghipour, S., & Khamooshi, H. (2018). A model to control environmental performance of project execution process based on greenhouse gas emissions using earned value management. *International Journal of Project Management*, *36*, 397–413. https://doi.org/10.1016/j.ijproman.2017.12.003

Adesanya, A., Yang, B., Iqdara, F. B., & Yang, Y. (2020). Improving sustainability performance through supplier relationship management in the tobacco industry. *Supply Chain Management: An International Journal*. https://doi.org/10.1108/scm-01-2018-0034

Adler, P. A., & Adler, P. (2012). How many qualitative interviews is enough. *Expert Voices and Early Career Reflections on Sampling and Cases in Qualitative Research, eds. Baker, SE, Edwards, R. & Doidge, M.. Southampton: National Centre for Research Methods*, page 5, paragraph 2.

Ahmed, K., Khodeir, L., & Gadelhak, M. (2024). Investigating the role of change management in achieving sustainable project management in construction firms. *IOP Conference Series: Earth and Environmental Science*, *1396*. https://doi.org/10.1088/1755-1315/1396/1/012034

Ahn, Y. H., Pearce, A. R., Wang, Y., & Wang, G. (2013). Drivers and barriers of sustainable design and construction: The perception of green building experience. *International Journal of Sustainable Building Technology and Urban Development*, *4*(1), page 43, paragraph 2.

Alaloul, W., Altaf, M., Musarat, M. A., Javed, M., & Mosavi, A. (2021). Life cycle assessment and life cycle cost analysis in infrastructure projects: A systematic review. https://doi.org/10.20944/preprints202103.0316.v1

Alaloul, W., Altaf, M., Musarat, M. A., Javed, M. F., & Mosavi, A. (2021). Life cycle assessment and life cycle cost analysis in infrastructure projects: A systematic review. https://doi.org/10.20944/preprints202103.0316.v1

Alawag, A. M., Alqahtani, F. K., Alaloul, W., Liew, M. S., Baarimah, A. O., Al-Mekhlafi, A.-B. A., & Sherif, M. A. (2024). Developing framework for implementing total quality management (tqm) in sustainable industrialized building system (ibs) in construction projects. *Sustainability*. https://doi.org/10.3390/su162310399

Alawneh, R., Jannoud, I., Rabayah, H. S., Asaad, S. A., Almasaeid, H. H., Imam, R., & Ghazali, F. E. M. (2024). Development of a new method for assessing project risks in sustainable building construction projects in developing countries: The case of jordan. *Buildings*. https://doi.org/10.3390/buildings14061573

Alghamdi, A. (2025). Sustainable practices in construction management and environmental engineering: A review. *Sustainability*. https://doi.org/10.3390/su172210027

Alrifae, A. A. M. (2026). Green human resource management and sustainable performance: A systematic literature review. *Sustainable Futures*. https://doi.org/10.1016/j.sftr.2025.101580

Altaf, M., Alaloul, W., Musarat, M. A., & Qureshi, A. H. (2022). Life cycle cost analysis (lcca) of construction projects: Sustainability perspective. *Environment, Development and Sustainability*, *25*, 12071–12118. https://doi.org/10.1007/s10668-022-02579-x

Andrieu, B., Boulzec, H. L., Delannoy, L., Verzier, F., Winter, G., Vidal, O., & Stadler, K. (2024). An open-access web application to visualise countries' and regions' carbon footprints using sankey diagrams. *Communications Earth Environment*, *5*. https://doi.org/10.1038/s43247-024-01378-8

Arabpour, S., & Silvius, G. (2023). Sustainability interventions of construction project managers—establishing a minimum baseline. *Sustainability*. https://doi.org/10.3390/su15129795

Armenia, S., Dangelico, R. M., Nonino, F., & Pompei, A. (2019). Sustainable project management: A conceptualization-oriented review and a framework proposal for future studies. *Sustainability*. https://doi.org/10.3390/su11092664

Arshad, H., Thaheem, M. J., Bakhtawar, B., & Shrestha, A. (2021). Evaluation of road infrastructure projects: A life cycle sustainability-based decision-making approach. *Sustainability*, *13*(7). https://doi.org/10.3390/su13073743

Ashabi, A., Mostafa, M., Hryshchenko, A., Bruton, K., & Sullivan, D. T. O. (2024). Design and utilization of a decision support tool to advance energy efficiency in industries. *Energy*. https://doi.org/10.1016/j.energy.2024.132975

Atkinson, R. (1999). Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International journal of project management*, *17*(6), 337–338. https://doi.org/https://doi.org/10.1016/S0263-7863(98)00069-6

Bahadorestani, A., Naderpajouh, N., & Sadiq, R. (2019). Planning for sustainable stakeholder engagement based on the assessment of conflicting interests in projects. *Journal of Cleaner Production*, *242*, 118402. https://doi.org/10.1016/j.jclepro.2019.118402

Bakhtawar, B., Thaheem, M. J., Arshad, H., Tariq, S., Mazher, K., Zayed, T., & Akhtar, N. (2021). A sustainability-based risk assessment for p3 projects using a simulation approach. *Sustainability*. https://doi.org/10.3390/su14010344

Bal, M., Bryde, D., Fearon, D. J., Ochieng, E., Ochieng, E., & Ochieng, E. (2013). Stakeholder engagement: Achieving sustainability in the construction sector. *Sustainability*, *5*, 695–710. https://doi.org/10.3390/su5020695

Banihashemi, S. A., & Khalilzadeh, M. (2022). Towards sustainable project scheduling with reducing environmental pollution of projects: Fuzzy multi-objective programming approach to a case study of eastern iran. *Environment, Development and Sustainability*, *25*, 7737–7767. https://doi.org/10.1007/s10668-022-02370-y

Barbhuiya, S., & Das, B. B. (2023). Life cycle assessment of construction materials: Methodologies, applications and future directions for sustainable decision-making. *Case Studies in Construction Materials*. https://doi.org/10.1016/j.cscm.2023.e02326

Bernat, G. B., Qualharini, E., & Castro, M. (2023). Enhancing sustainability in project management: The role of stakeholder engagement and knowledge management in virtual team environments. *Sustainability*. https://doi.org/10.3390/su15064896

Bhatti, M. A. A., Cheema, A. T., & Baig, M. (2026). Integrating sustainability into project management practices: Experiences of managers in infrastructure projects. *Social Science Review Archives*, *4*(1), 3660–3680.

Bovea, M., Pérez-Belis, V., Torca-Adell, L., & Ibáñez-Forés, V. (2021). How do organisations graphically communicate their sustainability? an exploratory analysis based on corporate reports. *Sustainable Production and Consumption*, *28*, 300–314. https://doi.org/10.1016/j.spc.2021.04.011

Bragança et al. (2014). Early stage design decisions: The way to achieve sustainable buildings at lower costs. *The Scientific World Journal*, *2014*(1), page 1, chapter 1. https://doi.org/https://doi.org/10.1155/2014/365364

Braulio-Gonzalo, M., & Bovea, M. (2020). Relationship between green public procurement criteria and sustainability assessment tools applied to office buildings. *Environmental Impact Assessment Review*. https://doi.org/10.1016/j.eiar.2019.106310

Bueno, P., Vassallo, J., & Cheung, K. (2015). Sustainability assessment of transport infrastructure projects: A review of existing tools and methods. *Transport Reviews*, *35*(5), 622–649. https://doi.org/10.1080/01441647.2015.1041435

Bueno Cadena, P., Vassallo, J. M., & Cheung, K. (2015). Sustainability assessment of transport infrastructure projects: A review of existing tools and methods. *Transport Reviews*, *35*, page 16, paragraph 1. https://doi.org/10.1080/01441647.2015.1041435

Buyle, M., Braet, J., & Audenaert, A. (2013). Life cycle assessment in the construction sector: A review. *Renewable and Sustainable Energy Reviews*, *26*, 379–388. https://doi.org/10.1016/j.rser.2013.05.001

Cabral, C., & Dhar, R. (2019). Green competencies: Construct development and measurement validation. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.07.014

Caselles, L. M. D., & Guevara, J. (2024). Sustainability performance in on-site construction processes: A systematic literature review. *Sustainability*. https://doi.org/10.3390/su16031047

Chatty, T., Harrison, W., Ba-Sabaa, H. H., Faludi, J., & Murnane, E. L. (2022). Co-creating a framework to integrate sustainable design into product development practice.

Coenen, T. B. J., Visscher, K., & Volker, L. (2023). A systemic perspective on transition barriers to a circular infrastructure sector. *Construction Management and Economics*, *41*(1), 22–43. https://doi.org/10.1080/01446193.2022.2151024

Cortés, D., Traxler, A. A., & Greiling, D. (2023). Sustainability reporting in the construction industry – status quo and directions of future research. *Heliyon*, *9*. https://doi.org/10.1016/j.heliyon.2023.e21682

Coskun, C., Dikmen, I., & Birgonul, M. T. (2023). Sustainability risk assessment in mega construction projects. *Built Environment Project and Asset Management*, *13*(5), 700–718.

Dasović, B., Galić, M., & Klanšek, U. (2020). A survey on integration of optimization and project management tools for sustainable construction scheduling. *Sustainability*. https://doi.org/10.3390/su12083405

Dasović, B., & Klanšek, U. (2021). Integration of mixed-integer nonlinear program and project management tool to support sustainable cost-optimal construction scheduling. *Sustainability*. https://doi.org/10.3390/su132112173

de Almeida Vittori Ferreira, M., Morgado, C., & Lins, M. P. E. (2023). Organizations and stakeholders' roles and influence on implementing sustainability requirements in construction projects. *Heliyon*, *10*. https://doi.org/10.1016/j.heliyon.2023.e23762

de la Cruz López, M. P., Barros, J. J. C., del Caño Gochi, A., & Coira, M. L. (2021a). New approach for managing sustainability in projects. *Sustainability*. https://doi.org/10.3390/su13137037

de la Cruz López, M. P., Barros, J. J. C., del Caño Gochi, A., & Coira, M. L. (2021b). New approach for managing sustainability in projects. *Sustainability*. https://doi.org/10.3390/su13137037

De Wit, A., & Over, E. (2024). Social cost benefit analysis – a powerful tool for decision making. *European Journal of Public Health*, *34*(Supplement$_3$), ckae144.406. https://doi.org/10.1093/eurpub/ckae144.406

Dessi, C., Basile, V., Caboni, F., & De Trane, F. (2026). Formalising sustainability management as a core process group in project management. *Business Strategy and the Environment*.

Dsilva, J., Zarmukhambetova, S., & Locke, J. (2023). Assessment of building materials in the construction sector: A case study using life cycle assessment approach to achieve the circular economy. *Heliyon*, *9*. https://doi.org/10.1016/j.heliyon.2023.e20404

Duong, T. B. A., Pham, T., Truong, Q., Nguyen, K., Pham, C. H., Hoang, T., & Pham, T. (2023). Risk in sustainable construction supply chains: Construct development and measurement validation. *Construction Management and Economics*, *41*, 634–650. https://doi.org/10.1080/01446193.2023.2189739

Ebbesen, J. B., & Hope, A. (2013). Re-imagining the iron triangle: Embedding sustainability into project constraints. *PM World Journal*, *2*(3), 1–13.

Eken, G., Bilgin, G., Dikmen, I., & Birgonul, M. T. (2020). A lessons-learned tool for organizational learning in construction. *Automation in Construction*, *110*, 102977. https://doi.org/10.1016/j.autcon.2019.102977
Elkington, J., et al. (1997). The triple bottom line. *Environmental management: Readings and cases*, *2*(1997), 49–66.
El-Sayegh, S., Manjikian, S., Ibrahim, A., Abouelyousr, A., & Jabbour, R. (2018). Risk identification and assessment in sustainable construction projects in the uae. *International Journal of Construction Management*, *21*, 327–336. https://doi.org/10.1080/15623599.2018.1536963
Elseknidy, M., Al-Mhdawi, M., Qazi, A., Ojiako, U., Mahammedi, C., & Rahimian, F. (2025). Developing a sustainability-driven risk management framework for green building projects: A literature review. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2025.145891
Erdenekhuu, N., Kocsi, B., & Máté, D. (2022). A risk-based analysis approach to sustainable construction by environmental impacts. *Energies*, *15*(18), 6736.
Ershadi, M., & Goodarzi, F. (2021). Core capabilities for achieving sustainable construction project management. *Sustainable Production and Consumption*, *28*, 1396–1410. https://doi.org/https://doi.org/10.1016/j.spc.2021.08.020
Ershadi, M., Jefferies, M., Davis, P., & Mojtahedi, M. (2021a). Achieving sustainable procurement in construction projects: The pivotal role of a project management office. *Australasian Journal of Construction Economics and Building*, *21*. https://doi.org/10.5130/ajceb.v21i1.7170
Ershadi, M., Jefferies, M., Davis, P., & Mojtahedi, M. (2021b). Barriers to achieving sustainable construction project procurement in the private sector. *Cleaner Engineering and Technology*. https://doi.org/10.1016/j.clet.2021.100125
Ezeh, M. O., Ogbu, A. D., Ikevuje, A. H., & George, E. P.-E. (2024). Stakeholder engagement and influence: Strategies for successful energy projects. *International Journal of Management Entrepreneurship Research*. https://doi.org/10.51594/ijmer.v6i7.1330
Fallah, M., & Moini, A. (2026). Examining the role of sustainability metrics in advancing sustainable construction project management. *Clean Technologies and Environmental Policy*, *28*. https://doi.org/10.1007/s10098-025-03380-w
Fath, A. A. A., Herwindiaty, D. E., Wibowo, M. A., & Sari, E. (2024). Readiness for implemented sustainable procurement in indonesian government construction project. *Buildings*. https://doi.org/10.3390/buildings14051424
Fesenko, T. (2022). Improving models for sustainability evaluation of construction projects in the initiation and planning processes. *Eastern-European Journal of Enterprise Technologies*. https://doi.org/10.15587/1729-4061.2022.263668
Flores, R. F., Montoliu, C. M., & Bustamante, E. G. (2016). Life cycle engineering for roads (lce4roads), the new sustainability certification system for roads from the lce4roads fp7 project. *Transportation research procedia*, *14*, 896–905. https://doi.org/10.1016/j.trpro.2016.05.069
Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society*, *21*(3). http://www.jstor.org/stable/26269981
Frefer, A., Mahmoud, M., Haleema, H., & Almamlook, R. (2018). Overview success criteria and critical success factors in project management. *Industrial engineering & management*, *7*(1), 1–6.
Fregonara, E., Ferrando, D. G., & Tulliani, J. (2022). Sustainable public procurement in the building construction sector. *Sustainability*. https://doi.org/10.3390/su141811616
Friedrich, K. (2021). A systematic literature review concerning the different interpretations of the role of sustainability in project management. *Management Review Quarterly*, *73*, 31–60. https://doi.org/10.1007/s11301-021-00230-z
Giannakis, M., Dubey, R., Vlachos, I., & Ju, Y. (2020). Supplier sustainability performance evaluation using the analytic network process. *Journal of Cleaner Production*, *247*, 119439. https://doi.org/10.1016/j.jclepro.2019.119439
Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the gioia methodology. *Organizational research methods*, *16*(1), 15–31.
Gluch, P., & Baumann, H. (2004). The life cycle costing (lcc) approach: A conceptual discussion of its usefulness for environmental decision-making. *Building and Environment*, *39*(5), 571–580. https://doi.org/10.1016/j.buildenv.2003.10.008
Goel, A., Ganesh, L., & Kaur, A. (2019). Sustainability integration in the management of construction projects: A morphological analysis of over two decades' research literature. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.117676
Griffiths, K., Boyle, C., & Henning, T. (2015). Infrastructure sustainability rating tools–how they have developed and what we might expect to see in the future. *Research Gates*, page 8, paragraph 'Conclusion'. https://www.researchgate.net/publication/299366012_Infrastructure_sustainability_rating_tools_-_how_they_have_developed_and_what_we_might_expect_to_see_in_the_future
Griffiths, K., Boyle, C., & Henning, T. (2018). Beyond the certification badge—how infrastructure sustainability rating tools impact on individual, organizational, and industry practice. *Sustainability*, *10*, 1038. https://doi.org/10.3390/su10041038
Grünewald, S., & De Schutter, G. (2016). Design considerations and sustainability of self-compacting concrete. *SCC*, 1023–1032.
Habib, M., Eldawla, M. A. K., & Zaki, M. (2022). A risk management model for large projects in the construction phase in egypt. *Journal of Project Management*. https://doi.org/10.5267/j.jpm.2022.9.001
Halttula, H., Haapasalo, H., & Silvola, R. (2020). Managing data flows in infrastructure projects - the lifecycle process model. *J. Inf. Technol. Constr.*, *25*, 193–211. https://doi.org/10.36680/j.itcon.2020.012

Haouat, Z. E., Essalih, S., Bennouna, F., & Amegouz, D. (2025). Development of a global framework for an integrated life cycle assessment (lca) model in quality, safety and environmental (qse) management systems: Improving environmental, social and economic sustainability performance. *Sustainability*. https://doi.org/10.3390/su17083521

Henderson, J., & Peeling, R. (2024). A framework for early-stage sustainability assessment of innovation projects enabled by weighted sum multi-criteria decision analysis in the presence of uncertainty. *Open Research Europe*, *4*, 162.

Henke, I., Cartenì, A., Molitierno, C., & Errico, A. (2020). Decision-making in the transport sector: A sustainable evaluation method for road infrastructure. *Sustainability*, *12*, 764. https://doi.org/10.3390/su12030764

Honic, M., Kovacic, I., & Rechberger, H. (2019). Improving the recycling potential of buildings through material flow analysis (mfa) in the early design stage. *Journal of Cleaner Production*, *232*, 1–10. https://doi.org/10.1016/j.jclepro.2019.05.329

Hoseini, S. A., Fallahpour, A., Wong, K. Y., Mahdiyar, A., Saberi, M., & Durdyev, S. (2021). Sustainable supplier selection in construction industry through hybrid fuzzy-based approaches. *Sustainability*. https://doi.org/10.3390/su13031413

Ishola, A. O., Odunaiya, O. G., & Soyombo, O. T. (2024). Stakeholder communication framework for successful implementation of community-based renewable energy projects. *International Journal of Frontiers in Engineering and Technology Research*. https://doi.org/10.53294/ijfstr.2024.7.2.0047

Ivandic Vidovic, D., Skunca, F., & Mihanovic, D. (2025). Integrating esg principles into project portfolio management: A pathway to enhanced sustainability rating in financial institutions. *Proceedings of the 13th IPMA Research Conference „Honoring 60 years of Project Management: Leading the Way into the Future "*, 619–628.

Jacobs, M., & Stott, M. (1992). Sustainable development and the local economy. *Local Economy*, *7*(3), 261–272. https://doi.org/10.1080/02690949208726152

Kehinde, S. (2025). Integrating sustainability into project management for eco-friendly outcomes. *Sustainable Social Development*. https://doi.org/10.54517/ssd2894

Keleş, A. E., Gülek, G. G., & Górecki, J. (2025). Use of project management knowledge areas in civil infrastructure projects: Implications for sustainability assessment and risk analysis. *Sustainability*, *17*(20). https://doi.org/10.3390/su17209129

Khahro, S., Memon, A., Memon, N. A., Arsal, A., & Ali, T. (2021). Modeling the factors enhancing the implementation of green procurement in the pakistani construction industry. *Sustainability*. https://doi.org/10.3390/su13137248

Khan, S., Kusi□Sarpong, S., Arhin, F. K., & Kusi-Sarpong, H. (2018). Supplier sustainability performance evaluation and selection: A framework and methodology. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.09.144

Kim, K.-H. (2020). Generalized resource-constrained critical path method to improve sustainability in construction project scheduling. *Sustainability*, *12*, 8918. https://doi.org/10.3390/su12218918

Kitsios, F., Kamariotou, M., & Talias, M. A. (2020). Corporate sustainability strategies and decision support methods: A bibliometric analysis. *Sustainability*, *12*(2). https://doi.org/10.3390/su12020521

Kivilä, J., Martinsuo, M., & Vuorinen, L. (2017). Sustainable project management through project control in infrastructure projects. *International Journal of Project Management*, *35*, 1167–1183. https://doi.org/10.1016/j.ijproman.2017.02.009

Kock, A., Schulz, B., Kopmann, J., & Gemünden, H. (2020). Project portfolio management information systems' positive influence on performance – the importance of process maturity. *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2020.05.001

Lam, T. Y. M. (2019). A sustainable procurement approach for selection of construction consultants in property and facilities management. *Facilities*. https://doi.org/10.1108/f-12-2018-0147

Larsen, V. G., Tollin, N., Sattrup, P. A., Birkved, M., & Holmboe, T. (2022). What are the challenges in assessing circular economy for the built environment? a literature review on integrating lca, lcc and s-lca in life cycle sustainability assessment, lcsa. *Journal of Building Engineering*. https://doi.org/10.1016/j.jobe.2022.104203

Lima, L., Trindade, E., Alencar, L., Alencar, M., & Silva, L. (2021). Sustainability in the construction industry: A systematic review of the literature. *Journal of Cleaner Production*, *289*, 125730. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.125730

Lima, O., Fernandes, G., & Tereso, A. (2023). Benefits of adopting innovation and sustainability practices in project management within the sme context. *Sustainability*. https://doi.org/10.3390/su151813411

Liu, Y., van Nederveen, S., Wu, C., & Hertogh, M. (2018). Sustainable infrastructure design framework through integration of rating systems and building information modeling. *Advances in Civil Engineering*, *2018*(1), 8183536. https://doi.org/https://doi.org/10.1155/2018/8183536

Lupton, R., & Allwood, J. (2017). Hybrid sankey diagrams: Visual analysis of multidimensional data for understanding resource use. *Resources Conservation and Recycling*, *124*, 141–151. https://doi.org/10.1016/j.resconrec.2017.05.002

Maddaloni, F., & Sabini, L. (2022). Very important, yet very neglected: Where do local communities stand when examining social sustainability in major construction projects? *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2022.08.007

Manning, B., Braam, G., & Reimsbach, D. (2018). Corporate governance and sustainable business conduct-effects of board monitoring effectiveness and stakeholder engagement on corporate sustainability performance and disclosure choices. *Corporate Social Responsibility and Environmental Management*. https://doi.org/10.1002/csr.1687

Mari, D. A., Raza, A., & Lahbar, G. M. (2023). The role of a project management office (pmo) in ensuring human resource (hr) sustainable operations. *Global Economics Review*, *8*(2), 162–171.
Marques, P., Sousa, P., & Tereso, A. (2023). Sustainability in project management: Pm2 versus prismtm. *Sustainability*. https://doi.org/10.20944/preprints202308.1786.v2
Mathur, V., Price, A., & Austin, S. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, *26*, 601–609. https://doi.org/10.1080/01446190802061233
Mavi, R. K., Gengatharen, D., Mavi, N. K., Hughes, R., Campbell, A., & Yates, R. (2021). Sustainability in construction projects: A systematic literature review. *Sustainability*. https://doi.org/10.3390/su13041932
Mohd Zawawi, N. F., & Abd Wahab, S. (2019). Organizational sustainability: A redefinition? *Journal of Strategy and Management*, *12*(3), 397–408.
Moins, B., Bergh, W. V. D., & Audenaert, A. (2020). Implementing life cycle cost analysis in road engineering: A critical review on methodological framework choices. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2020.110284
Montalbán-Domingo, L., García-Segura, T., Sanz, M. A., & Pellicer, E. (2018). Social sustainability criteria in public-work procurement: An international perspective. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.07.083
Montalbán-Domingo, L., García-Segura, T., Sanz, M. A., & Pellicer, E. (2019). Social sustainability in delivery and procurement of public construction contracts. *Journal of Management in Engineering*. https://doi.org/10.1061/(asce)me.1943-5479.0000674
Montalbán-Domingo, L., Torres-Machí, C., Sanz-Benlloch, A., Pellicer, E., & Molenaar, K. (2023). Green public procurement in civil infrastructure construction: Current performance and main project characteristics. *Journal of Construction Engineering and Management*. https://doi.org/10.1061/jcemd4.coeng-13502
Montelisciani, G., Gabelloni, D., & Fantoni, G. (2015). Developing Integrated Sustainable Product-Process-Service Systems at the Early Product Design Stages. *International Journal of Sustainable Manufacturing*, *3*(4), 310–332. https://doi.org/10.1504/IJSM.2015.073819
Moreno-Monsalve, N., Delgado-Ortiz, M., Rueda-Varón, M., & Fajardo-Moreno, W. S. (2023). Sustainable development and value creation, an approach from the perspective of project management. *Sustainability*, *15*(1). https://doi.org/10.3390/su15010472
Moshood, T., Rotimi, J., & Shahzad, W. (2024). Enhancing sustainability considerations in construction industry projects. *Environment, Development and Sustainability*, *27*, 29287–29313. https://doi.org/10.1007/s10668-024-04946-2
Moutinho, A., Sousa, P., & Tereso, A. (2025). Applying the prism™ methodology to raise awareness of the importance of using sustainable project management practices in organizations. *Syst.*, *13*, 69. https://doi.org/10.3390/systems13020069
Muflih, M., Saide, S., & Dewi, A. K. (2026). Digital knowledge management in project-based organizations: A decade of evidence and emerging landscape for innovation, efficiency, and sustainability. *Journal of Information Knowledge Management*. https://doi.org/10.1142/s0219649225501370
Ogbeibu, S., Emelifeonwu, J., Senadjki, A., Gaskin, J., & Kaivo□oja, J. (2020). Technological turbulence and greening of team creativity, product innovation, and human resource management: Implications for sustainability. *Journal of Cleaner Production*, *244*, 118703. https://doi.org/10.1016/j.jclepro.2019.118703
Ojeda, O., & Reusch, P. J. A. (2013). Sustainable procurement - extending project procurement concepts and processes based on pmbok. *2013 IEEE 7th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS)*, *02*, 530–536. https://doi.org/10.1109/idaacs.2013.6662981
Olawumi, T. O., & Chan, D. W. M. (2018). A scientometric review of global research on sustainability and sustainable development. *Journal of Cleaner Production*, *183*, 231–250. https://doi.org/10.1016/j.jclepro.2018.02.162
Onat, N. C., Kucukvar, M., Halog, A., & Cloutier, S. (2017). Systems thinking for life cycle sustainability assessment: A review of recent developments, applications, and future perspectives. *Sustainability*, *9*(5), 706. https://doi.org/https://doi.org/10.3390/su9050706
Orieno, O. H., Ndubuisi, N. L., Eyo-Udo, N. L., Ilojianya, V. I., & Biu, P. W. (2024). Sustainability in project management: A comprehensive review. *World Journal of Advanced Research and Reviews*. https://doi.org/10.30574/wjarr.2024.21.1.0060
O'Shea, R., Deeney, P., Triantaphyllou, E., Diaz-Balteiro, L., & Armagan Tarim, S. (2026). Weight stability intervals for multi-criteria decision analysis using the weighted sum model. *Expert Systems with Applications*, *296*, 128460. https://doi.org/https://doi.org/10.1016/j.eswa.2025.128460
Pardo-Bosch, F., & Aguado, A. (2016). Sustainability as the key to prioritize investments in public infrastructures. *Environmental Impact Assessment Review*, *60*, 40–51. https://doi.org/https://doi.org/10.1016/j.eiar.2016.03.007
Peenstra, R. T., & Silvius, A. (2018). Considering sustainability in projects: Exploring the perspective of suppliers. *International Journal of Information Systems and Project Management*, *6*(2), 5–22.
Peng, J., Feng, Y., Zhang, Q., & Liu, X. (2023). Multi-objective integrated optimization study of prefabricated building projects introducing sustainable levels. *Scientific Reports*, *13*. https://doi.org/10.1038/s41598-023-29881-6
Pereira, A., Serra da Fonseca, M., & Fernandes, P. (2019). Come in, who is it? the predisposition of the social economy toward the circular economy. *4th Regional Helix | Porto, 2019- Book of Abstracts*, 287–295.
Perrini, F., & Tencati, A. (2006). Sustainability and stakeholder management: The need for new corporate performance evaluation and reporting systems. *Business Strategy and The Environment*, *15*, 296–308. https://doi.org/10.1002/bse.538

Pots, J. M. (2018). The stimulation of circular economy in the dutch construction industry : How procurement processes can realize a transition arena that is required in order to stimulate the transition to a circular economy. https://api.semanticscholar.org/CorpusID:169606951

Prins, M. M., Mohammadi, S., & Slob, N. (2015). Radical circular economy. https://api.semanticscholar.org/CorpusID:113016070

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability science*, *14*(3), 681–695.

Putro, A., Latief, Y., Nursin, A., & Soepandji., B. S. (2022). Development of work breakdown structure for stadium work as project guideline and standard. *International Journal of Engineering*. https://doi.org/10.5829/ije.2022.35.07a.08

Raitviir, C., & Lill, I. (2024). Conceptual framework of information flow synchronization throughout the building lifecycle. *Buildings*. https://doi.org/10.3390/buildings14072207

Rajabi, S., El-Sayegh, S., & Romdhane, L. (2022). Identification and assessment of sustainability performance indicators for construction projects. *Environmental and Sustainability Indicators*. https://doi.org/10.1016/j.indic.2022.100193

Ramohlokoane, M. M., Awuzie, B., Sathvik, S., & Singh, A. (2025). Evaluating sustainability-related deliverables across the construction project lifecycle: A delphi study. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/sasbe-10-2023-0299

Raouf, A. M., & Al-Ghamdi, S. G. (2020). Framework to evaluate quality performance of green building delivery: Construction and operational stage. *International Journal of Construction Management*, *23*, 253–267. https://doi.org/10.1080/15623599.2020.1858539

Ricci, A., Enei, R., & Ma, E. (2021). Social cost–benefit analysis—supporting urban planning and governance for enhancing social integration. *Towards Socially Integrative Cities*. https://doi.org/10.3390/books978-3-03936-679-8-12

Rietbergen, M., & Blok, K. (2013). Assessing the potential impact of the co2 performance ladder on the reduction of carbon dioxide emissions in the netherlands. *Journal of Cleaner Production*, *52*, 33–45. https://doi.org/10.1016/j.jclepro.2013.03.027

Rietbergen, M., Opstelten, I., & Blok, K. (2016). Improving energy and carbon management in construction and civil engineering companies—evaluating the impacts of the co2 performance ladder. *Energy Efficiency*, *10*, 55–79. https://doi.org/10.1007/s12053-016-9436-9

Rokio et al. (2024). Projects as drivers of sustainability: How the adoption of the reuse principle affects the front-end of a construction project. *International Journal of Project Management*, *42*(7), 102647. https://doi.org/https://doi.org/10.1016/j.ijproman.2024.102647

Ruparathna, R., & Hewage, K. (2015). Sustainable procurement in the canadian construction industry: Current practices, drivers and opportunities. *Journal of Cleaner Production*, *109*, 305–314. https://doi.org/10.1016/j.jclepro.2015.07.007

Rusu, T., Odagiu, A., Pop, H., & Paulette, L. (2024). Sustainability performance reporting. *Sustainability*. https://doi.org/10.3390/su16198538

Ruuska, I., & Vartiainen, M. (2005). Characteristics of knowledge sharing communities in project organizations. *International Journal of Project Management*, *23*, 374–379. https://doi.org/10.1016/j.ijproman.2005.01.003

Salah, M., Elmasry, M., Mashhour, I., & Amer, N. (2023). A framework for assessing sustainability of construction projects. *Cleaner Engineering and Technology*. https://doi.org/10.1016/j.clet.2023.100626

Salihu, M. R. B., Sazali, A. W., & Yasin, M. I. (2025). Organizational sustainability: More a square than a triangle. *International Journal of Business Strategy and Social Sciences*, *8*(1), 1–10.

Sánchez, M. A. (2015). Integrating sustainability issues into project management [Integrating Cleaner Production into Sustainability Strategies]. *Journal of Cleaner Production*, *96*, 319–330. https://doi.org/https://doi.org/10.1016/j.jclepro.2013.12.087

Santos, J., & Fernandes, G. (2024). Prioritizing stakeholders in collaborative research and innovation projects toward sustainability. *Project Management Journal*, *55*, 423–440. https://doi.org/10.1177/87569728241231266

Sarpong, F. A., Kissi, E., Acheamfour, V., Abu, I., & Eluerkeh, K. (2023). Establishing the economic sustainability criteria for assessing tenders in the procurement of building works. *Public Works Management Policy*, *29*, 612–635. https://doi.org/10.1177/1087724x231221432

Scanlon, J., & Davis, A. (2011). The role of sustainability advisers in developing sustainability outcomes for an infrastructure project: Lessons from the australian urban rail sector. *Impact Assessment and Project Appraisal*, *29*(2), 121–132.

Scherz, M., Zunk, B., Steinmann, C., & Kreiner, H. (2022). How to assess sustainable planning processes of buildings? a maturity assessment model approach for designers. *Sustainability*. https://doi.org/10.3390/su14052879

Schröpfer, V., Tah, J., & Kurul, E. (2017). Mapping the knowledge flow in sustainable construction project teams using social network analysis. *Engineering, Construction and Architectural Management*, *24*, 229–259. https://doi.org/10.1108/ecam-08-2015-0124

Shaawat, M. M. E., Alqahtani, S., Qasem, A., Jamil, R., Almohassen, A. S., & Bongwirnso, U. (2023). A performance quality index to assess professional conduct of contractors at sustainable construction projects in saudi arabia. *Sustainability*. https://doi.org/10.3390/su15097500

Shen, L.-Y., Li Hao, J., Tam, V. W.-Y., & Yao, H. (2007). A checklist for assessing sustainability performance of construction projects. *Journal of civil engineering and management*, *13*(4), 273–281.

Shokouhi, M., & Senisel Bachari, M. (2025). An overview of the aspects of sustainability in project management. *Progress in Engineering Science*, *2*(1). https://doi.org/https://doi.org/10.1016/j.pes.2024.100048
Silva, V. B. S., Schramm, F., & Damasceno, A. C. (2016). A multicriteria approach for selection of agile methodologies in software development projects. *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 002056–002060. https://doi.org/10.1109/SMC.2016.7844542
Silvius, A. G., & Schipper, R. (2014). A maturity model for integrating sustainability in projects and project management.
Silvius, A. G., & Schipper, R. P. (2014). Sustainability in project management competencies: Analyzing the competence gap of project managers. *Journal of Human Resource and Sustainability Studies*, Section 1, 3.3, 3.4 and 7. https://doi.org/http://dx.doi.org/10.4236/jhrss.2014.22005
Silvius, G., & Schipper, R. (2019). Planning project stakeholder engagement from a sustainable development perspective. *Administrative Sciences*. https://doi.org/10.3390/admsci9020046
Silvius, G., & Schipper, R. (2014). Sustainability in project management: A literature review and impact analysis. *Social Business*, *4*(1), 63–96.
Soares, I., Fernandes, G., & Santos, J. (2024). Sustainability in project management practices. *Sustainability*. https://doi.org/10.3390/su16104275
Song, J., Munyinda, M., & Sarfo, P. A. (2025). Examining the impact of risk management practices on sustainable project performance in the construction industry: The role of stakeholder engagement. *Frontiers in Built Environment*. https://doi.org/10.3389/fbuil.2025.1575827
Sroufe, R. (2017). Integration and organizational change towards sustainability. *Journal of Cleaner Production*, *162*, 315–329. https://doi.org/10.1016/j.jclepro.2017.05.180
Stanitsas, M., & Kirytopoulos, K. (2021). Investigating the significance of sustainability indicators for promoting sustainable construction project management. *International Journal of Construction Management*, *23*, 434–448. https://doi.org/10.1080/15623599.2021.1887718
Stocker, F., de Arruda, M. P., Mascena, K. M. C., & Boaventura, J. (2020). Stakeholder engagement in sustainability reporting: A classification model. *Corporate Social Responsibility and Environmental Management*. https://doi.org/10.1002/csr.1947
Stray, V. (2018). Planned and unplanned meetings in large-scale projects. *Planned and unplanned meetings in large-scale projects*. https://doi.org/10.1145/3234152.3234178
Suhanda, R., & Pratami, D. (2021). Raci matrix design for managing stakeholders in project case study of pt. xyz. *International Journal of Innovation in Enterprise System*. https://doi.org/10.25124/ijies.v5i02.134
Suprayoga, G. B., Witte, P., & and, T. S. (2020). Identifying barriers to implementing a sustainability assessment tool for road project planning: An institutional perspective from practitioners in indonesia. *Journal of Environmental Planning and Management*, *63*(13). https://doi.org/10.1080/09640568.2020.1724083
Tahir, A. H., Umer, M., Nauman, S., Abbass, K., & Song, H. (2024). Sustainable development goals and green human resource management: A comprehensive review of environmental performance. *Journal of environmental management*, *370*, 122495. https://doi.org/10.1016/j.jenvman.2024.122495
Taneja, P., van Rhede van der Kloot, G., & van Koningsveld, M. (2021). Sustainability performance of port infrastructure—a case study of a quay wall. *Sustainability*. https://doi.org/10.3390/su132111932
Teigiserova, D. A., & Schraven, D. F. (2024). A comprehensive framework for circular product-service systems in infrastructure: Enhancing customer-contractor collaboration. *Journal of Cleaner Production*, *479*, 144010. https://doi.org/https://doi.org/10.1016/j.jclepro.2024.144010
Toljaga-Nikolić, D., Todorović, M., Dobrota, M., Obradović, T., & Obradović, V. (2020). Project management and sustainability: Playing trick or treat with the planet. *Sustainability*. https://doi.org/10.3390/su12208619
Tumpa, R., & Naeni, L. (2025). Improving decision-making and stakeholder engagement at project governance using digital technology for sustainable infrastructure projects. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/sasbe-10-2024-0451
Tushar, Z. N., Bari, A., & Khan, M. A. (2022). Circular supplier selection in the construction industry: A sustainability perspective for the emerging economies. *Sustainable Manufacturing and Service Economics*. https://doi.org/10.1016/j.smse.2022.100005
van Hoek, R., & Udesen, T. (2023). Developing a benchmark for supplier code of conducts – lessons learned from bayer's journey towards sustainable procurement and research opportunities. *Benchmarking: An International Journal*. https://doi.org/10.1108/bij-09-2022-0571
van Lieshout, M. (2019). Een overwinning voor de natuur: Raad van state vernietigt plan voor verbreding a27 en a12. *de Volkskrant*. https://www.volkskrant.nl/nieuws-achtergrond/een-overwinning-voor-de-natuur-raad-van-state-vernietigt-plan-voor-verbreding-a27-en-a12~bfa4d345/
van der Voet, E., van Oorschot, J., Verhagen, T., van Oers, L., van Straalen, V., Tunn, V., Kersten, K., & Delahaye, R. (2025). The urban mine of the netherlands: The material basis for a circular economy. *Journal of Industrial Ecology*, *29*(3), 967–981. https://doi.org/10.1111/jiec.70030
Veen, C. (2023). Reducing ambition erosion to achieve strategic sustainability ambitions a research on the realisation of strategic sustainability ambitions in the exploration phase.
Veličković, M., Stojanović, Đ., Ilin, V., & Mirčetić, D. (2025). A combined multi-criteria decision-making and social cost–benefit analysis approach for evaluating sustainable city logistics initiatives. *Sustainability*, *17*(3). https://doi.org/10.3390/su17030884

Viles, E., Cavallieri, M. S., Kalemkerian, F., Montoya-Torres, J. R., & Santos, J. (2023). Assessing sustainable production: A selection of indicators aligned with the sdgs. *Sustainable Development*. https://doi.org/10.1002/sd.2793

Villena, E. G., Villar, S. G., López, L. D. D., Álvarez, R. M., Noya, I. D., & Mazón, J. L. V. (2021). Approach to a project framework in the environment of sustainability and corporate social responsibility (csr): Case study of a training proposal to a group of students in a higher education institution. *Sustainability*. https://doi.org/10.3390/su131910880

Wang, Y. (2023). Ecological risk identification and assessment of land remediation project based on gis technology. *Environmental Science and Pollution Research*, *30*, 70493–70505. https://doi.org/10.1007/s11356-023-27158-z

Wirahadikusumah, R., Abduh, M., Messah, Y., & Aulia, M. (2019). Introducing sustainability principles into the procurement of construction works – case of indonesian developers. *International Journal of Construction Management*, *21*, 932–944. https://doi.org/10.1080/15623599.2019.1599559

Woodward, D. G. (1997). Life cycle costing — theory, information acquisition and application. *International Journal of Project Management*, *15*(6), 335–344. https://doi.org/10.1016/S0263-7863(96)00089-0

Wuni, I. (2024). Developing a multidimensional risk assessment model for sustainable construction projects. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ecam-11-2023-1201

Yu, M., Zhu, F.-w., Yang, X., Wang, L., & Sun, X. (2018). Integrating sustainability into construction engineering projects: Perspective of sustainable project planning. *Sustainability*, *10*, 1–17. https://doi.org/10.3390/su10030784

Zuo, J., & Zhao, Z.-Y. (2014). Green building research–current status and future agenda: A review. *Renewable and sustainable energy reviews*, *30*, 271–281.

Books

Kibert, C. J. (2016). *Sustainable construction: Green building design and delivery*. John Wiley & Sons.

Project Management Institute. (2017). *A guide to the project management body of knowledge (pmbok® guide)* (6th).

Project Management Institute. (2021). *A guide to the project management body of knowledge (pmbok® guide)* (7th).

World Commission on Environment and Development. (1987). *Our Common Future: Report of the World Commission on Environment and Development*. Oxford University Press. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Theses

Stevenson, N. (2013). *A better world by design?: An investigation into industrial design consultants undertaking responsible design within their commercial remits* [Doctoral dissertation, Loughborough University Loughborough, England].

Wong, W. K. Y. (2024). *Sustainability in construction management: How can sustainability be effectively incorporated into risk management and measured in projects?* [Honours Program Master Thesis]. Delft University of Technology.

Reports and standards

Deloitte Southeast Asia Ltd. (2019). *Sustainability risk management: Powering performance for responsible growth* (tech. rep.).

Fuller, S. (2016). *Life-cycle cost analysis (lcca)* (tech. rep.). National Institute of Building Sciences. Washington, D.C. https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca

ISO 14040: Environmental management – Life cycle assessment – Principles and framework. (2006). International Organization for Standardization.

Ministerie van Infrastructuur en Waterstaat. (2023, February). *Nationaal programma circulaire economie 2023–2030* (Beleidsnota / Policy Report). Rijksoverheid. https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030

Network, S. D. S. (2012). *A framework for sustainable development* (tech. rep.). Sustainable Development Solutions Network. http://www.jstor.org/stable/resrep16082

PIANOo & Rijksoverheid. (2021, January). *Opdrachtgeven met ambitie, inkopen met impact: Nationaal plan maatschappelijk verantwoord inkopen 2021–2025* (tech. rep.). PIANOo / Rijksoverheid. https://www.pianoo.nl/sites/default/files/media/documents/2021-02/plan_mvi_opdrachtgeven_met_ambitie_inkopen_met_impact_2021-2025-jan2021.pdf

Royal College of Pathologists and Crossrail Learning Legacy. (2018). *Ceequal case study* (tech. rep.). Royal College of Pathologists / Crossrail Learning Legacy. https://learninglegacy.crossrail.co.uk/documents/ceequal-in-complex-projects/

Sustainable Development Solutions Network (SDSN). (2025b). *Sustainable development report 2025: Netherlands country profile*. United Nations Sustainable Development Solutions Network (SDSN). https://dashboards.sdgindex.org/profiles/netherlands/

UNEP. (2011). *United nations environment programme* (Technical Report). United Nations Environment Programme / SETAC Life Cycle Initiative. Paris, France. https://wedocs.unep.org/bitstream/20.500.11822/8001/UNEP_LifecycleInit_Dec_FINAL.pdf

Williams, T., Vo, H., Edkins, A., & Samset, K. (2019). *A systematic literature review: The front end of projects* (White Paper). Project Management Institute. https://www.pmi.org/learning/library/front-end-definition-projects-success-11822

Websites and online sources

Ambitieweb. (2024, January). Duurzaam gww. https://www.duurzaamgww.nl/documenten/58-ambitieweb
Barclay, C. (2018). Semi-structured interviews. %7Bhttps://know.fife.scot/data/assets/file/0019/18370/KnowHow-Semistructured-interviews.pdf%7D
Bauer, K. (2014). Advancing sustainability in infrastructure planning, procurement, delivery and operation: Isca and the is rating scheme. *Infrastructure Sustainability Council of Australia (ISCA)*. Retrieved October 13, 2025, from https://www.eianz.org/document/item/3422
Building Research Establishment. (1990). How breeam works. https://breeam.com/about/how-breeam-works
CEEQUAL Ltd. (2018, May). An introduction to ceequal. https://www.ceequal.com
Cisar, S. (2023, February). The sdgs wedding cake: A visual overview of the global goals. %7Bhttps://www.linkedin.com/pulse/sdgs-wedding-cake-visual-overview-global-goals-sasha-cisar/%7D
CROW Kennisplatform. (2026). Programma schoon en emissieloos bouwen in de aanbesteding. https://www.crow.nl/Onderwerpen/aanbesteden-contracteren/aanbesteden/programma-schoon-en-emissieloos-bouwen-in-de-aanbesteding/
CROW / Kennisplatform Aanpak Duurzaam GWW. (2025). Aanpak duurzaam gww: Een praktische werkwijze om duurzaamheid in gww projecten een plaats te geven. https://www.duurzaamgww.nl/aan-de-slag/aanpak-duurzaam-gww
Dutch Green Building Council (DGBC). (2025). Breeam□nl (english) – building research establishment environmental assessment method. https://www.breeam.nl/english-9
Duurzaam GWW. (2026). Over kci – duurzaam gww. https://www.duurzaamgww.nl/over-kci
Duurzaam GWW CROW. (2016, December). Aanpak duurzaam gww. https://www.duurzaamgww.nl/documenten/67-aanpak-duurzaam-gww
EPA. (2025). Overcoming barriers to green infrastructure. https://www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure
Frank, E. (2025). Gioia-methodology. https://sustainabilitymethods.org/index.php/Gioia-Methodology
GIH. (2021). Sustainable infrastructure: Tools and frameworks. https://www.gihub.org/sustainable-infrastructure/
Government of the Netherlands. (2025). Circular dutch economy by 2050. https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050
Het Nieuwe Normaal / Cirkelstad. (2026). Het Nieuwe Normaal. https://www.hetnieuwenormaal.nl/
House of Tenders. (2025, October). Wat is de m.a.r.k.-methodiek en waarom is het belangrijk? *House of Tenders*. Retrieved June 5, 2026, from https://houseoftenders.nl/blogs/wat-is-de-mark-methodiek-en-waarom-is-het-belangrijk/
Informatiepunt Leefomgeving. (2026). Procedure bij een aanvraag om een omgevingsvergunning waarvoor de reguliere procedure geldt. https://iplo.nl/regelgeving/overzicht-procedures/procedure-aanvraag-omgevingsvergunning-regulier/
Infrastructure Sustainability Council (ISC). (2021). Is v2.1 design and as□-built rating. https://www.iscouncil.org/is-v2-1/
Infrastructure Sustainability Council (ISC). (2025). Is planning rating: Informed infrastructure decisions. https://www.iscouncil.org/is-planning-tool/
Infrastructure Sustainability Council of Australia. (2025). Is rating scheme. https://sustainable-infrastructure-tools.org/tools/is-rating-scheme/
ISI. (2023). Use envision. https://sustainableinfrastructure.org/envision/use-envision/
Omgevingswijzer. (2023, February). Duurzaam gww. https://www.duurzaamgww.nl/documenten/55-omgevingswijzer
PIANOo / Expertisecentrum Aanbesteden. (2026). Nationaal plan maatschappelijk verantwoord inkopen 2021–2025. https://www.pianoo.nl/nl/themas/maatschappelijk-verantwoord-inkopen/beleid-en-uitvoering/nationaal-plan-maatschappelijk
Procura+ / ICLEI Europe. (2025). Rijkswaterstaat – public authority profile. https://procuraplus.org/about-procura/public-authorities/rijkswaterstaat
Programma Schoon en Emissieloos Bouwen. (2024, November). Routekaart seb: Schoon en emissieloos bouwen. https://www.opwegnaarseb.nl/documenten/2024/11/04/routekaart-seb
Rijksdienst voor Ondernemend Nederland. (2025). Circulariteit: 4 strategieën & de R-ladder. https://www.rvo.nl/onderwerpen/circulaire-economie/r-ladder
Rijksoverheid. (2026). Vergunningverlening, toezicht en handhaving (VTH). https://www.rijksoverheid.nl/onderwerpen/gezonde-en-veilige-leefomgeving/vergunningen-toezicht-en-handhaving
Rijksoverheid / Ministerie van Economische Zaken en Klimaat. (2019, June). Klimaatakkoord. https://www.rijksoverheid.nl/documenten/rapporten/2019/06/28/klimaatakkoord
Rijkswaterstaat. (2020). Duurzaamheid in de gww: Stand van zaken. https://www.rijkswaterstaat.nl/en
Rijkswaterstaat. (2025, March). Kompas RWS is geactualiseerd! https://www.rijkswaterstaat.nl/nieuws/archief/2025/03/kompas-rws-is-geactualiseerd

Rijkswaterstaat. (2026a). Co□-prestatieladder als inkoopinstrument. https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/duurzaam-inkopen/co2-prestatieladder

Rijkswaterstaat. (2026b). Economisch meest voordelige inschrijving / beste prijs-kwaliteit verhouding (bpkv). https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/aanbesteden/economische-meest-voordelige-inschrijving

Rijkswaterstaat. (2026c). Integraal projectmanagement. %7Bhttps://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/werkwijzen/werkwijze-in-gww/werken-in-projecten/integraal-projectmanagement%7D

Rijkswaterstaat DuboCalc. (2025). Dubocalc; duurzaam bouwen calculator. https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/duurzaam-inkopen/dubocalc

Stichting Klimaatvriendelijk Aanbesteden & Ondernemen. (2025a, September). Aanbesteden met gunningscriterium co□-prestatieladder 4.0 in vier stappen. https://www.co2-prestatieladder.nl/blog/aanbesteden-met-gunningscriterium-co2-prestatieladder-4-0-in-vier-stappen/

Stichting Klimaatvriendelijk Aanbesteden & Ondernemen. (2025b, Maart). Wat is de co□-prestatieladder? https://www.co2-prestatieladder.nl/wat-is-de-co2-prestatieladder/

Stockholm Resilience Centre. (2016). The sdgs wedding cake. %7Bhttps://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html%7D

Sustainable Development Solutions Network (SDSN). (2025a). Netherlands — country profile | sustainable development report 2025. https://dashboards.sdgindex.org/profiles/netherlands/

Toni Aschwanden. (2007). Betuwe and Ibt: A tale of two infrastructure projects. https://www.transportenvironment.org/articles/betuwe-and-Ibt-tale-two-infrastructure-projects

UN Global Compact Network Netherlands. (2026). Sustainable development goals. %7Bhttps://www.unglobalcompact.nl/sustainable-development-goals%7D

A

Literature review

The SDG-development of the Netherlands

The development of the Netherlands regarding the Sustainable Development Goals (SDGs) performance is outstanding and widely recognized as one of them most world's advanced nations integrating infrastructural development and industrial change. The remarkable SDGs that excel are ((Kingdom of the Netherlands, 2022)):

- SDG 9 (Industry, Innovation and Infrastructure)
- SDG 7 (Affordable and Clean Energy)
- SDG 11 (Sustainable Cities and Communities)
- SDG 12 (Responsible Consumption and Production)
- SDG 13 (Climate Action)
- SDG 8 (Decent Work and Economic Growth)

In terms of the transport and logistic infrastructure, the Netherlands is a big pioneer due to Europe's largest port, the Port of Rotterdam. The port plays a key role due to its strong use of inland waterways reducing its dependency on road transport and lower emissions. In 2022, inland waterways accounted for 41% of inland freight transport. In 2023 this was made up to 35.7% of total throughput in 2023, behind pipelines (37.6%) but ahead of road (19.9%) and rail (6.8%). For container transport to and from the hinterland, inland waterways held a 30.5% share, compared to 59.2% for road and 10.3% for rail. Inland waterway cargo volumes slightly increased to 141.9 million tonnes in 2024 (from 140.9 million tonnes in 2023) (Central Commission for the Navigation of the Rhine, 2024). By 2050, the Port Authority aims to achieve carbon neutrality while maintaining its role as a major economic driver (Port of Rotterdam Authority, 2025, 2026). The integrated transportation system of the Netherlands, includes Schiphol Airport, high-speed rail a dense road- and rail network facilitates economic growth while maintaining or even improving low-carbon mobility within the company. Besides the sophisticated and complete infrastructure on land, the climate-resilient water infrastructure such as the historic Delta Works (Deltawerken) and the ongoing dike reinforcement projects under the Delta Program, function as flood-protection system which protects the lower lying regions of the Netherlands against sea-level rise and extreme weather scenarios (Rijkswaterstaat, 2026b). These efforts directly improve SDG 9 by strengthening the quality and reliability of the Dutch infrastructure and support SDG 13 on the long run by long term climate adaptive measures (Delta Programme, 2024).

Besides the transport and logistic infrastructure, the energy infrastructure developed rapidly alongside, in order to support the national target of a fully sustainable energy system by 2050. Nowadays, the Dutch (highway) roads are are packed with electrical vehicles (EVs) due to organizational policies (related to reputational and sustainable goals and ambitions). The Netherlands increasingly gains more households with solar panels, since new built houses tend to be designed on 'net-zero' base, meaning that they are not polluting the environment in any way. However, this leads to an intensity/capacity problem of the electrical Dutch storage system on the grid (national charging network). Therefore, the transmission system operator TenneT is reinforcing the grid on massive scale, with plans to lay approximately 100,000 km of new electricity cable by 2050 to accommodate surging renewable capacity (TenneT, 2023). Per 2020 the European Comission and European Parliament, set the ambition to achieve 55% reduction in CO_2-emissions by 2030 compared to the levels of 1990. The offshore wind development in the Netherlands is hence a priority in meeting this target. An approach was defined by the Dutch government in early 2022, to realize a total offshore wind capacity of +/- 21GW around 2033 (with potential upscale of 30-40 GW by 2040). This represents an additional 9.5 gigawatts on top of the earlier ambition of 11.5 gigawatts, as established in the Routekaart 2030 (Noordzeeloket, 2026). Projects like the NortH2 are contributing to this which aims to produce green hydrogen from North Sea wind power for use in industry and heavy transport (RWE, 2026). In the Netherlands, this project is supported by the development of a pipeline of 1400 km by 23030, functioning as the hydrogen backbone in the Netherlands, connecting other regions with each other. Around 85% of the backbone is expected to consist of reused gas infrastructure (Netherlands Enterprise Agency (RVO), 2022). Altogether these initiatives make

it easier to clean up industrial processes and improve overall resource use efficiency, which contributes to SDGs 7 and 9.

The developments within the infrastructure of the Netherlands of as mentioned in the paragraphs earlier, has automatically impact on the Dutch economy. In the last decade the economy has transitioned, due to these industrial changes and therefore a circular economy has been adopted (CE) aligning with the SDGs 8, 9 and 12. Based on the economical developments, the Dutch government introduced a national wide program, called the 'National Programme Circular Economy' (NPCE) 2023-2030 was setup with an ambitious target by 2030 of reducing 50% of primary raw material use and a waste-free economy by 2050 (Government of the Netherlands, 2023). Due to this ambition, several strategies are set in place for the upcoming years in order to achieve this main and overarching goal of the Netherlands. One of the strategies is the Duurzaam GWW 2030, which has a primary goal which is to facilitate the exchange of knowledge and information about policy development such as the KCI (Duurzaam GWW, 2026) and the SEB (CROW Kennisplatform, 2026). The KCI cover the objectives and approaches of climate, clean and emission-free construction and circular construction in GWW. Different governmental bodies (Rijkswaterstaat, ProRail, Waterboard Authority and municipalities) are working together to determine the transition pathways, with the biggest environmental impact, which is documented as a the SEB Roadmap with concrete measures. The defined pathways, in collaboration with these governmental bodies and market stakeholders, are as follows:

- Transitiepad (TP) Weg, Dijk en Spoor (WDS) (TP) Road, Dike and Rail
- Transitiepad Woningbouw en Utiliteitsbouw (W&U) (TP) Residential and Utility Construction (W&U)
- Transitiepad Kustlijnzorg en Vaargeulonderhoud (KLZ & VGO) (TP) Coastline Care and Fairway Maintenance (KLZ & VGO)
- Transitiepad Energie (TP) Energy

For the provinces, this is done on a provincial level for the KCI, which is the PKCI. Wherever is spoken about the KCI, the words PKCI and KCAO are also mentioned. All of the KCI measures are contributing to the goals and ambitions of the Klimaatakkoord (Rijksoverheid / Ministerie van Economische Zaken en Klimaat, 2019), SEB (Programma Schoon en Emissieloos Bouwen, 2024) and the NPCE (Ministerie van Infrastructuur en Waterstaat, 2023).

Undergoing such developments and transformation as a country including tailored strategies and policies, innovation is inevitable. The Netherlands is ranking itself among the top performers in research and development intensity. Companies like ASML, institutes and organization like Brainport Eindhoven (Brainport Eindhoven, 2026) and Institute for Sustainable Process Technology (ISPT, 2026) accelerate the Industry 4.0 applications, digital twins (smart cities) for planning and circular design innovations and the application of AI. The Public-Private Partnership (PPP) strengthens and accelerates the rate of development of the 4.0 Industry. Who is backed by the establishment of the EU support and national funding, which boosts SDG 9 targets. An important note to this is that, per 2019 the 'SDG-check' was introduced for new policies which ensures that infrastructure and industrial projects consider their impact on developing countries (empathic and ethical inclusion). Since, that is where the raw materials are collected by child-labor under worse circumstances. The 2022 report of the United Nations of the Kingdom of the Netherlands identified innovation and strong institutions as key national strengths and highlighted the Netherlands' ambitious plans for transitioning to sustainable energy and economic systems (Kingdom of the Netherlands, 2022). From the perspective of a consultancy engineering firm as W+B, their contribution comes from the tendering phase where circular principles. are now more and more embedded in public procurement for roads, bridges and other structures taking into account the EMVI/MEAT criteria (MVI Criteriatool, 2025; Rijkswaterstaat, 2026c). This is done, by taking into account the R-ladder strategies, bio-based materials (with a low MKI) or modular construction like the IFD, that is mentioned by a participant, during the SSIs.

Interview excerpt

] "Another opportunity is standardization, although in the Netherlands that's almost a taboo word, because our architects' lobby is incredibly strong. But you can easily standardize the basic elements of many common structures, such as viaducts and bridges. That allows you to produce efficiently, replace components easily and reuse them. And the outer layer, the visual, defining elements, can still be made location-specific. That way you maintain variety in what you see, while the underlying structure remains the same. You benefit from the advantages of standardization without everything becoming uniform. It still results in a diverse landscape. I think we pay far too little attention to this."

"Industrial, Flexible and Demountable (IFD). It means thinking carefully about how you construct things so that, in the future, parts can be replaced or reused more easily. Don't cast everything together as one solid piece, but instead, create connections that can be detached. That way, you can remove components from object A and implement them in object B.

"Those are the moments when real coupling opportunities come into play, when you're dealing with an asset category that urgently needs replacement. In that situation, you simply don't have the luxury to think extensively about everything you might want to add or do." *— Technical Manager [P15*

Sustainability in Dutch infrastructure development

The statistic on sustainability performance of the Netherlands in various industries within the construction sector are reflect in the Sustainable Development Report 2025 and the SDGs Index Dashboard. Worldwide, the Netherlands is ranked 23rd with a score of 78.1 out of 100, showing an outstanding performance on SDG 9, but facing challenges with SDG 12. This is a result of big investments within research and development (R&D) and national established knowledge base due to its high innovation capacity. On the other hand, the economical strength of the country is confronted with environmental challenges like CO_2 emissions and electronic waste (e.g. transport/logistic infrastructure and energy infrastructure).

Sustainable Development

To make sure that these (inter)national SDGs are achieved, it is important that they are addressed adequately and collectively within the Dutch construction sector. Thus, sustainable development emerged, which is a subjective concept everyone is for, but there are deep disagreements about how to improve it or understood (Jacobs and Stott, 1992). There have been numerous academic papers that have provided definitions of sustainable development, which appears to be more effective in explaining what this term means. That is why the term is often used when referring to sustainability in projects involving construction. For example, a report by Sustainable Development Solutions Network, defines it (based on a framework) as *society's commitment to achieving interconnected objectives of economic development (including ending poverty), social inclusion, environmental sustainability and good governance with personal security* (Network, 2012), mainly referring to the QBL as elaborated in Subsubsection 3.1.1.2. World Commission on Environment and Development, 1987 states that development and environment need to be in a 'balancing system' as mentioned earlier in Section 3.1, finding the sweet spot within the supply (development) and demand (environment). This indicates that sustainability is often interpreted and defined differently and can be only realized when impacting variables are altogether in harmony. Table A.2 provides an overview of the comparison and logic between the sustainability rating systems and to what extent they are relevant to the context of this research.

In practice, some sustainability rating tools that have been developed within the field of engineering, such as Envision (ISI, 2023), the IS Rating Scheme (Infrastructure Sustainability Council (ISC), 2021, 2025; Infrastructure Sustainability Council of Australia, 2025), CEEQUAL (CEEQUAL Ltd., 2018; Royal College of Pathologists and Crossrail Learning Legacy, 2018) and BREEAM-NL (Building Research Establishment, 1990; Dutch Green Building Council (DGBC), 2025). All of them are strong at making sustainability visible and comparable, but are weak at embedding it inside day-to-day project control. They are more focused towards evaluation of projects across social, environmental and economic criteria throughout the entire project LC and are providing a 'common national language for evaluating sustainability in infrastructure development'. That is the reason why they can be useful for sustainability integration , but are not fully 'anchored' in traditional project control and project management practices. These rating systems contain a scoring mechanism, which eventually awards the project after a design review for example. This indicates that the tools mainly serve as as a certification system rather than as an active decision support tool for sustainability integration (on PPS-level). In addition, these tools are often applied during or after design development, meaning that planning is not completely taken into account and that is where project control comes into play as well. The rating systems lack real time decision making and early integration into cost estimation, risk management and scheduling for example.
In summary, these sustainability rating systems add value to sustainability integration by giving projects criteria, benchmarks and verification routes, but they are not operationalizing inside the PM-domains where decisions are actually controlled and managed during infrastructural projects. The sustainability rating systems rather answer 'how sustainable is this project?' instead of 'how should sustainability reshape the next planning, cost, risk or procurement decision?' which is exactly the gap this research identifies for the planning and design phase. Thus, the sustainability rating systems are valuable in assessment and certification framework, but they are not sufficient as embedded project control and management mechanisms, so a specific PM oriented approach still needs to translate sustainability from a rating outcome into a FEDP decision logic. Regardless of the inapplicable use of these rating systems in practice there are some Dutch initiatives that has been designed for the construction industry originated from governmental strategies to strengthen sustainability (integration).

Sustainable Construction

Overall, even though the Dutch industry remains a European leader in innovation and technological infrastructure, the main difficulty now and in the future lies in accelerating the shift to closed loops and systems. This will ensure that innovation driven competitiveness goes hand in hand with real improvements in resource efficiency and climate resilience (Sustainable Development Solutions Network (SDSN), 2025a, 2025b). Indicating that sustainable construction must compete with the pace of this acceleration. Sustainable construction in the Dutch infrastructure industry is becoming more and more important which is shaped by several national targets in terms of climate, procurement rules and a growing set of practical guidelines and approaches. The Dutch government aims for an interim goal of reducing 49% of the CO_2-emission by 2030, besides the goal of 2050. The Dutch construction sector accounts for approximately 33% of the national CO_2-emissions and uses around 250 tons of raw materials per person per year, so procurement is a key influencing factor. The national plan for incorporating social and environmental friendly and circular requirements in purchasing by the government is introduced as Sustainable Procurement (MVI) (Maatschappelijk Verantwoord Inkopen), which is part of 'Duurzaam inkopen GWW', focusing on public and private entities to reduce CO_2-emissions, close material loops and stimulate innovation in infrastructure projects. The goal of this is to use purchasing power to promote sustainability

Sustainability rating system	Geographical application and scope	Methodology	Characteristics	Fit for PM sustainability integraiton
Envision	Applied internationally, mainly focused on civil infrastructures	It works with a TBL credit-based LC assessment, with verification after design review	The rating system contains a file which covers social, environmental and economic criteria across the LC and functions as a tool to guide decision-making and recognize high sustainability levels	The rating system works strong as a sustainability benchmark, but it shows that it is still mainly verification-led rather than being suitable for integration into day-to-day project control
IS Rating Scheme	Applied in Australia and New Zealand, mainly focused on infrastructure programs, projects, networks and assets	It works with a QBL based rating framework across project phases with separate tools for each stage	The rating system is broader than focusing on a single phase and contains a file noting that planning, design, procurement and construction require different modules, making it more phase-sensitive than a simple checklist	The rating system might be useful for LC sustainability thinking, but is not completely anchored within the FEDP project control or project management, as explicitly mentioned in Appendix A
CEEQUAL	Applied in the UK and Ireland plus an international manual, mainly focused on civil engineering, infrastructure, landscaping and public realm	It works with an evidence-based question set, scored through manuals and external (third-party) verification and awarded via a percentage scoring mechanism	The rating system distinguishes itself due to its adaptability to local context, whereas the international version requires local weighting, with separate project/contract routes and a whole-team award option	The rating system encourages early sustainability considerations, as documented evidence and question sets support strategy and design-phase thinking, but it still mainly functions as an assessment and award system
BREEAM-NL	Dutch adaptation of BREEAM, mainly focused on the built environment and buildings	It works with certification across the whole building LC	The rating system is adapted to the Dutch context and used by building owners, project teams and facility managers to benchmark or certify buildings; more building-focused than infrastructure-focused	The rating system is the least central to this research scope, as it is treated as a building-industry tool rather than a mechanism for embedding sustainability into infrastructure project control

Table A.2: *

Comparison of sustainability rating systems (source: Author)

(e.g. reducing emissions), ensuring fair labor conditions and fostering chain responsibility rather than focusing solely on price and quality. This plan supports the Rijksinkoopstrategie “Inkopen met Impact”, which asks contracting authorities to integrate sustainability systematically in all phases of the procurement cycle (PIANOo / Expertisecentrum Aanbesteden, 2026; PIANOo & Rijksoverheid, 2021).

Therefore, Dutch policy developments on strategic level were are such as the Klimaatakkoord (Rijksoverheid / Ministerie van Economische Zaken en Klimaat, 2019), SEB (Programma Schoon en Emissieloos Bouwen, 2024) and the NPCE (Ministerie van Infrastructuur en Waterstaat, 2023). The SEB Covenant (Clean and Emission-Free Construction program) was introduced and signed by 45 parties that are committed to incorporate SEB requirements into procurement procedures. Showing that sustainability in the Dutch construction industry is not only treated as a design ambition, but also policy driven to realize a transition that is pushed through procurement. The SEB plays a big role and provides practical guidance and instruments that support implementation by combining ’pull measures’ that encourage cleaner construction equipment with ’push measures’ imposing regulatory requirements, as shown in Figure A.1.



Figure A.1: *

Push- en pull-measure within the SEB Roadmap (Made by Author using (Programma Schoon en Emissieloos Bouwen, 2024))

The dynamic interplay between the 'push' and 'pull measures are valuable, since it translates sustainability ambitions into actionable procurement and execution requirements, especially for mobile machinery, vehicles and vessels. This makes the scope of the approach selective, since the SEB Roadmap (Programma Schoon en Emissieloos Bouwen, 2024), excludes emissions from material production, other industrial processes and emissions arising from use of the completed project or asset. Therefore, the SEB contributes to operational decarbonization, but it does not by itself provide a framework for the integration of sustainability across the full project LC. In line with these ambitions, objectives and strategic frameworks, CROW has developed a set of tools and instruments to support clients and market actors in achieving these transitions. The total set of this approach is called 'Aanpak Duurzaam GWW' (Sustainable GWW Approach) (Duurzaam GWW, 2026), whereas the the base of the TBL framework (People Plant and Prosperity) is incorporated. The Aanpak Duurzaam GWW supports parties in the civil engineering sector in putting the KCI strategy into practice. The approach is based on the following five core principles (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025):

- Translate the sustainability objectives of an organization into concrete projects and tasks.
- Integrate sustainability as early as possible, preferably already during the integrated area development stage. The planning phase offers the greatest opportunities for sustainability. Make use of opportunities to achieve sustainability goals together with other stakeholders.
- Focus each project or task on the themes where the greatest sustainability gains can be achieved.
- Create opportunities for innovations and new sustainable solutions by allowing room for parties to propose their own approaches. This gives the market and innovation processes more opportunities.
- Assess sustainability in a uniform manner, a set of instruments has been selected to ensure consistent evaluation and safeguarding. Use the shared set of tools such as Omgevingswijzer (Omgevingswijzer, 2023), Ambitieweb (Ambitieweb, 2024), the CO_2-Prestatieladder (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b) and DuboCalc (Rijkswaterstaat DuboCalc, 2025).

The Omgevingswijzer provides a thorough analysis of the project its impact on its surroundings and presents this visually. This tool is incorporates social, ecological and economical sustainability aspect (People, Planet and Prosperity) which are included in terms of 12 themes (see Figure A.2). The Omgevingswijzer involves digital survey of which results into a visualization of the impact of the project on its surroundings (Duurzaam GWW CROW, 2016). The initial ambitions are defined by using the Omgevingswijzer the first time during a collaborative and interactive session, with all involved (internal/external) stakeholders. Since 'good begun is half done', the composition of the group is essential since it influences the outcome of the session. The approach for this first time is that the questions should be answered from a 'grey-zone', meaning that the mindset should be only about 'doing a project' and not taking sustainability or innovative considerations into account. This results into all potential impacts on the project area. Depending on the size and complexity of the project, the Omgevingswijzer can be filled in per phase in one session or per phase on different transition moments using several sessions.

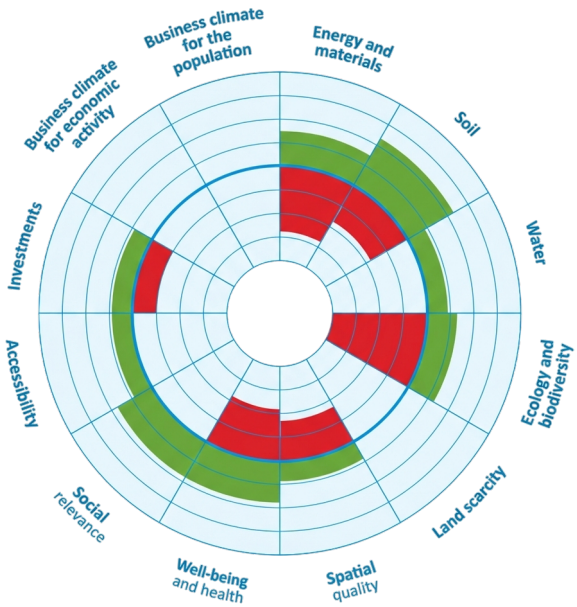


Figure A.2: *
Example of Omgevingswijzer (made by Author from (Duurzaam GWW CROW, 2016))

Besides the evaluation of impacts using the Omgevingswijzer, it can also be used as an assessment framework to compare different options within a project, see Figure A.3 However, it should be noted that this framework is only suitable for sustainable projects, since the themes are related to sustainability. Meaning that the assessment framework can or should be tailored to the project circumstances in order to obtain relevant end-results for the options that are considered.

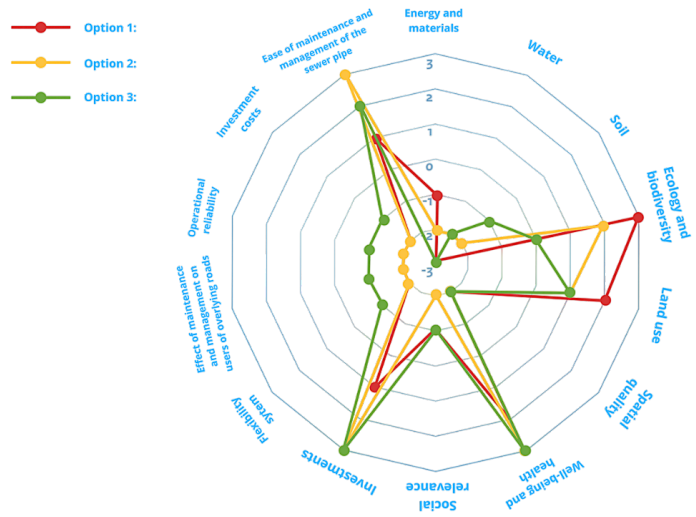


Figure A.3: *
An example of comparison of alternatives based upon the Omgevingswijzer (made by Author from (Duurzaam GWW CROW, 2016))

Apart from the estimation of the environmental impact or alternative assessment, the Ambitieweb is a tool for systematically recording and maintaining sustainability ambitions throughout the entire project. The Ambitieweb is most effective when used during the concept or planning phase and the development or design phase of a project (the FEDP) offering a visual representation of 12 sustainability themes, as shown in Figure A.4.

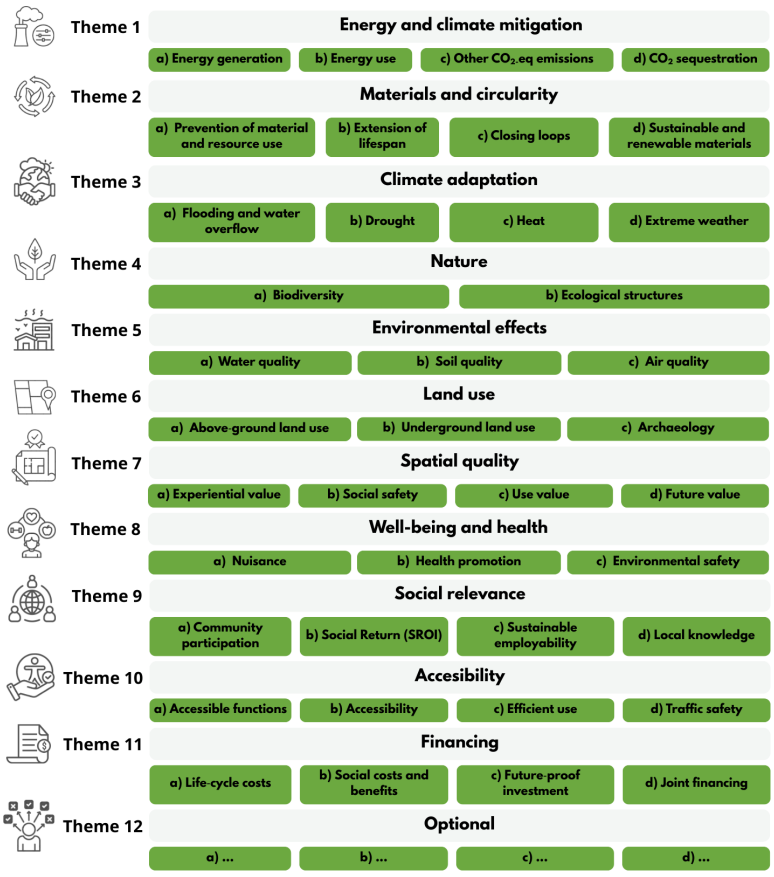


Figure A.4: *
The Ambitieweb themes within the Duurzaam Aanpak GWW (made by Author using source (Duurzaam GWW CROW, 2016))

The Ambitieweb session can be held on several levels, namely on organizational level, project level or evaluation level. On a project level, as shown in Figure A.5, sufficient knowledge prior to the context of the project is essential in order to obtained a structured overview of sustainability ambitions, in case a reference of a generic Ambitieweb is available as a starting point, this can be compensated perhaps. Regardless, as mentioned earlier for the Omgevingswijzer, the composition of the group is essential since it will determine the overall knowledge and capacity influencing the outcome. Especially for the facilitator who is in lead and guides the session accordingly within context of the project. This interactive

session on organizational level, ensures that insights are systematically translated into clear and supported ambitions level. Meaning, that first opportunities and (potential) negative impacts of the project are identified and kept separately to balance them out against each other and understand the projects' sustainability performance (which is broad scan used as a foundation for further analysis). Secondly, concrete sustainability measures are defined, by working in smaller groups with different assigned themes and afterwards rotated between groups, which allows the participants to contribute to each team. This iterative approach helps to refine ideas and ensures that all opportunities are explored from multiple perspectives. Thirdly, participants individually determine their preferred ambition level by placing post-its or markers on the Ambitieweb, making the distribution visible within a glance and encourages transparency and discussion. Lastly, the groups get to an agreement on what the final ambition level for each theme is and connect these into an overall ambition profile and document these choices. This provides clarity on the selected ambition levels and can be clearly communicated and used during each project phase.

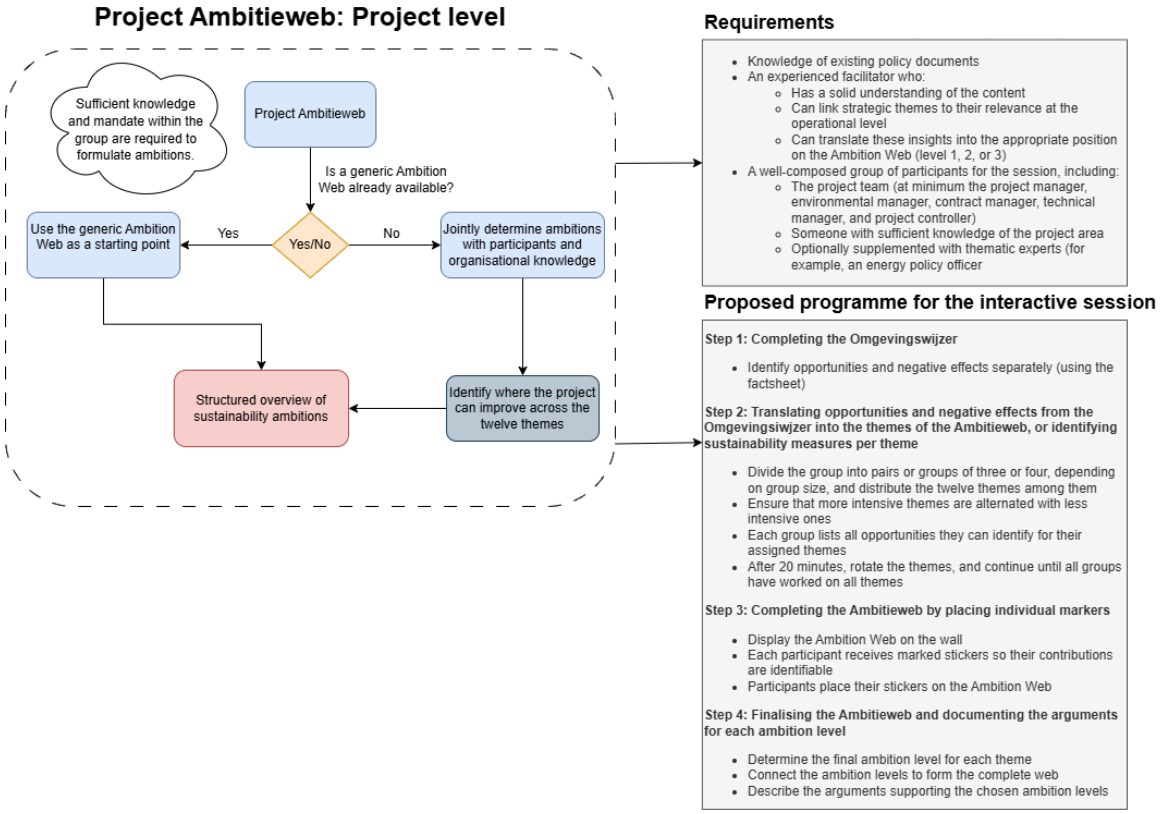


Figure A.5: *
Flowchart of the project Ambitieweb on project level including requirements and a proposed program (made by Author using source source: Duurzaam GWW CROW, 2016)

This process is executed during project development within the engineering consultancy firm W+B, using a funnel methodology as an approach that incorporates these steps of the Omgevingswijzer and Ambitieweb as basis for MIRT-fase. The MIRT stands for Multi-Year Programme Infrastructure, Spatial Planning and Transport (MIRT) (Rijksoverheid, 2007, which is a plan made by the central government to promote accessibility, safety and spatial planning of the Dutch infrastructure collaborating with provinces, municipalities, transport regions and water boards on these projects. From the perspective of W+B, the steps that are taken during an MIRT-phase and corresponding infrastructure project are shown in Figure A.6.

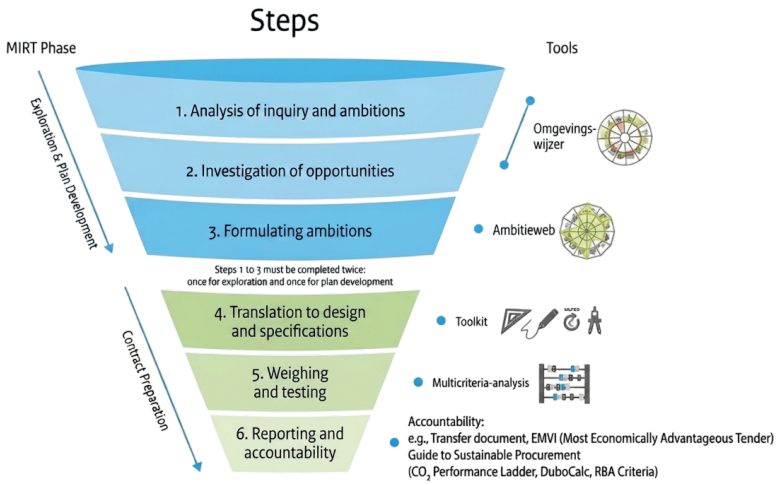


Figure A.6: *
Steps for sustainability integration of project in the Netherlands within the MIRT phase (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025)

Figure 3.3 covers the exploration, plan development and contract preparation phase, where each step is considered as a gradual understanding of the project from broad ambitions to concrete (sustainable) outcomes. The funnel shape means shows that the process starts wide, meaning that a lot of possibilities and ideas are identified and becomes progressively narrow whereas specific choices are made and decision are finalized. The exploration phase (verkenningsfase), is about understanding the project context and defining sustainability ambitions. This starts off with analyzing project questions and ambitions together with involved stakeholders, using the Omgevingswijzer and Ambitieweb (once done during the high level initial exploration phase and a second time during transition to the plan development phase). During the plan development phase (plantuitwerking) the defined ambitions are translated into specified designs with technical specifications. Meaning that sustainability goals are incorporated into the project through design choices, requirements and performance criteria. After having a few design options, the alternatives are assessed and evaluated against relevant criteria by using the MCDA method to support decision making. This phase is more oriented on determining what is achievable and how can it be implemented, instead of what is desirable. Finally, in the contract preparation phase (contractvoorbereiding), the selected solutions and (design) decisions are documented, to be a foundation and justification of the decisions made, particularly in terms of sustainability performance. This will function as an input for the contract documents and procurement procedures, so that sustainability ambitions are secured. Some accountability measures like handover documents and application of instruments (e.g. CO_2-Prestatieladder defining the CO_2 emissions and DuboCalc defining the MKI) are included as well. By contractual embedment of sustainability requirements during this phase in such a way, provides certainty on the fact that pre-defined ambitions are carried through the implementation and execution phase. In summary, this approach consists of (CROW / Kennisplatform Aanpak Duurzaam GWW, 2025):

1. Analyzing the question and ambitions
2. Exploring opportunities
3. Defining ambitions and opportunities
4. Translating these into specifications and design
5. Assessing and evaluating sustainability
6. Reporting on sustainability

The CO_2-Prestatieladder is a Dutch sustainability instrument, developed by ProRail and since 2011 the ownership and management is transferred to 'Stichting Klimaatvriendelijk Aanbesteden en Ondernemen' (SKAO) (Foundation for Climate-Friendly Procurement and Business Practices). It enables both companies and public authorities to reduce CO_2-emissions internally, collaboratively and throughout the supply chain. As a management system, it supports structured emission reduction within the organization and its value chain. This instrument is used during the procurement phase, which allows organizations to leverage their purchasing power to drive sustainable impact (Duurzaam GWW CROW, 2016). Initially, this is also how RWS introduced the instrument to the market, by using it as a way to formulate concrete and measurable (SMART) formulated conditions on procurement that are agreed upon in the contracts for awarding projects. Parties who submit a bid and proof they are genuinely working towards a method to reduce CO_2 emissions receive and advantage on their tender submitted to RWS by a fictional discount. The CO_2-Prestatieladder, as shown in Figure A.7, consists of 3 steps which are:

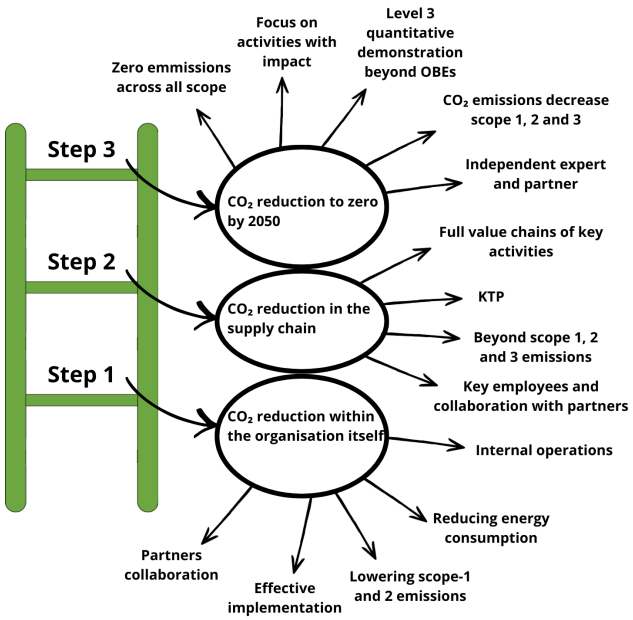


Figure A.7: *
CO_2-Prestatieladder (made by Author using source (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b)

- At **Step 1** the organization brings its internal operations in order within one to three years. The organization focuses on reducing energy consumption and lowering its scope 1 and 2 emissions. In addition, the organization has insight into the employees in key positions for an effective implementation of the Ladder and understands which partners it can collaborate with effectively (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b).
- At **Step 2**, the organization focuses on the full value chains of its key activities. For this level, the organization must develop a Klimaat Transitie Plan (KTP), outlining a strategy for achieving CO_2 reduction in the medium term (5 to 10 years). It looks beyond scope 1, 2 and 3 emissions, supported by a partner who helps determine the most effective approach. Employees in key positions are actively involved and the organization works closely with various partners. Step 2 requires a similar level of effort as Level 5 of CO_2–Prestatieladder version 3.1 (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b).
- At **Step 3**, the long term objective for Level 3 is zero emissions across all scopes by 2050. For this level, the company must focus on all activities over which it can exert influence. Organizations seeking Level 3 certification must demonstrate quantitatively in their KTP how it will achieve CO_2 reduction within their organization, across the value chain and where applicable beyond (OBE) on the path to 2050. Total CO_2–emissions in scopes 1, 2 and 3 decrease rapidly. The organization works together with an independent expert and a partner. Level 3 therefore requires the most ambitious goals and plans (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b)

When bidding for infrastructure projects, the bidder indicates that the offer will be aligned with one of the first three levels of the ladder. The higher the level, the greater the effort required and the more challenging it becomes to reduce CO_2–emissions. On the other hand, a higher level (if achieved) results in a higher fictitious discount on the tender price, thereby increasing the likelihood of winning the contract. The amount of this discount and the method by which it is calculated together with the other qualitative elements of the tender are based upon the BPKV (Best Price-Quality Ratio) criteria (Rijkswaterstaat, 2026a). This criteria is related and computed from the EMVI criteria since 2016, RWS selects bidders based on the combination of price and quality. Quality includes aspects such as public engagement, sustainability and risk management. In this way, Rijkswaterstaat also aims to stimulate innovation within the (GWW) sector. RWS uses a scale ranging from 2 to 10 in the sector, however since 2023 it was adopted a different (progressive) scale from 0 to 3, where 0 represents no added value and 3 represent 100% added value, see Table A.3. Submissions that are done with disadvantageous or posing risks, the letter code 'NR' is assigned, which results in a higher fictitious tender price (Rijkswaterstaat, 2026c).

Table A.3: *
Scoring system and corresponding percentage of maximum quality value for bidding (Rijkswaterstaat, 2026c)

Description of the score	Score	% of maximum quality value
Excellent (significant added value)	3	100
Good (clearly sufficient to considerable added value)	2	60
Fair (sufficient added value)	1	25
Neutral (little or no added value)	0	0
Adverse and/or risky	NR	-50

The BPKV methodology is applied within the civil engineering sector for engineering services that are covered by the agreement. Other procurement domains are generally using a point based BPKV model without applying monetization. During the tender, RWS elaborates the methodology for the specific project in the tender guidelines, these set out the objectives, the criteria on which RWS assesses them and the maximum value (expressed in monetary terms) are assigned to these criteria. The purchasing processes is as follows (Rijkswaterstaat, 2026c):

- Formulating criteria based on the project's objectives and risks
- Carrying out the actual procurement process by preparing the tender documents, evaluating the submissions and providing feedback to the bidders
- Safeguarding the EMVI added value offered during the execution phase

During the award of the project, the proposed level of the ambition becomes part of the contract and must be achieved during the execution of the project. This is a performance mandate for the contractor. In case it appears that after a while this won't be achieved, then a sanction will be assigned of 1.5 times the fictitious discount of the bid (Rijkswaterstaat, 2026c).In case the CO_2-Prestatieladder 4.0 is used as a BPKV criterium, Table A.4 shows what rules apply to this (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a).

Table A.4: *

CO_2 ambition levels and corresponding award advantage (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a)

CO_2 Ambition level	**Award advantage**
No CO_2 ambition level	0% or €0 or 0 points
CO_2 ambition level 1	5% or €37,500 or 50 points
CO_2 ambition level 2	10% or €75,000 or 100 points
CO_2 ambition level 3	15% or €112,500 or 150 points

Note: Using the absolute scoring method, the total award advantage ranges between €800,000 and €1.1 million, based on a total of 550 points.

Companies are able to bid using this methodology with the BPKV criterion in two ways, namely:

1. The first option is for the company to submit its 'CO_2 Awareness Certificate', which shows that the entire organization operates CO_2 consciously in line with the levels of the award criterion.
2. The second option is for the company to demonstrate at project level that, for this specific project, it meets the ambition level and underlying levels of its tender

In short, tenders that use the CO_2-Prestatieladder as a BPKV criterion, holding or obtaining a 'CO_2 Awareness Certificate' is not mandatory, it is simply one possible way to meet the criterion. The methodology can be applied to this specific domain in the procurement stage. However, it is essential to be aware of the consequences in case the performance on the long run does not meet the documented level during the bidding phase. A penalty might be assigned, so overestimating might backfire (1.5 times). The core principle of the ladder is that demonstrable effort is rewarded.

Additionally, DuboCalc stands for 'Duurzaam Bouwen Calculator' (Sustainable Building Calculator) and was developed by Rijkswaterstaat to calculate and compare the sustainability and environmental costs of public tenders. DuboCalc is used by contracting authorities and potential contractors to analyze design variants and to prepare and assess BPKV/EMVI tenders for civil engineering (GWW) works (Rijkswaterstaat DuboCalc, 2025). The tool can represent effects of the equivalent emissions into 'shadow' prices of which the summation is expressed in the MKI-value. The higher the MKI the more (the material) will harm the environment. The main goals is to significantly influence environmental advantage within the design, execution and bidding of civil engineering (GWW) projects, therefore interesting for bids using the BPKV criterion. Environmental costs allow contracting parties to assess tenders quickly and consistently, whereas potential contractors and third parties can use this info to improve their bids. Figure 3.4 shows the MKI score of three variants. A higher score indicates a greater environmental impact in terms of total life cycle costs (LCC) (Duurzaam GWW CROW, 2016). A lower MKI-value often also results in CO_2 reduction and contributes to the objectives of the Circular Economy (CE).

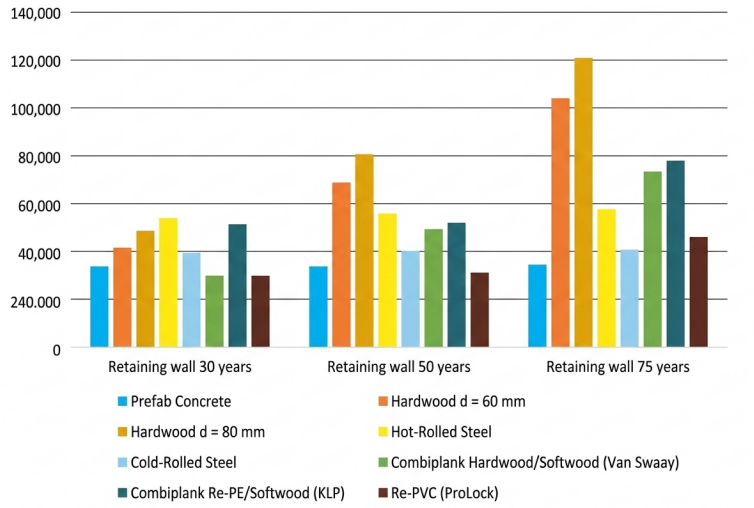


Figure A.8: *
Example of using DuboCalc for several cases and material use (Duurzaam GWW CROW, 2016)

These methodologies and approaches are all contributing to the phenomena of a Circular Economy (CE). Sustainable construction and development both contribute to a (CE), which becomes more important in the Dutch construction industry.

Circular Economy (CE)
Today's Dutch construction industry is significantly influenced by sustainability, driven by trends such as circularity and bio-based innovation. As a leader in this field, the Netherlands has committed to achieving a fully circular economy by 2050, guided by the National Programme Circular Economy (NPCE) from 2023 till 2030 (Ministerie van Infrastructuur en Waterstaat, 2023). In order to achieve the full CE goal this strategic plan is extended and guided by the Circular Dutch Economy ('Circulaire Nederlandse Economie') (Government of the Netherlands, 2025). The timeline is shown below in Figure A.9.

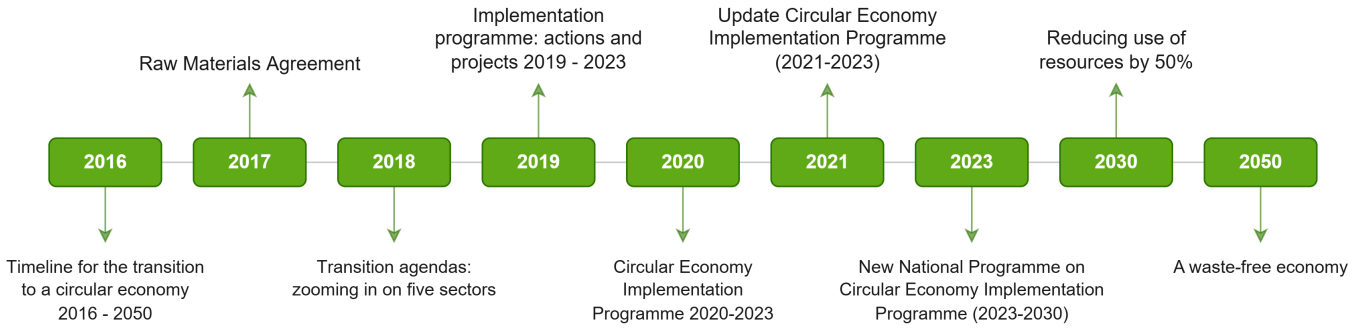


Figure A.9: *
Timeline for the transition to a circular economy 2016 - 2050 (Government of the Netherlands, 2025).

The analogy of circularity within the economy of the Netherlands can be expressed as a shift from a linear project delivery towards a collaborative, procurement driven value maintenance across the whole project LC. Not only does this in the Netherlands mean that circular construction is about recycling (e.g. using the R-ladder, Rijksdienst voor Ondernemend Nederland, 2025), but also about redesigning roles, contract and information- and workflows, so materials stay valuable for a longer period of time. Besides that, reverse cycles (of closed loop systems) become feasible and project teams can work with suppliers earlier within the chain or process. As stated by van der Voet et al., 2025, there is not an accepted definition for circular economy, but the core concept is relatively clear. A circular economy aims at keeping resources in use as long as possible. Meaning that waste generation and resource extraction should both be reduced to minimize the impact. Use of different strategies in practice that are developed within current frameworks, aiming at keeping resource as long as possible in the use phase without causing any waste or emissions.

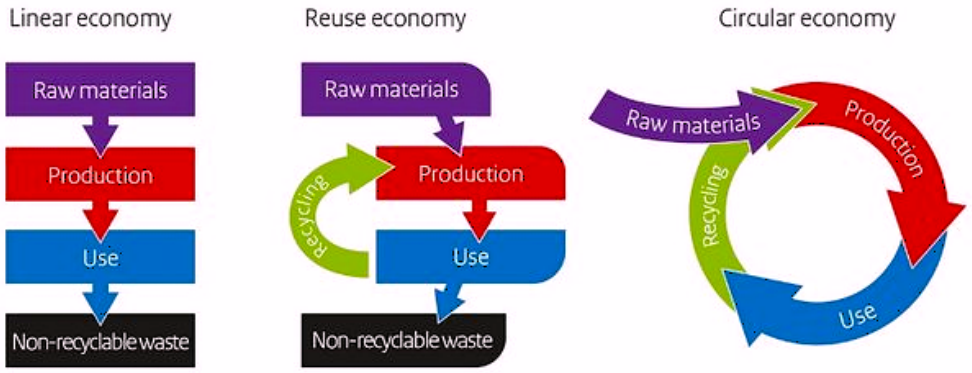


Figure A.10: *
Transition between linear economy and circular economy (Pereira et al., 2019)

Therefore, the narrative of a circular economy is moreover emphasized on the principle of extracted resource in the past that are now in use for structures in projects. van der Voet et al., 2025 refers to this 'in-use stocks in society'. These provide services to the society, such as mobility or shelter. Indicating that these 'in-use stocks' should be kept healthy for a longer period of time and is not about only process efficiency or closing loops, but about comprehensive asset management. Since a circular economy can be realized by maintenance of 'in-use stocks', less input of newly extracted materials and decoupling its effect from economic development. Pots, 2018 argues that the economic development can be positive influenced through the procurement processes that create a 'transition arena' for learning where early procurement, (functional) specifications, shared risk and cooperation between client and partner come together. In contradiction, Prins et al., 2015 stated that the Dutch construction sector is already fragmented and overly linear and supports a more 'radical' CE interpretation that better fits the economic incentives of the sector. The approach in this doesn't necessarily indicate that transition will be successful, however Coenen et al., 2023 identified three vicious cycles that form persistent barriers to increase the success rate. These barriers all relate to procedural, organizational and institutional challenges rather than technological ones. These require explicit changes in scope definition, procurement timing, risk sharing and financial responsibilities, since Dutch circular construction is being operationalized through procurement, collaboration and thinking, but the literature still treats it as a project level transition rather than an embedded routine within everyday project control. To do so, there are some current approaches (e.g. LCA and LCCA) that help analyzing circularity on project or element level, which is also done by W+B

Life-Cycle Analysis (LCA)
The Life-Cycle Analysis (LCA) is a methodology that is standardized under the ISO-14040 and ISO-14044 certification, which is used to assess the environmental impact of products or projects across its entire LC from raw materials extraction through production, use and end of life disposal ("ISO 14040: Environmental management – Life cycle assessment – Principles and framework", 2006). In the Dutch construction industry, the LCA is more and more applied to quantify embodied CO_2 and material related pollution at project and element level. A study by Buyle et al., 2013 argues that LCA is relevant for the built environment, as building account for a significant share of global resource consumption and emissions. Regarding a CE, LCA allows project teams to compare material strategies (e.g. reuse, recycling or replacing from the R-ladder strategy (Rijkswaterstaat, 2025)) and evaluate the environmental trade-offs across the entire project LC (Honic et al., 2019). In practice, application of LCCA still remains fragmented since it differs per situation, since it is dependent on data availability, boundary definitions and functional unit choices that changes per project. This results into a limitation of comparing and integration in FEDP procurement decisions (Buyle et al., 2013).

Life-Cycle Cost Analysis (LCCA)
The Life-Cycle Cost Analysis (LCCA) is a decision support method that evaluates the total cost of ownership of an assets or structure over its entire service life which involves initial investment, operation, maintenance and end-of-life costs (Fuller, 2016). This indicates that total cost of ownership is a summation of CAPEX and OPEX. In general, the LCCA allows clients and procurement teams to make decisions beyond 'low initial cost selection' meaning that a more value-based decision can be made, that consider the principles of a CE (Woodward, 1997). According to Gluch and Baumann, 2004, LCCA serves as a bridge between economic and environmental objectives if integrated with LCA, which allows project teams to assess both financial and ecological performance in parallel. In Dutch context, the LCCA is more and more included in procurement frameworks, where the total cost of ownership (CAPEX + OPEX) criteria are used to incentivize long term asset performance and circular material recycling. Nevertheless, uncertainties in future cost estimates (e.g. discount rates, maintenance cycles or residual material value and performance) still remains a barrier to the use of this method in circular construction (Gluch and Baumann, 2004)

(Inter)national sustainability rating systems and approaches

At national and international levels, the existing rating systems and approaches differ greatly in the types of projects they apply to as well as the sustainability criteria or level they quantify or certify. They incorporate regional priorities, regulatory frameworks and sector-specific standards along with environmental, social and performance measures. A

thorough review of these sustainability-oriented rating systems is provided, including scopes, methodologies, evaluation metrics and areas of focus. This will help to understand the global landscape of sustainability assessment frameworks.

Envision

What is Envision?

Developed by the Institute for Sustainable Infrastructure (ISI), the Envision Sustainability Tool helps plan, design and deliver sustainable infrastructure. Projects are evaluated according to a number of social, environmental and economic criteria throughout their entire life cycle, from the initial design stage to the final maintenance stages. It's a tool to guide decision-making, promote collaboration and recognize projects that achieve high sustainability levels (Institute for Sustainable Infrastructure, 2024).

At Harvard University's Graduate School of Design, ISI collaborates with the Zofnass Program for Sustainable Infrastructure to develop Envision. ISI was founded by the American Public Works Association (APWA), the American Society of Civil Engineers (ASCE) and the American Council of Engineering Companies (ACEC). The rating system consists of:

- A guidance manual that includes 64 sustainability and resiliency criteria
- Project assessment tools
- Professional training and credentialing
- Third-party project verification

Over 160 infrastructure projects have been completed and registered using Envision. The combined portfolio of completed and registered Envision projects is worth over $237 billion.

Who uses Envision?

The Envision system is used worldwide by more than 300 cities, towns, counties, public agencies and academic institutions. In these organizations, Envision Sustainability Professionals (ENV SPs) use the framework to set standards for sustainable infrastructure and guide procurement. Envison is used by over 260 private organizations and associations, including public agencies, in order to set higher performance goals for projects and collaborate and communicate on achieving them (for example, Arup and Arcadis in the Netherlands).

How is Envision structured?

Envision contains 5 categories of sustainability and resilience with in total 64 credits:

1. Quality of Life – 14 credits
   Considering well-being, mobility and community. This categories addresses a project's impact on communities, from health, well-being and equity of individuals to that of the larger social fabric.
2. Leadership – 12 credits
   Considering collaboration, planning and economy. Reward communication, collaboration, teamwork, leadership and commitment to sustainability. Also rewards meaningful stakeholder engagement and life-cycle economic evaluation.
3. Resource Allocation – 14 credits
   Considering materials, energy and water. Broadly concerned with quantity, source and characteristics of the resources needed to build infrastructure and keep it running.
4. Natural World – 14 credits
   Considering siting, conservation and ecology. Addresses how projects are located within and affect the natural world and ecosystem services. Reward projects that minimize negative impacts and those that protect and restore habitats.
5. Climate and Resilience – 10 credits
   Considering emissions and resilience. Focuses on minimizing emissions that exacerbate climate change and magnify short- and long-term risks, ensuring projects are resilient and contribute to resilient communities.

What is Envision's approach?

Envision has been setup based on the its proven and best-practice approach with the aim to achieve sustainable, resilient and equitable infrastructure. These incorporated best-practices involve:

- Mitigation hierarchy
  The mitigation hierarchy at Envision prioritizes the steps needed when building civil infrastructure. *Avoidance* stands for the measures taken from the outset to avoid creating negative impacts. *Minimization* stands for measures taken to reduce the duration, intensity or extent of impacts that can not be avoided. *Abatement* stands for measures taken to rehabilitate degraded ecosystems. *Offsetting* stands for measures taken to compensate for any residual adverse, see Figure A.11.

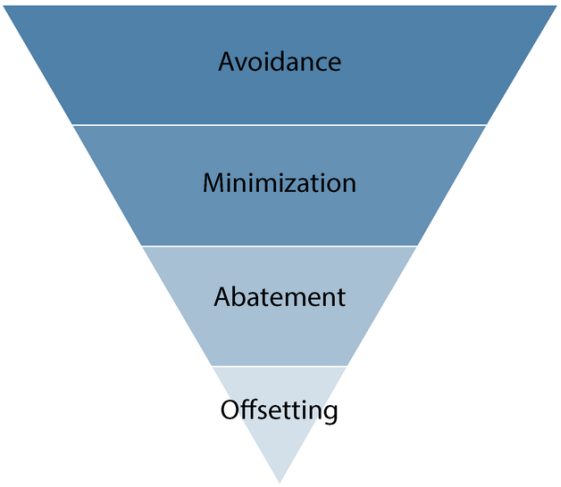


Figure A.11: [
]The mitigation hierarchy visualization (Institute for Sustainable Infrastructure, 2024)

- Triple Bottom Line (TBL)
  The TBL represents the sustainability part, see Figure A.12. In other words, Envision bolsters environmental protections and conserves resources, promotes social well-being/equity and helps communities thrive economically. This concept is elaborated in Triple Bottom Line (TBL) 3.1.1.1.



Figure A.12: *
The Triple Bottom Line (TBL) (Institute for Sustainable Infrastructure, 2024)

- Innovation
  Envision encourages innovation across all aspects of sustainability and resilience. Some topics and approaches in Envision are aspirational, laying out a best-case scenario and allowing projects to determine the best approach for achieving this scenario. Other approaches are a blank slate, allowing project teams to innovate and develop new solutions to suit their present and future needs.
- Performance improvement
  The performance improvement is of essence to optimize the rating system. The goal is to incentivize a higher performance (based on opportunities) in 3 dimensions, see Figure A.13:

  1. Project Phase and Life-Cycle (LC)
     The first part is the project life cycle. Teams are using Envision not just for planning and design, but also through construction, thinking ahead to operations, maintenance and even the project's end of life, like how easily materials can be taken apart or reused.

2. Stakeholder Collaboration
   When a diverse group is involved from the start of planning and design, projects end up meeting what the community actually wants and needs. Working with stakeholders also helps uncover the biggest range of sustainable options, like ways to share resources or create social benefits.
3. Performance Levels
   Each credit in the Envision framework has up to five achievement levels, starting with *Improved*, meaning performance that's a bit better than standard practice and going up to *Restorative*, where the project actually helps repair natural or social systems.

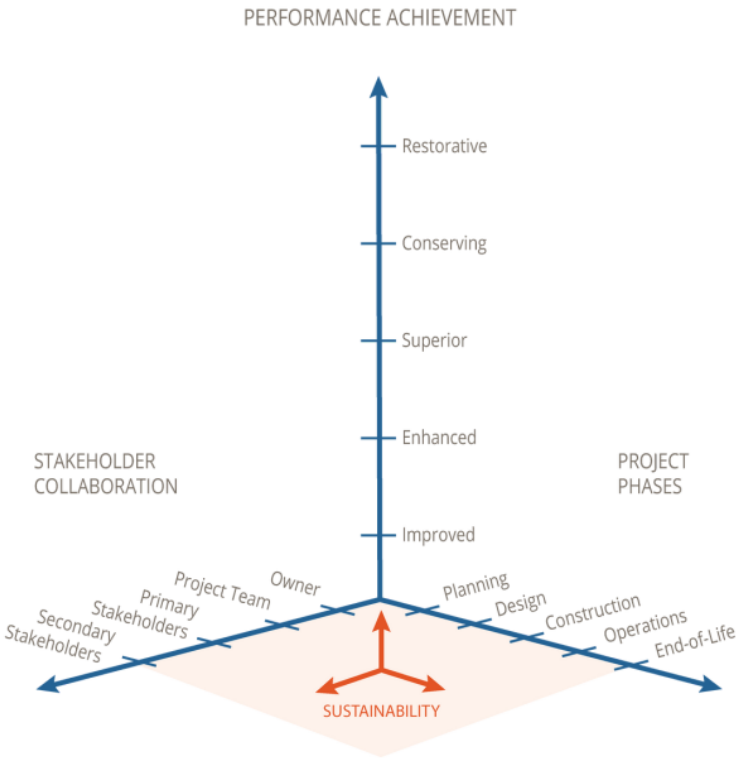


Figure A.13: *
3D performance improvement diagram (Institute for Sustainable Infrastructure, 2024)

Verification and certification
In order to obtain an official verification for Envision, there are basically 2 pathways, namely:

Pathway A. This is a way that allows one to pursue Envision verification during a project's design phase, see Figure A.14.



Figure A.14: *
Pathway A verification (Institute for Sustainable Infrastructure, 2024)

Pathway B. This is a way that allows one to pursue verification after construction is complete (as an afterthought), see Figure A.15.



Figure A.15: *
Pathway B verification (Institute for Sustainable Infrastructure, 2024)

Verification provides a range of significant benefits to both project teams and the wider community. It builds confidence among ratepayers and taxpayers by demonstrating that public funds are being allocated and managed responsibly. Moreover, verification encourages and rewards the adoption of industry best practices, inclusive engagement and sustainable

performance, therefore strengthening community trust. It also enables teams to clearly define, document and communicate their achievements in sustainability, resilience and equity. Additionally, the verification process contributes to learning by expanding knowledge of sustainable practices and processes. Finally, it promotes collaboration and creates opportunities for more effective dialogue, innovation and critical thinking across stakeholders.

Award levels for projects/companies based on the percentage of applicable Envision points attained in verification. According to Clevenger et al., 2013 Envision is a two-stage assessment tool, the first stage is a Self-Assessment Checklist (see example in Figure A.16) and the second stage involves a Third Party Verification and Public Recognition. Regarding the award levels, there are 4 Envision certifications that exists:

Certification 1. Acknowledgment of Merit

Certification 2. Silver Award (8% minimum in each category)

Certification 3. Gold Award (15% minimum in each category)

Certification 4. Platinum Award (20% minimum in each category)

Envision Rating System
Self-Assessment Checklist
For Public Comment Only - Not for Project Use

				Y	N	NA		
1	QUALITY OF LIFE	PURPOSE	QL1.1 Improve community quality of life	2	1	0		2 of 3
2			QL1.2 Stimulate sustainable growth and development	1	1	1		1 of 2
3		COMMUNITY	QL1.3 Develop local skills and capabilities	0	3	0		0 of 3
4			QL2.1 Enhance public health and safety	0	1	0		0 of 1
5			QL2.2 Minimize noise and vibration	0	0	1		0 of 0
6			QL2.3 Minimize light pollution	1	0	0		1 of 1
7			QL2.4 Improve community mobility and access	0	2	1		0 of 2
8			QL2.5 Encourage alternative modes of transportation	1	1	0		1 of 2
9			QL2.6 Improve site accessibility, safety and wayfinding	1	1	1		1 of 2
10		WELLBEING	QL3.1 Preserve historic and cultural resources	1	1	0		1 of 2
11			QL3.2 Preserve views and local character	2	0	0		2 of 2
12			QL3.3 Enhance public space	2	0	0		2 of 2
			TOTAL	**11**	**11**	**4**		11 of 22
13	LEADERSHIP	COLLABORATION	LD1.1 Provide effective leadership and commitment	3	0	0		3 of 3
14			LD1.2 Establish a sustainability management system	1	0	0		1 of 1
15			LD1.3 Foster collaboration and teamwork	3	0	0		3 of 3
16			LD1.4 Provide for stakeholder involvement	3	0	0		3 of 3
17		MANAGEMENT	LD2.1 Pursue by-product synergy opportunities	1	0	0		1 of 1
18			LD2.2 Improve infrastructure integration	3	0	0		3 of 3
19		PLANNING	LD3.1 Plan for long-term monitoring and maintenance	2	0	0		2 of 2
20			LD3.2 Address conflicting regulations and policies	2	0	0		2 of 2
21			LD3.3 Extend useful life	0	0	1		0 of 0
			TOTAL	**18**	**0**	**1**		18 of 18
22	RESOURCE ALLOCATION	MATERIALS	RA1.1 Reduce Net Embodied Energy	0	1	1		0 of 1
23			RA1.2 Support Sustainable Procurement Practices	0	3	0		0 of 3
24			RA1.3 Use Recycled Materials	1	1	0		1 of 2
25			RA1.4 Use Regional Materials	2	0	0		2 of 2
26			RA1.5 Divert Waste from Landfills	1	2	0		1 of 3
27			RA1.6 Reduce Excavated Materials Taken off Site	2	1	0		2 of 3
28			RA1.7 Provide for Deconstruction and Recycling	0	2	1		0 of 2
29		ENERGY	RA2.1 Reduce energy consumption	0	0	3		0 of 0
30			RA2.2 Use renewable energy	0	0	2		0 of 0
31			RA2.3 Commission and monitor energy systems	0	0	3		0 of 0
32		WATER	RA3.1 Protect fresh water availability	6	0	1		6 of 6
33			RA3.2 Reduce potable water consumption	4	0	0		4 of 4
34			RA3.3 Monitor water systems	0	0	4		0 of 0
			TOTAL	**16**	**10**	**15**		16 of 26
35	NATURAL WORLD	SITING	NW1.1 Preserve prime habitat	5	0	0		5 of 5
36			NW1.2 Protect wetlands and surface water	2	1	0		2 of 3
37			NW1.3 Preserve prime farmland	0	1	0		0 of 1
38			NW1.4 Avoid adverse geology	3	0	0		3 of 3
39			NW1.5 Preserve floodplain functions	3	1	2		3 of 4
40			NW1.6 Avoid unsuitable development on steep slopes	1	1	0		1 of 2
41			NW1.7 Preserve greenfields	1	1	0		1 of 2
42		LAND & WATER	NW2.1 Manage stormwater	1	0	1		1 of 1
43			NW2.2 Reduce pesticide and fertilizer impacts	4	0	1		4 of 4
44			NW2.3 Prevent surface and groundwater contamination	4	0	-1		4 of 4
45		BIODIVERSITY	NW3.1 Preserve species biodiversity	4	0	0		4 of 4
46			NW3.2 Control invasive species	3	0	0		3 of 3
47			NW3.3 Restore disturbed soils	2	0	0		2 of 2
48			NW3.4 Maintain wetland and surface water functions	4	0	1		4 of 4
			TOTAL	**37**	**5**	**4**		37 of 42
49	CLIMATE	EMISSION	CR1.1 Reduce greenhouse gas emissions	0	1	1		0 of 1
50			CR1.2 Reduce air pollutant emissions	1	1	0		1 of 2
51			CR2.1 Assess climate threat	0	1	0		0 of 1
52		RESILIENCE	CR2.2 Avoid traps and vulnerabilities	2	0	0		2 of 2
53			CR2.3 Prepare for long-term adaptability	1	0	0		1 of 1
54			CR2.4 Prepare for short-term hazards	2	0	0		2 of 2
55			CR2.5 Manage heat islands effects	0	0	1		0 of 0
			TOTAL	**6**	**3**	**2**		6 of 9

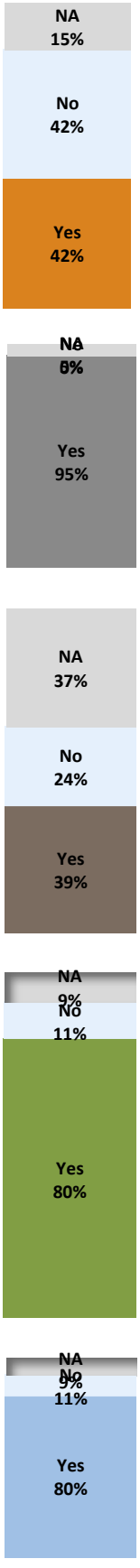


Figure A.16: *
The Self-Assessment Checklist from the UTR project (Wilkins and Schuster, 2025).

In short, the Envision rating tool offers a comprehensive framework for sustainability planning, leading to more detailed analysis and ultimately more sustainable civil infrastructure projects, including restoration efforts like the Upper Truckee River Restoration Strategy (Wilkins and Schuster, 2025).

Red thread

Regarding the topic of this research, this rating system is a comprehensive approach taking into account the sustainability TBL (which verifies the sustainability integration part) and beyond that. However according to the 2 pathways of verifying the projects sustainability level, it only defines that the award is provided after the design review, which confirms the fact that it is done as an afterthought or an add-on to check its sustainability level. Therefore, it is not a system that incorporates sustainability integration during the FEDP within project control and project management.

IS Rating Scheme

What is IS Rating Scheme?

The IS Rating Scheme is Australia and New Zealand's rating framework, since 2012, that is used to evaluate economic, social, environmental and governance performance (also called the QBL) of infrastructure development across all phases of their LC. The LC consists of the planning, design, construction and operation phases of infrastructure programs, projects, networks and assets (Infrastructure Sustainability Council of Australia, 2025), see Figure A.17.

According to the presentation of Kristy Bauer, the benefits of the infrastructure sustainability approach is that the initiatives provide common national language for evaluating sustainability in infrastructure development and support consistent application of sustainability criteria throughout tendering processes. They help organizations identify LC sustainability risks for projects, but also enabling smarter solutions/measures that reduce these risks and therefore also costs. Lastly, these initiatives promote resource efficiency and waste reduction, encourage innovation and continuous improvement and strengthen an organization's credibility and reputation in its approach to sustainable infrastructure (ISCA, 2016).

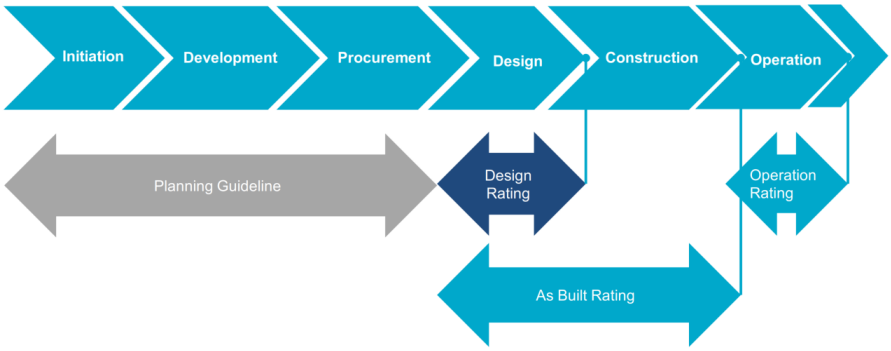


Figure A.17: *
The project LC and its applicable rating modules/frameworks (ISCA, 2016)

Who uses IS Rating Scheme?

The IS Rating Scheme is mainly used by infrastructure owners, operators, project delivery teams and procurement/contracting organizations in Australia and New Zealand. The scheme is administered by the Infrastructure Sustainability Council of Australia (ISCA). It is often applied to major infrastructure projects where sustainability performance (in terms of the QBL) is measured and benchmarked as shown in Figure A.18.

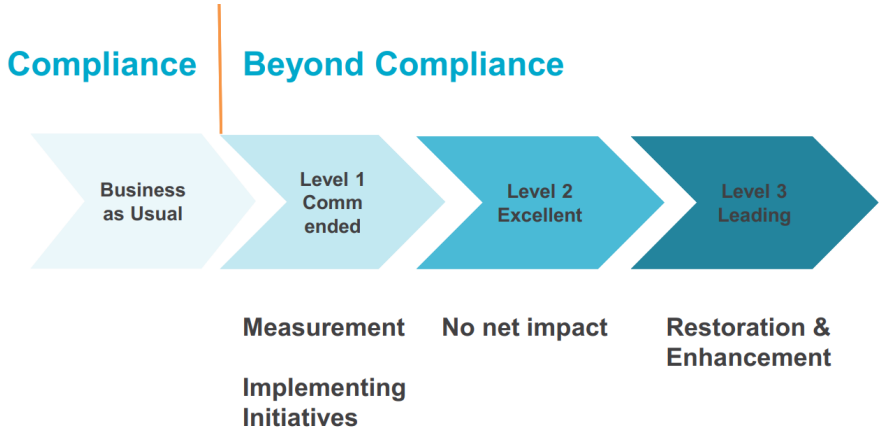


Figure A.18: *
Benchmark procedure (ISCA, 2016).

How is IS Rating Scheme structured?

On the website of the Infrastructure Sustainability Council, several manuals and resources are available, covering different phases of the infrastructure cycle, see Figure A.17. The essential and main ones are represented by the *IS Design & As Built v2.1* and *IS Planning v2.1*:

1. *IS Design & As Built v2.1*
   This rating tool give stakeholders, investors and community members assurance that a project is sustainable, cost-effective and positive for the community. It independently verifies and certifies that a project has been designed and built to best-practice industry standards and that it performs sustainability, now and for the future. How this is done, will be elaborated later (Infrastructure Sustainability Council (ISC), 2021).

2. *IS Planning v2.1*
   This rating tool can be used for numerous types of infrastructure assets and major works in infrastructure development (e.g. roads, pathways, rails, aviation and maritime). Additionally, it provides the opportunity to incorporate sustainability into early-stage decision-making, which allows organization to seek smarter and more efficient for solutions/measures which minimizes projects risks and costs. The rating tool also drives community and cultural engagement in project planning, guaranteeing assets are fit for purpose and meet stakeholders needs/desires, which improves the reputation of the company and builds trust and support with stakeholders (Infrastructure Sustainability Council (ISC), 2025).

The themes and categories that are used in order perform the assessment is shown in Table A.5. These are aspects that will be evaluated with the aim to get the final verification and certification, which will be elaborated later on.

Themes	Categories
Management and governance	Management systems
	Procurement and purchasing
	Climate change adaptation
Using resources	Energy and carbon
	Water
	Materials
Emissions, pollution and waste	Discharges to air, land and water
	Land
	Waste
Ecology	Ecology
People and place	Community health, well-being and safety
	Heritage
	Stakeholder participation
	Urban and landscape design
Innovation	Innovation
Workforce*	
Economic*	

Table A.5: *
IS Rating Scheme themes and categories (ISCA, 2016)

What is IS Rating Scheme's approach?
The IS Rating Scheme's approach an integrative approach and LC-oriented since it looks beyond design or construction phase. Regarding sustainability, as mentioned earlier, it emphasizes a QBL taking into account the governance, economic, environmental and social perspectives. According to the steel manufacturer BlueScope, the rating system is less prescriptive than some other tools, meaning its not prescribing one solid and specific solution, it allows evidence based outcomes and variation in how compliance is realized (BlueScope Steel Limited, 2025). In addition, in an article Juliana Bedggood from Anthesis, a sustainability and climate change consultancy, states that the tool support innovation and continuous improvement and therefore intends to help organization quantify and manage sustainability as well as building organizational capacity (Bedggood, 2025).

Verification and certification
In case a project is wishing for an IS-Rating, then the applicant mut first register their interest using an ROI form and sign a rating agreement with the ISCA. During this application the applicant works with a case manager who enables ISCA to assess the proposal. As mentioned earlier, after the assessment, a third part verifier (independently) undertake its verification which can potentially take up to 3 months. Going through this, the applicant receives a verification besides the rating/certification once verification is complete. Projects are scored through specific IS credits and achieve one of five performance ratings (Construction Law Made Easy, 2025):

- 20 to 39 equates to a Bronze rating
- 40 to 59 equates to a Silver rating
- 60 to 79 equates to a Gold rating
- 80 to 94 equates to a Platinum rating
- 95 or above equates to a Diamond rating

Red thread
In relation to the focus of this research, the rating system represents a comprehensive approach that incorporates the QBL, ensuring the integration of sustainability principles, including governance. However, it extends beyond this by

considering the existence of multiple rating tools applicable to different stages of a project. For example, the initiation, development and procurement stages utilize the *IS Planning v2.1*, while the design and construction stages make use of the *IS Design & As Built v2.1*, respectively. The use of various tools across project phases, along with the involvement of third parties for certification and verification, contributes to the complexity of sustainability integration rather than reducing it, due to dependencies for example. Additionally, the system does not embed sustainability integration within the FEDP as part of project control and management practices.

CEEQUAL

What is CEEQUAL?

CEEQUAL, or the Civil Engineering Environmental Quality Assessment & Award Scheme, is an international tool for assessing and rating the sustainability of civil engineering projects. It was originally developed by the Institution of Civil Engineers (ICE) in the United Kingdom and launched publicly in 2003. In recent years, CEEQUAL has become part of the broader family under the BREEAM Infrastructure umbrella (managed by BRE Global) which signals a merging/integration of the infrastructure-rating offerings (CEEQUAL Ltd., 2018).

Who uses CEEQUAL?

This rating tool is used by project teams (clients, designers and contractors) involved within the civil engineering field focused on infrastructure works (e.g. transport, utilities, highways and tunneling) as stated by a publication of sustainability manager Mike de Silva from United Kingdom (de Silva, 2016). Besides the Unite Kingdom, organizations from Ireland also aim to demonstrate leadership in infrastructure delivery, but also internationally via the international manual. This is proven by the case study A470 Cambach to Newbridge on Wye (Royal College of Pathologists and Crossrail Learning Legacy, 2018). Lastly, agencies and funders who require independent verification of sustainability performance in their projects also use CEEQUAL that can be used to complement the Environmental Impact Assessment (EIA) (Institute of Sustainability and Environmental Professionals (ISEP), 2025).

How is CEEQUAL structured?

CEEQUAL is divided into two systems:

- *CEEQUAL for Projects v5*
  This assessment framework is mainly used for individual infrastructural projects across its whole LC. Useful for civil engineering, infrastructure, landscaping and public realm works wherever the project is located in the world. However, within this system, there is an additional division in terms of international projects or United Kingdom and Ireland projects. The primary difference lies in the level of detail in the guidance provided and the need on international assessment for a weighting exercise to be undertaken in the locality of the project. The local weightings are needed in order to enable CEEQUAL to re-score the questions based on the local context (this is called differentiation). The scheme for this framework is available for United Kingdom & Ireland projects (1) and international projects (2) (CEEQUAL Ltd., 2018).
- *CEEQUAL for Term Contracts v5*
  This assessment framework is created for civil engineering and public realm works that are done through contracts over a number of years and in a geographical or operational area. In general, the benefits are similar to *CEEQUAL for Project v5*, but the methodology has been modified for the way these contracts are procured, managed and delivered. As construction works orders often run into thousands per month, not only is the nature of the work different from projects, but so is the procurement and management. If a project involves construction of new works which consists of many small-scale and repetitive operations, for example linear projects like electrification of railways, then it is logical, appropriate and efficient to use the Term Contracts Assessment Manual for Construction of small or repetitive new works than using CEEQUAL for Projects (CEEQUAL Ltd., 2018).

What is CEEQUAL's approach?

CEEQUAL uses a widened scope related to the initial base of the TBL theory. This is show in Figure A.19, whereas all of the characteristics of 'sustainable development' are taken into account.

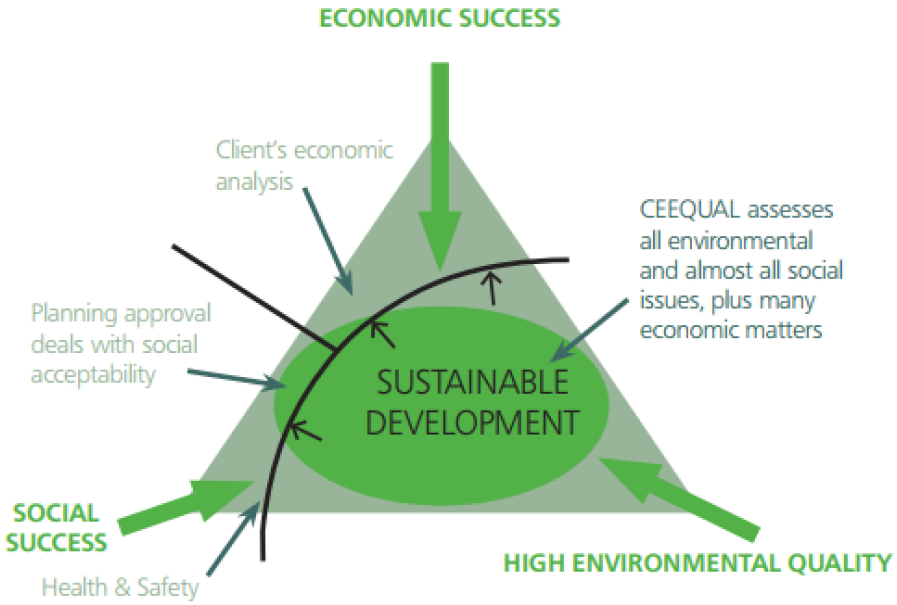


Figure A.19: *
CEEQUAL V5 (CEEQUAL Ltd., 2018)

CEEQUAL uses a self-assessment process in which CEEQUAL trained-Assessors rigorously assess project or contract strategy and performance on a range of economic, social and environmental issues (TBL), arranged in nine section (CEEQUAL Ltd., 2018):

Section 1. Project Strategy or Client Contract Strategy
Section 2. Project Management or Contract Strategy
Section 3. People and Communities
Section 4. Land use and Landscape
Section 5. The Historic Environment
Section 6. Ecology and Biodiversity
Section 7. Water Environment
Section 8. Physical Resources Use and Management
Section 9. Transport

The analogy of the assessment for both systems is shown in Table A.6

Table A.6: *
CEEQUAL Assessment Types and Corresponding Award Types (CEEQUAL Ltd., 2018; SE 2050 Secretariat, 2025).

Assessment type	**Strategy**	**Design**	**Construction**	**Applicable award type**
Whole Project *(Joint application by Client, Designer and Principal Contractor)*	Optional	Optional	Mandatory	Whole Team award Whole Team Award with Interim Design Award
Strategy & Design *(Joint application by Client and Designer)*	Optional	Mandatory	–	Client & Design award
Design only *(by Lead Designer)*	–	Mandatory	–	Design award
Design & Construction *(Joint application by Client and Contractor)*	–	Optional	Mandatory	Design & Construction award
Construction only *(by Lead Contractor)*	–	–	Mandatory	Construction award

After completion of one or multiple Assessments, taking into account Table A.6 and depending on project team members preferences, it is externally verified by a CEEQUAL-appointed Verifier and then confirmed by the Scheme Management

Team. Assessors use the appropriate CEEQUAL Manual to score performance against questions relevant to their project or contract. Assessors must do this by collecting evidence to support their scores for each question, using our Online Assessment Tool for capturing those scores and evidence commentary. Once the Assessment score is ratified, the project or contract team is granted an Award based on the percentage score achieved (this will be elaborated later). For CEEQUAL an online assessment platform is used to record the scoring, evidence and comments from the verifier, so every case is tracked and therefore no confusion can occur about the progress (CEEQUAL Ltd., 2018).

Because CEEQUAL uses documented evidence and a question-set, project teams are encouraged to consider sustainability from early stages (strategy/design) rather than only after construction. This emphasizes the checklist or afterthought story. For example, the scheme encourages early adoption to influence design/contractor choices. This might cause a specific behavior, meaning that clients can integrate the use into their requirements, while use my be voluntary (Royal College of Pathologists and Crossrail Learning Legacy, 2018). This increases the opportunity for benchmark and demonstrating its value and leadership within the market of sustainability rating tools or methodologies in mainly United Kingdom and Ireland.

CEEQUAL for Projects v5 procedural steps
For the project framework the following steps are used in order to obtain the right award scheme:

Step 1. Determine whether 'Project Strategy' is included or not (this determines the sections for assessment)

- Yes: Sustainability Strategy & Performance Assessment (using criteria from sections 1 - 9)
- No: Sustainability Performance Assessment (using criteria from sections 2 - 9)

Step 2. Select the 'Award' to achieve. This depends on which members of the 'Project Team' want to assess their performance against CEEQUAL

Table A.7: *

CEEQUAL Applicants and Award Types (CEEQUAL Ltd., 2018).

Applicant(s)	Award Type
Client, Designer & Contractor	Whole Team Award
Client, Designer & Contractor	Whole Team Award with Interim Design Award *(available when a Client & Design Award is integrated en route to a Whole Team Award)*
Client & Designer	Client & Design Award
Designer only	Design Award
Designer & Contractor	Design & Construction Award
Contractor only	Construction Award

*Note: The Client does not have to have already appointed the Contractor in order to apply for a Whole Team Award (CEEQUAL Ltd., 2018).

CEEQUAL for Term Contracts v5 procedural steps
For the contract framework the following steps are used in order to obtain the right award scheme and manual:

Step 1. Determine whether The Contract Team is wanting to have their work assessed together.

- Yes: Whole Team Award & Assessment (using criteria from sections 1 - 9) by the Whole Team
- No: Delivery Award & Assessment (using criteria from sections 2 - 9) by the Delivery Team

Step 2. Determine which Assessment Manuals should be used. This is dependent and governed by the nature of the work and type of asset (maintaining, creating, modifying or a mix of this).

- Maintenance Manual
- Construction Manual

*Note: For contracts whose scope includes both maintenance and construction works, both Assessment Manuals are used, the assessments are undertaken in parallel within the overall assessment and the scores aggregated to arrive at an overall score (CEEQUAL Ltd., 2018).

Verification and certification
CEEQUAL's approach to awarding certification levels is based on the percentage score obtained in each section, as described earlier in the previous chapters. Based on this, the CEEQUAL Award certificate demonstrates their level of achievement by:

Level 1. Outstanding

Level 2. Excellent

Level 3. Very Good

Level 4. Good

Level 5. Pass

Pass – Good – Very Good – Excellent – Outstanding

Red thread
In general, this rating tool is also very sophisticated and useful for infrastructural projects within the local contexts of United Kingdom and Ireland. A unique selling point here is that it contains the capability of interplay with EIA, because the same evidence may support both methodologies (Institute of Sustainability and Environmental Professionals (ISEP), 2025). In addition to this, the international manual allows adaptation of weightings and criteria to local context (differentiation), making CEEQUAL suitable for projects outside United Kingdom and Ireland. It is unclear whether this differentiation is valid and useful for the specific local country and how this is measured. Additionally, it must be mentioned that there are multiple parties involved in order to get the award granted and in terms of process management, it is quiet complex and time-consuming. Lastly, this rating tool does not include and emphasize the sustainability integration related aspects within project control and project management. Despite the fact, that it uses the TBL theory.

BREEAM-NL

What is BREEAM-NL?

BREEAM (Building Research Establishment Environmental Assessment Method) is a widely used sustainability certification for the built environment that assesses and certifies the environmental performance of buildings and infrastructure projects. Developed by the Building Research Establishment in the United Kingdom, it is used in over 80 countries to evaluate projects across their entire LC. BREEAM-NL is the Dutch adaptation of BREEAM, whereas the national scheme operator in the Netherlands is Dutch Green Building Council (DGBC), which holds the license from the UK parent organization. In the Netherlands it has been in use since 2009 under the name “BREEAM-NL”.

Who uses BREEAM-NL?

The BREEAM-NL rating tool is used by developed, building owners, project teams and facility managers in the Netherlands who want to benchmark, certify or improve the sustainability of their building(s). The rating tool is applicable for several type of construction work, from new construction to large-scale renovation and existing buildings, so it spans different LC-stages. Besides this, the projects also differ across functions, like offices, retail, schools, apartments and industrial space(s). The BREEAM-NL certification is a major option if you are operating in the Netherlands, own, develop or manage a building (or multiple buildings) and wish to demonstrate sustainability credentials. This is not the focus of my research and therefore, the further analysis on this rating tool will be left out.

Red thread

The BREEAM-Nl tool is a comprehensive assessment tool for the building industry across their entire LC. Since the building industry is out of the scope of this research, it is not relevant to continue elaborating on it.

Dutch sustainability rating systems and approaches

Sustainability has become a fundamental part of infrastructure projects in the Netherlands (roads, bridges, locks, tunnels). The goal is a climate-neutral and circular infrastructure by 2050, with an interim target of a 55% CO_2 reduction by 2030 (a tightening of the previous 49% target). In the Netherlands there are several (governmental) organizations that write guidelines and approaches on how to include sustainability in projects. An example is the publication in the Government Gazette of the Clean and Emission-Free Construction (SEB = Schoon en Emissieloos Bouwen) Covenant. On 30 October 2023, the SEB Covenant was signed by 45 parties. These include national government bodies, provinces, water authorities and several municipalities. By signing, they committed to incorporating the SEB requirements from the SEB Roadmap into their procurement procedures (Rijksoverheid & Partijen, 2023).

Clean and Emission-Free Construction Program (SEB)

The Clean and Emission-Free Construction Program (SEB) helps governments and the civil engineering sector with practical tools and instruments to build in a cleaner way and with fewer emissions. The program is committed to achieving a successful transition to clean and emission-free construction by 2030 and beyond. In cooperation with fellow authorities, market parties and knowledge institutions, work is done to create one unified approach for the entire construction sector. CROW, as a knowledge platform, is involved in the program in several ways. They also helped shape the Roadmap and the Covenant and on behalf of the Ministry of Infrastructure and Water Management and the program we prepared the Guideline for Clean and Emission-Free Construction in Procurement (CROW Kennisplatform, 2026).

Th guidelines for the SEB is based on and extracted from the initial SEB Roadmap, which described the emissions requirements with a corresponding timeline. These were defined and translated by the working group of experts from the sector. The guideline (which is open source and free of charge) helps contracting authorities easily include the emission requirements from the SEB Roadmap in their procurement documents. In any case, these are the requirements at the basic level.

The SEB program offers practical guidance and instruments (tools) that provide direction and support implementation. The guideline therefore contributes to a uniform approach and provides clarity to market parties about what they can do. Ultimately, this support and implementation also contribute to considerations regarding possible legislation. This guideline described in short the following:

1. How the SEB Routemap and the Covenant work and which levels exist (Minimum, Basic and Ambitious)
2. That you do not need to use SEB suitability requirement, but you do include contract requirements
3. Complete contract clauses that can be copied directly into your contract
4. Model texts for award criteria, making it possible (for example) to reward additional deployment of zero-emission requirement
5. Improve choices through a decision tree

An important note is that this guideline is also helpful for contracting authorities that have not (yet) signed the covenant but still want to start working on clean and emission-free construction. The contract texts in the guideline are applicable to both UAV- and UAV-GC-contracts. A RAW version of the contract texts will soon become available, which can be included in Part 3 of the RAW specification (CROW Kennisplatform, 2026).

Objective of the SEB Roadmap
The objective of the SEB program is to improve nature, the climate and public health by reducing emissions from construction machinery, vehicles and vessels. In doing so, the program contributes to the goals and ambitions set out in (see Figure A.20):

- Programma Stikstofreductie en Natuurverbetering
  This is the so called 'Nitrogen Reduction and Nature Improvement Program' (Rijksoverheid / Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2022)
- Het Klimaatakkoord
  This is the so called '*The Climate Agreement*' (Rijksoverheid / Ministerie van Economische Zaken en Klimaat, 2019)
- Klimaatneutrale en Circulaire Infraprojecten (KCI)
  This is the so called '*Climate Neutral and Circular Infrastructural Projects*' (Rijksoverheid / Ministerie van Infrastructuur en Waterstaat & Ministerie van Volkshuisvesting en Ruimtelijke Ordening, 2025)
- het Schone Lucht Akkoord
  This is the so called '*The Clean Air Agreement*' (Rijksinstituut voor Volksgezondheid en Milieu (RIVM), 2026; Schone Lucht Akkoord, 2026)

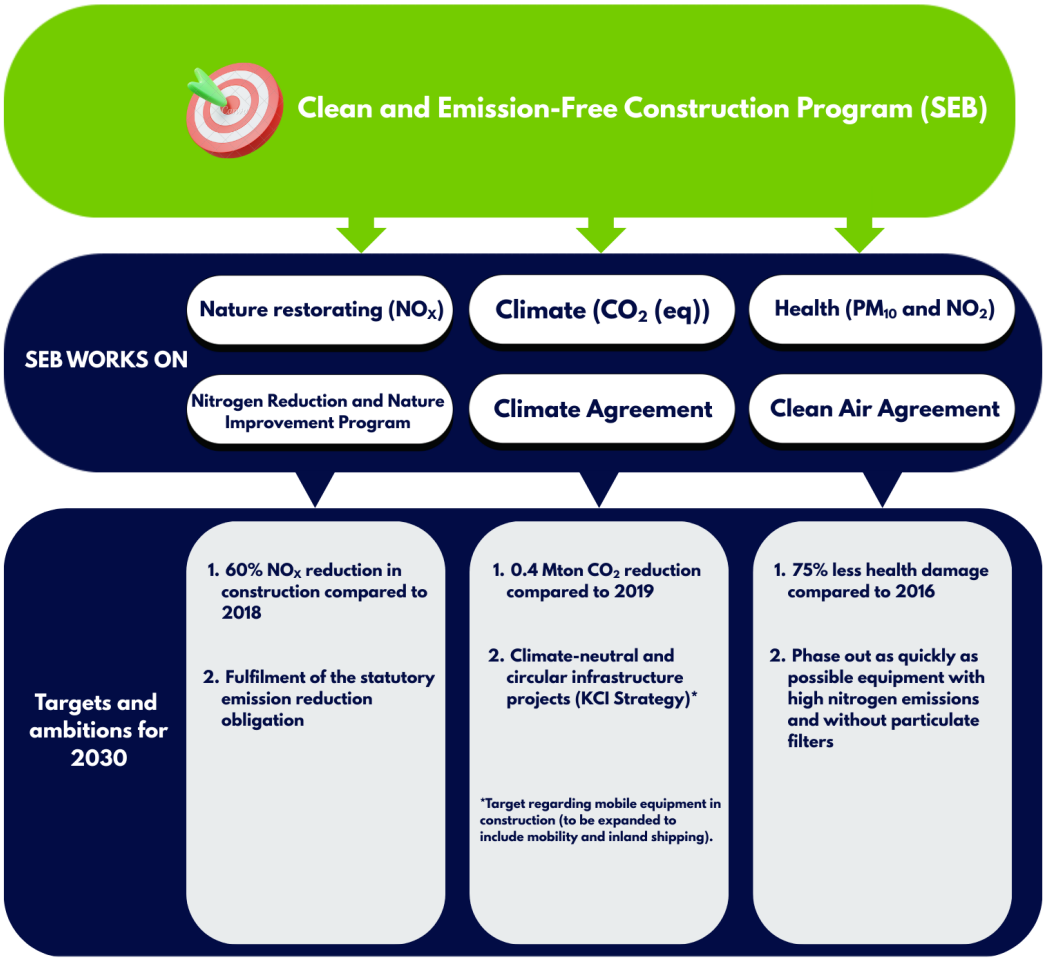


Figure A.20: *
Objectives and ambitions of SEB (Programma Schoon en Emissieloos Bouwen, 2024)

To achieve these goals and ambitions, the SEB program employs a range of instruments. These include both incentives that encourage the use of clean and emission-free construction equipment ("pull measures") and more regulatory, mandatory measures ("push measures"), as highlighted in Figure A.21.

Measures of the SEB Roadmap
The Schoon en Emissieloos Bouwen (Clean and Emission□Free Construction) Roadmap serves as a key framework linking the emission-reduction targets for construction equipment to a set of time-bound measures. This document essentially provides a shared understanding on how the transition should move towards more sustainable mobile machinery, vehicles and vessels in the Dutch construction industry and how it will unfold in the upcoming years.

It not only provides practical guidance, but also offers market stakeholders the insight needed to anticipate future requirements in a timely manner, enabling them to plan their decision□making on necessary investments already today. This

creates a snowball effect throughout the entire project chain, including procurement processes and innovation trajectories, which can use this document as a guiding framework. At the same time, it introduces a new way of thinking within the market, aimed at achieving the established objectives, in which both supply and demand play a crucial role.

The SEB Roadmap for example, operationalizes the emission-reduction obligation set out in the 'Besluit bouwwerken leefomgeving (Bbl)' (*Living environment building decree*), which put indirectly force towards project initiators requiring them to take 'adequate measures' to limit nitrogen emissions during construction and demolition activities. This obligation applies to the construction or demolition of structures (e.g. buildings, civil engineering artifacts), but no to the construction or removal of infrastructure works (e.g. roads or railways). Besides the structures, it also applies only to activities that require a permit (construction) or a formal notification (construction and demolition). Other possible measures include, for example, reducing vehicle movements on the construction site or using prefabrication to shorten construction time.



Figure A.21: *
Push- en pull-measure within the SEB Roadmap (Programma Schoon en Emissieloos Bouwen, 2024)

Scope of the SEB Roadmap
The SEB Roadmap targets, see Figure A.22, the sustainability of mobile machinery, vehicles and vessels used in the construction sector. The construction sector includes activities related to new construction, maintenance, renovation, demolition and the removal of immovable structures, as well as the organization of public space in their immediate surroundings. Daily routine green maintenance is excluded. Mobile machinery refers to equipment such as excavators and mobile cranes. Vehicles concern construction logistics, the planning and execution of transporting materials and equipment to and from worksites. Vessels include floating construction equipment for activities on inland and offshore waters, including coastal and fairway maintenance. Construction concepts and digitization fall within the scope when they contribute to these transport movements. Construction-related passenger transport is excluded. Emissions from this activity are difficult to define and allocate specifically to construction and broader cross-sector initiatives already address them. This topic may be incorporated in the future. The SEB Roadmap also excludes emissions from the industrial production of construction materials, other industrial processes and emissions arising from the use of the completed asset.

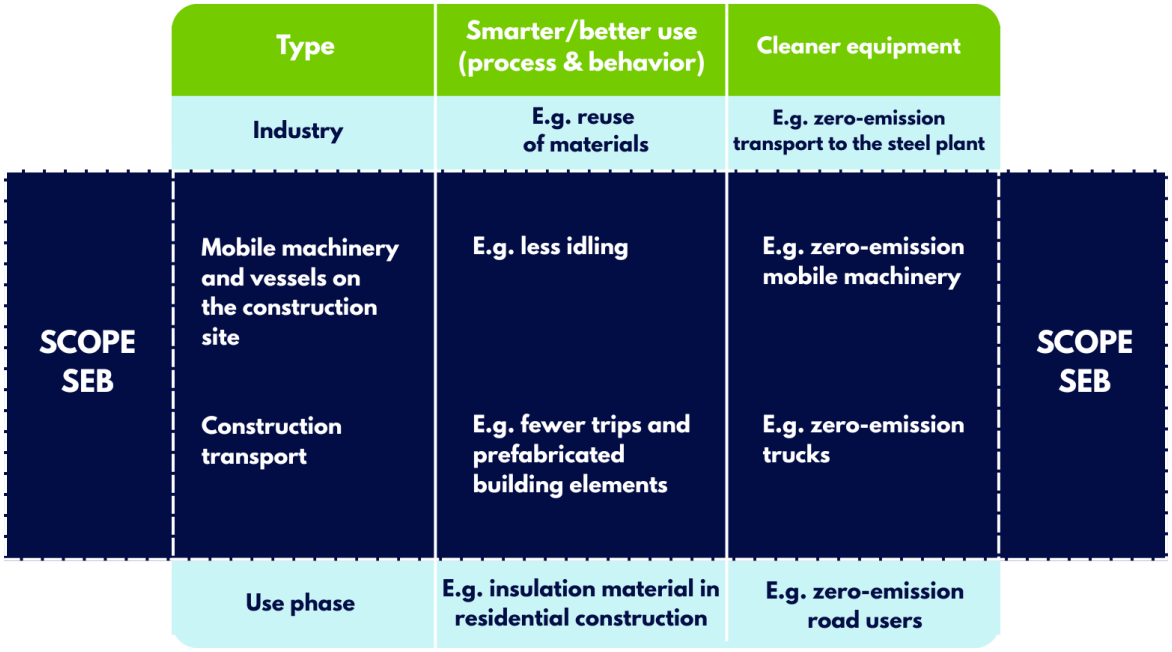


Figure A.22: *
Scope of the SEB Roadmap (made by Author from (Programma Schoon en Emissieloos Bouwen, 2024

This program has influence and interfaces other programs working on sustainability of the construction sector of mobile machinery, vehicles and vessels. Some even beyond trajectories for which the SEB provides guidance for construction equipment, which are:

- Programma Circulaire Economie (Circular Economy Programme)
- ZE-stadslogistiek (Zero-Emission Urban Logistics)
- Green Deal Binnenvaart (Green Deal Inland Shipping)
- Green Deal Duurzaam GWW (Green Deal Sustainable Civil Engineering)
- Maritiem Masterplan (Maritime Master Plan)
- Vrachtwagenheffing (Truck Levy)
- NAL werkgroep Logistiek (National Logistics Working Group)

Aside from the interfacing programs, this roadmap distinguishes the construction sector into 4 other sub-sectors, whereas for each sub-sector a dedicated transition pathway has been developed. This is a framework with the aim of deploying clean and emission-free construction equipment in construction maintenance and demolition projects in the upcoming years.

Transition pathways
By defining a transition pathway for each sub-sector, feasible measures have been formulated that align with the specific opportunities for sustainable deployment of construction equipment, tailored to the characteristics of that particular segment of the construction sector. This segmentation makes it possible to account for factors such as the construction site, the nature and scale of the project or activities, the procurement method, the type of client and the availability of charging and refueling infrastructure. These characteristics strongly influence the potential for making construction equipment more sustainable.

The transition pathways were developed based on the expected achievement of nitrogen, CO_2 and particulate matter reduction targets, as well as technical feasibility and cost considerations. The guiding principle is that the measures must be realistic and achievable, while still sufficiently ambitious to meet the stated goals and ambitions. The transition pathways were developed in collaboration with governmental partners and market stakeholders. In addition to expert judgment from those involved, the process was supported by analyses conducted by TNO.

The SEB roadmap consists of the following four transition pathways:

- Transitiepad Weg, Dijk en Spoor (WDS) (Transition Pathway (TP) Road, Dike and Rail)
- Transitiepad Woningbouw en Utiliteitsbouw (W&U) ((TP) Residential and Utility Construction (W&U))

- Transitiepad Kustlijnzorg en Vaargeulonderhoud (KLZ & VGO) ((TP) Coastline Care and Fairway Maintenance (KLZ & VGO))
- Transitiepad Energie ((TP) Energy)

The collaborative aim for these initiatives is to reinforce one another. As part of the SEB Programme, agreements are being established between public authorities, market actors and knowledge institutions regarding the implementation of this SEB Roadmap. These agreements are formalized in the Clean and Emission-Free Construction Covenant (Rijksoverheid & Partijen, 2023).

Pilot project
Under the SEB Covenant, it has been agreed that SEB contracting authorities will monitor compliance with the established SEB requirements. In practice it can still be quiet challenging to verify whether construction equipment actually meet those requirements. Therefore, the SEB organization is exploring on how to provide support in monitoring compliance.

Combined with Top Sector Logistics, a pilot program has started where 25 projects will receive on-site inspections to find out what works, what does not and what is future-proof. The pilot project is running until March 2026 and then a decision will be made on how to optimize it (up/down-scale it). The participating contracting authorities and contractor are helping to design and implement the pilot. This makes sense, since a policy advisor stated the following:

"For contractors, it is important that contracting authorities check, in a uniform and above all practically workable way, matters such as the deployment of zero-emission equipment. This creates greater clarity, a level playing field and the certainty needed to invest."

This makes sense, since it is essential to 'trial and error' the concept in practice in order to understand what the success-rate is of this program and whether there are practical hurdles to overcome. Before launching this on a larger scale in the Netherlands, a small pilot project will minimize potential negative impacts (e.g. loss of investments or resistance from contractors) as mentioned earlier.

Another Dutch relevant foundation that is well-known for it guidelines in infrastructural projects, is the CROW ('Centrum voor Regelgeving en Onderzoek in de Grond-, Water- en Wegenbouw en de Verkeerstechniek'). This stand for 'Center for Regulation and Research in Earthworks, Water, Road Construction and Traffic Engineering'. CROW is an independent knowledge center for infrastructure, public space and traffic and transport.

CROW: Aanpak Duurzaam GWW

In addition to the development of SEB, which focuses primarily on the sustainability of construction equipment, a complementary strategy has been established through collaboration between the Ministry of Infrastructure and Water Management, Rijkswaterstaat, ProRail, provinces, water authorities, municipalities and various market parties. This strategy is known as Climate-Neutral and Circular Infrastructure (KCI). In line with these ambitions, objectives and strategic frameworks, CROW has developed a set of tools and instruments to support clients and market actors in achieving these transitions as mentioned earlier in Figure A. The total set of this approach is called 'Aanpak Duurzaam GWW' (Duurzaam GWW, 2026) or 'Sustainable GWW Approach'. The Duurzaam Aanpak GWW supports parties in the civil engineering sector in putting the KCI strategy into practice. The approach is based on the following five core principles:

- Translate the sustainability objectives of an organization into concrete projects and tasks.
- Integrate sustainability as early as possible, preferably already during the integrated area□development stage. The planning phase offers the greatest opportunities for sustainability. Make use of opportunities to achieve sustainability goals together with other stakeholders.
- Focus each project or task on the themes where the greatest sustainability gains can be achieved.
- Create opportunities for innovations and new sustainable solutions by allowing room for parties to propose their own approaches. This gives the market and innovation processes more opportunities.
- Assess sustainability in a uniform manner, a set of instruments has been selected to ensure consistent evaluation and safeguarding. Use the shared set of tools such as Omgevingswijzer (Figure A), Ambitieweb (Figure A, the CO_2-Prestatieladder (Figure A and DuboCalc (item A).

This approach consists of 6 steps in total:

1. Analyzing the question and ambitions
2. Exploring opportunities
3. Defining ambitions and opportunities
4. Translating these into specifications and design

5. Assessing and evaluating sustainability
6. Reporting on sustainability

This Sustainable GWW Approach again applies the three Ps: People (mens), Planet (milieu) and Prosperity (welvaart), which closely resemble the theoretical concept of the Triple Bottom Line (TBL). The balance between these elements may vary per theme and per project, see Figure A.23.

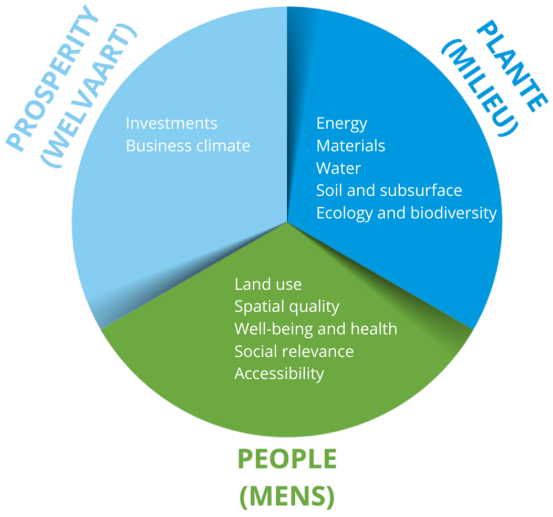


Figure A.23: *
The pillars and corresponding themes within the Sustainable GWW Approach (Duurzaam GWW CROW, 2016)

The Ambitieweb is a tool for systematically recording and maintaining sustainability ambitions throughout the entire project. The Omgevingswijzer and the Ambitieweb are comparable instruments, but each serves a different purpose.

- **The Ambitieweb (Ambition Web Tool)**
  The Ambitieweb, by contrast, offers a visual representation of twelve sustainability themes and their corresponding ambition levels.
- **The Omgevingswijzer (Environmental Impact Guide)**
  The Omgevingswijzer provides a thorough analysis of the project its impact on its surroundings and presents this visually.

Most users consider the Ambitieweb to be the most important instrument within the 'Aanpak Duurzaam GWW'. Its use enables them to translate the sustainability ambitions from general organizational policy documents into concrete project-level objectives. The Ambitieweb can also be effectively used to translate organizational goals into socially responsible procurement practices.

Omgevingswijzer
The Omgevingswijzer and the Ambitieweb are comparable instruments/tools with each another goal. The Omgevingswijzer helps making a good analysis on the impact of the surroundings of the project area/scope, which can be made visual. The instrument helps to systematically determine and clarify the sustainability of tasks and projects in an area. It facilitates a structured discussion and develops a collective problem perspective in an area. The social, ecological and economical sustainability aspect (People, Planet and Prosperity) are included in terms of 12 themes (see Figure A.24). The Omgevingswijzer involves digital survey of which results into a visualization of the impact of the project on its surroundings (Duurzaam GWW CROW, 2016).

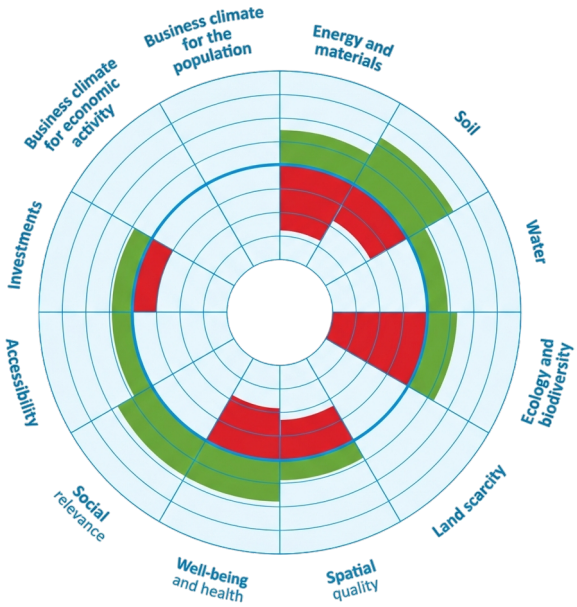


Figure A.24: *
Example of Omgevingswijzer (made by Author from (Duurzaam GWW CROW, 2016))

Initial ambitions
The first steps in order to get to the initial ambitions is done by executing the Omgevingswijzer during a collaborative and interactive session. The function of this, is to determine the impact of the project on the environment en find potential opportunities. The questions involved are applicable to every sort and kind of project. However, this does require a specific capacity and understanding from the facilitator, in order to translate general questions towards to the project. Therefore, it is essential that the facilitator knows what specifically is meant with the questions and how they should be interpreted. The digital survey covers the following points per question:

1. What effect does the project have on the theme in question: positive, negative or none
2. Why does it have a positive or negative effect
3. What opportunities exist to improve the project on this point

A good preparation is essential, as they say 'good begun is half done' this accounts here as well. This can be done, by an upfront conversation between the facilitator (1), project leader (or project manager and/or technical manager) (2) and the client (3). During this preparation the next topics are discussed:

- Purpose(s) of using the Omgevingswijzer
- Participants in the session
- Required time and materials
- Structure of the session
- Expected outcomes and next steps
- Documentation of the session

The composition of the group that participants is important, since it influences the outcome of the session. Because of this, consider carefully who takes part to the session. A team of ideally, 7 to 10 participants with diverse background is sufficient. The following profiles are good to have:

- Project team members (IPM roles = Integration Project Management roles)
- Asset management & maintenance
- Policy & advisory
- Account managers
- Specific sustainability expertise
- Participants from other organizations (if relevant)

It is better and more effective to carry out the steps together with external partners and where relevant market parties. This setup does not differ significantly from what is described. The main principle is to ensure that the session report aligns with the purpose of the meeting. The minimum is to substantiate the choices made in the Omgevingswijzer and highlight key opportunities and points of attention. An example of multiple Omgevingswijzer analysis' is shown in Figure A.25.

	Korftlaan			Klaas Engelbrecht			Totaal		
	Positief	Negatief	Totaal	Positief	Negatief	Totaal	Positief	Negatief	Totaal
Water	8	1	9	0	0	0	8	1	9
Soil	1	1	2	1	0	1	2	1	3
Energy and materials	2	7	9	3	1	4	5	8	13
Ecology and biodiversity	1	2	3	5	0	5	6	2	8
Land use	4	1	5	0	1	1	4	2	6
Spatial quality	6	1	7	3	3	6	9	4	13
Social relevance	2	0	2	2	0	2	4	0	4
Well-being and health	1	0	1	0	0	0	1	0	1
Accessibility	1	0	1	0	0	0	1	0	1
Investments	2	6	8	0	1	1	2	7	9
Business climate for economic activity	0	0	0	1		1	1	0	1
Business climate for the population	0	0	0	0	0	0	0	0	0

Figure A.25: *
Examples of Omgevingswijzer analysis (made by Author from (Duurzaam GWW CROW, 2016))

The way the questions (as mentioned earlier) are answered, is by approaching the questions from a 'grey-zone' which implies that the initial mindset of 'doing a project' are considered (without any attention to sustainability or innovation). The opportunities are not assessed within the Omgevingswijzer, only identified. Approaching this with a 'grey-zone' perspective, it provides an overall view of the impact on the project area/scope/surroundings. An important note, is that before filling in the Omgevingswijzer it is essential to determine for which project phase it is. For small and simple projects the Omgevingswijzer can be filled in for different phases simultaneously, such as the end/use phase and the construction phase. Regarding big and complex projects it is recommended to fill the Omgevingswijzer in per phase. The result of the session is a visual display of the Omgevingswijzer with an automated report of the arguments and a (temporary) report with arguments provided. The next step is to determine the ambitions for the project using the Ambitieweb.

Comparison of alternatives
The themes of the Omgevingswijzer can also be used as an assessment framework to compare the different variants within a project. By using the Omgevingswijzer the assessment framework exists mainly out of themes relevant for a sustainable project. Therefore, it is of importance to tailor the assessment framework to the project (circumstances). This can be done by adjusting the parts of the Omgevingswijzer to the project and if necessary complement with topics if applicable. In case the assessment framework is defined, then the session can start with several and diverse employees from different departments. The following approach is an example can help in practice:

- Divide the participants in smaller groups of 2 to 3 participants
- Every group rates the variants based upon a part of the themes with pluses and minuses (from 3 (- - -) towards 3 pluses (+++))
- If the groups are done, the themes ar rotated across the groups, so that at the end of the session all groups had passed the variants based upon all themes
- Everyone has the opportunity to add an extra criteria
- At the end of the session, the whole group reflects upon the process and result

Figure A.25 shows an example of the assessment of the variants/options based upon the assessment framework. This assessment results into a final web, whereas the 3 variants analyzed and compared. Only the themes that are relevant and potentially have the most impact are shown to get a clear view, see Figure A.26.

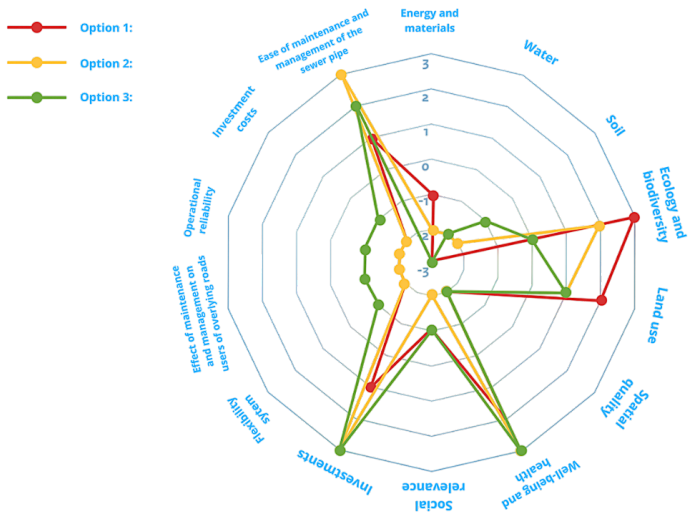


Figure A.26: *
An example of comparison of alternatives based upon the Omgevingswijzer (made by Author from (Duurzaam GWW CROW, 2016))

Ambitieweb

Besides the estimation of the environmental impact of the project, the Ambitieweb is a tool for systematically recording and maintaining sustainability ambitions throughout a project. The Ambitieweb is most effective when used during the concept or planning phase and the development or design phase of a project. The Ambitieweb on the contrary, offers a visual representation of 12 sustainability themes and their corresponding ambition levels as shown in Figure A.27.

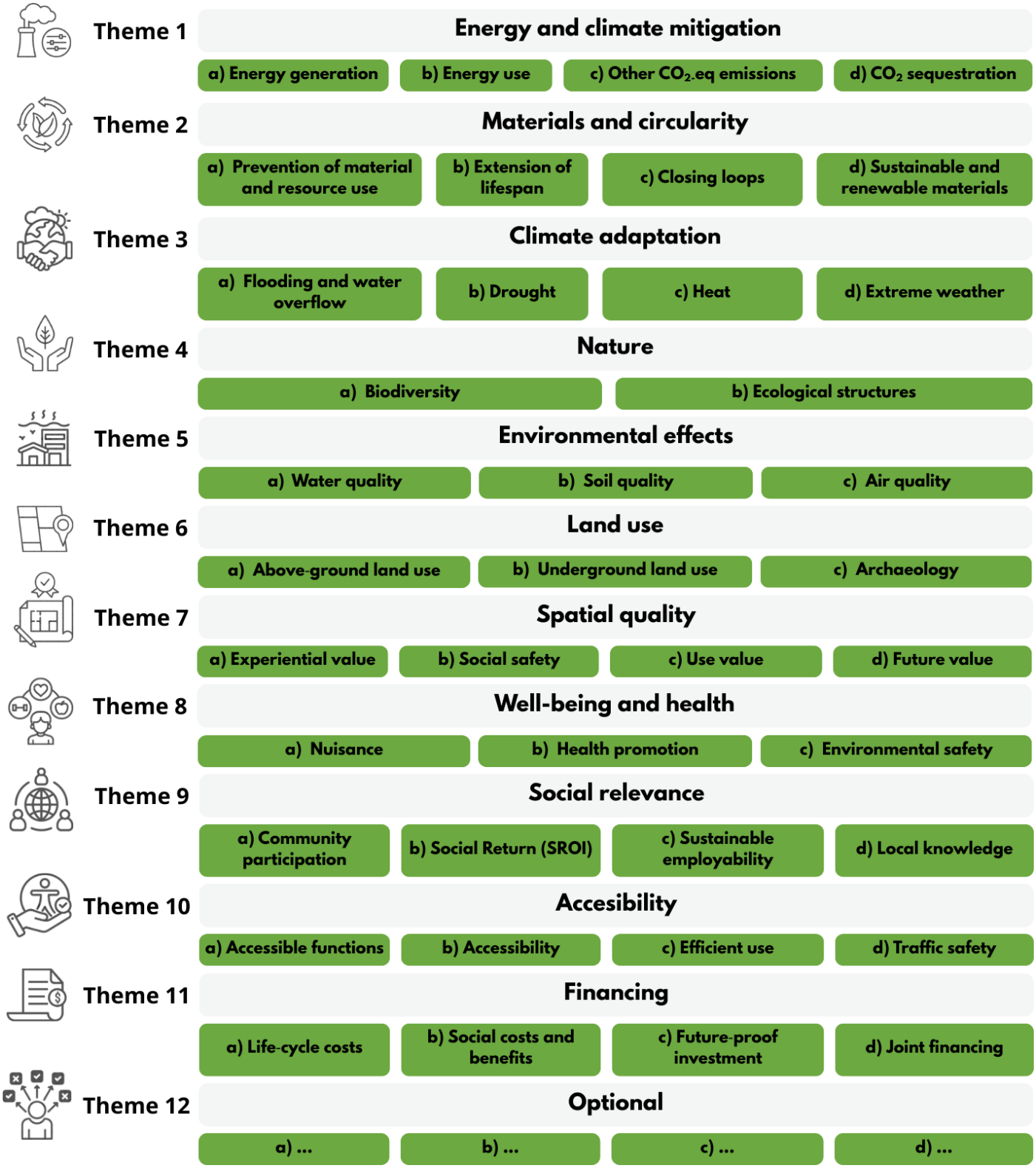


Figure A.27: *
The Ambitieweb themes within the Duurzaam Aanpak GWW (made by Author using source (Duurzaam GWW CROW, 2016))

Most users consider the Ambitieweb to be the most important instrument within the Duurzaam Aanpak GWW. Its use enables one to:

- Translate the sustainability ambitions from general organizational policy documents into concrete project level objectives.
- Be effectively used to translate organizational goals into socially responsible procurement practices (Duurzaam GWW CROW, 2016).
- Communicate within project team, but also towards, for example residents during an information meeting
- Use as a brainstorming aid (for policymakers), because of the abstraction level, without technical choices or explanation/descriptions, it provides justification for the selected ambitions and as summary of the discussions held

- A means to provide focus (and perhaps motivation) to third parties such as consultancy firms like Witteveen+Bos, contractors and suppliers for example (Ambitieweb, 2024)

The Duurzaam GWW 2030 has a primary goal which is to facilitate the exchange of knowledge and information about policy development such as the KCI and the SEB.The KCI cover the objectives and approaches of climate, clean and emission-free construction and circular construction in GWW. Different governmental bodies (Rijkswaterstaat, ProRail, Unie van Waterschappen and municipalities) are working together to determine the transition pathways (read Figure A), with the biggest environmental impact which documented as a roadmap with concrete measures. For the provinces, this is done on a provincial-level for the KCI, which is the PKCI. The Water Authorities work on the Climate–Neutral and Circular Asset Management and Commissioning (KCAO). Wherever is spoken about the KCI, the words PKCI and KCAO are also mentioned.

All of the KCI measures are contributing to the goals and ambitions of the Klimaatakkoord Rijksoverheid / Ministerie van Economische Zaken en Klimaat, 2019, SEB (Programma Schoon en Emissieloos Bouwen, 2024) and the NPCE (Ministerie van Infrastructuur en Waterstaat, 2023. All parties have agreed to jointly monitor the achievement of the goals and ambitions of the KCI by using the 'Dashboard Monitoring Duurzaam GWW'.

The manual of the Ambitieweb shows for the themes 'Energie en Klimaatmitigatie', 'Materialen en Circulariteit' and 'Milieueffecten' is shown which measures must be taken per ambition level, considering the KCI, in order to contribute to both KCI- and the SEB-objectives. The themes 'Materialen en Circulariteit' are mainly corresponding to the material-related transition pathways, 'Energie en Klimaat' and 'Milieueffecten' are mainly corresponding to the equipment-related transition pathways. The indicators mentioned for these themes are aligning with those from the Dashboard Monitoring Duurzaam GWW.

A similar development within the company of Witteveen+Bos is another dashboard, which is stated by one of the participants of the interviews. This dashboard is made by using the +Circular Design tool, which stands for +CD Tool.

Interview excerpt

)] "So that's how we try to approach it with the Plus CD tool (+CD Tool). It may come up again in other meetings. The tool was also developed within our PMC, essentially to translate those Ambitieweb sessions and link them to MKI-calculations."— Sustainability Advisor - ([P4

+Circular Design Tool
The +Circular Design Tool (+CD Tool) has the ability to determine the most sustainable and circular designs with the lowest MKI and CO_2-equivalents. This makes decision making on the alternatives relatively easy. Additionally, the +CD Tool also shows the origin of materials, as well as where they go once the service life of the structure or artifact has ended. This information is especially of relevance to clients, contractors and designers since they can change their way of thinking and also adapt their design and consider material and reuse possibilities (R-strategy ladder) at an early stage. Using the +CD Tool, the opportunities and boundary conditions for circular solutions are set and identified (Witteveen+Bos N.V., 2026).

The material in the +CD Tool can be chosen from reused, recycled, bio-based and new materials. The output is split into; components that can be directly reused (1), components that can be reused after processing (2) which is called recycling and downcycling and parts of the design that will become waste (3). The tool also involves an indicator for the environmental impact (e.g. Environmental Cost Indicator (ECI also called MKI) and greenhouse gas emissions (CO_2)) which be estimated parallel to the design of the structure. This will all be visualized in a dashboard, in which a Sankey diagram highlights the material flows. This +CD Tool has been developed for more advanced possibilities, in order to enable efficient and data-driven working methods. Using an integrated database and a Power BI dashboard, it is possible to extract cross-project insights and provide advisory service to clients. This strong feature allows Witteveen+Bos to monitor circularity across the entire process, from design to realization and across the full asset portfolio of the clients (Witteveen+Bos N.V., 2026). The advantages of the +CD Tool are:

1. **Visual and, therefore, comparable**
   The +CD Tool makes circularity visual, measurable, discussable and comparable.
2. **Useful parameters**
   The +CD Tool's dashboard expresses the concept of circularity in useful parameters.
3. **Monitoring throughout the entire process**
   By using the +CD Tool, you can monitor the circularity of a project, from design right up to construction.

Generic
The generic Ambitieweb, see Figure A.28, is applied at the policy level rather than within a specific project. It provides strategic direction for programs and projects across an organization and can be used for broad policy themes such as water safety, sustainable procurement or road maintenance. It can also support multi□year collaborations by allowing

each participating organization to define its own ambitions and compare them side by side, creating immediate clarity at the start of a partnership. In practice, organizations have used the Ambitieweb to structure existing policies and identify which sustainability themes are well developed and which remain underexposed (Duurzaam GWW CROW, 2016).

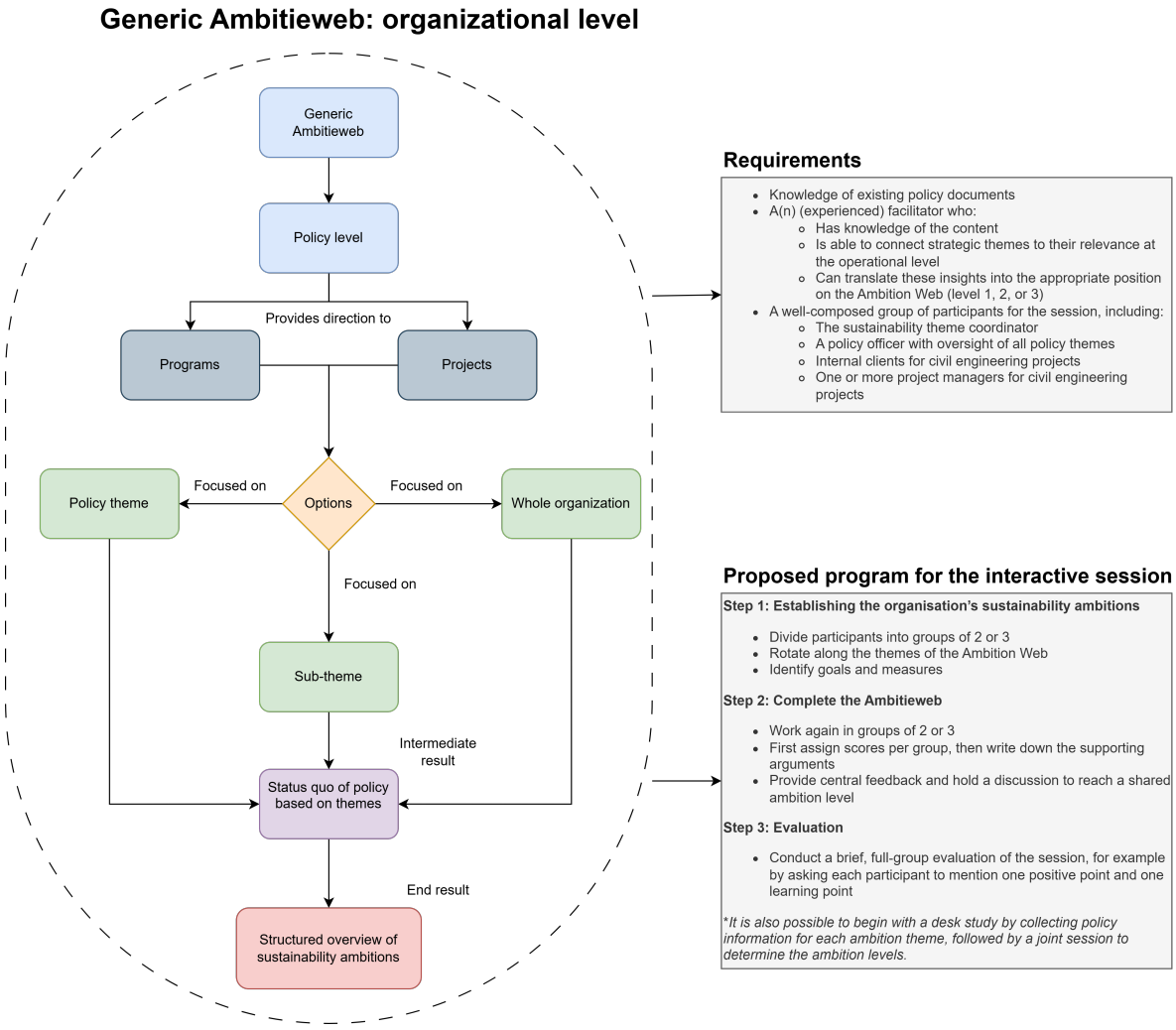


Figure A.28: *
Flowchart of the generic Ambitieweb on organizational level including requirements and a proposed program (source: Author)

Project

The project Ambitieweb can be executed in order to come up with collective sustainability ambitions. In case, the generic Ambitieweb (as mentioned in Figure A.29) is available, then it can be used as a starting point. However, often a generic Ambitieweb is not obtained in practice, so the participants will determine all collective ambitions based upon the knowledge within their ambitions.

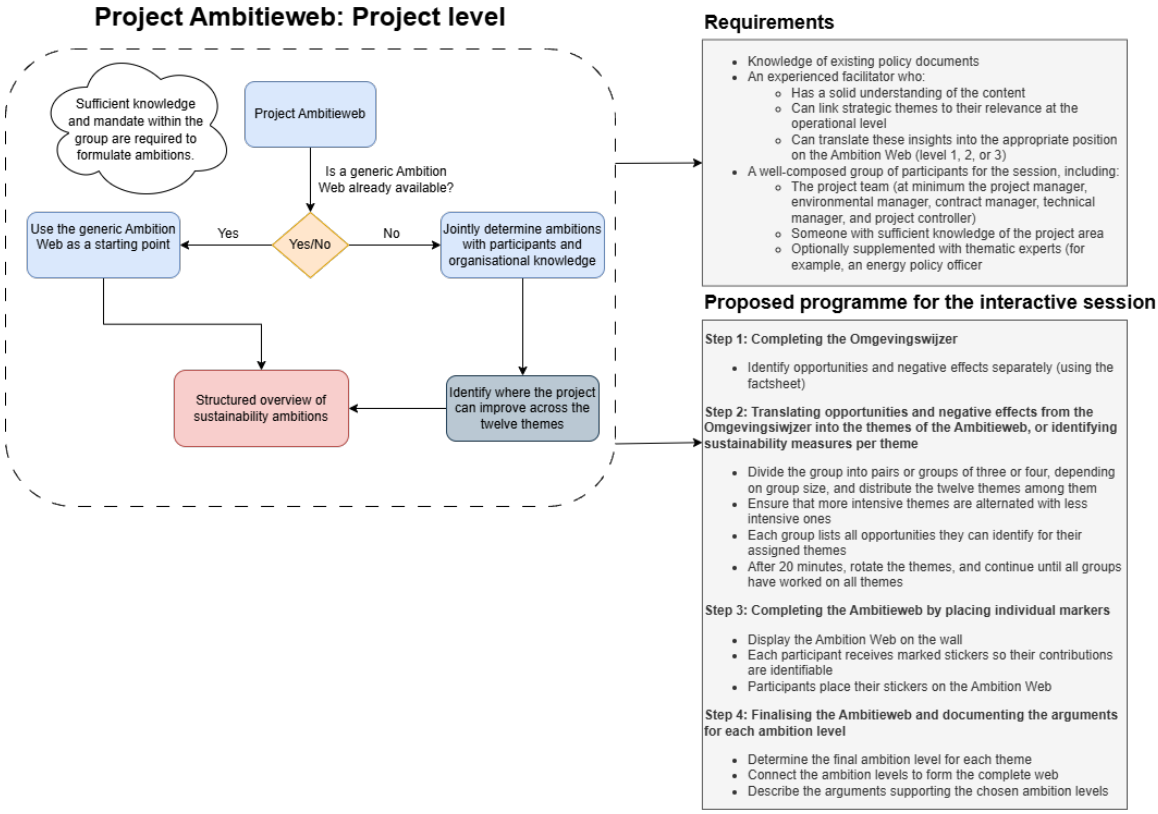


Figure A.29: *
Flowchart of the project Ambitieweb on project level including requirements and a proposed program (source: Author)

The pace and intensity of which these steps in the proposed program of Figure A.29 are carried out, can vary and depends per project. Some projects are done within a two-hour session, while larger or more complex projects may require multiple sessions to go through. In this case, the total time investment for the project team can count up to several working days per person in order to complete the whole process. The responsible team member (e.g. environmental manager or sustainability manager) should expect to spend roughly half a day per week on this. Afterwards, the identified ambitions and measures in the Ambitieweb must be translated into project-specific requirements. *The way this is done depends on the project phase, the most experience is gained in the design phase, which is also the most critical and last moment at which the sustainability measures can still be integrated.* As was stated by a cost manager and technical manager, about the critical design phase for Witteveen+Bos:

Interview excerpt

)] "During the sketch design phase and the subsequent design phase. In many cases, this is when Witteveen+Bos provides its advice." — *Cost Engineer ([P7*

Interview excerpt

)] "That is why life□cycle management is so important. It reflects the core idea of our PMC: you need to consider the entire life cycle of an asset. And that thinking already starts in the design phase." — *Technical Manager ([P3*

The earlier this is done, the better as measures can be incorporated into the design of quality requirements for the contractor (Duurzaam GWW CROW, 2016. *Presenting the Ambitieweb with the contractor without explanation is not recommended, as the ambition levels for the various themes are often not described explicitly*. This has been addressed by a contract manager as well:

Interview excerpt

)] "But what I often notice is that the sustainability ambitions are not formulated in a SMART way." — *Contract Manager ([P5*

On the other hand, it is just safe and more effective to walk through the steps as outlined in Figure A.29 and determine per theme whether the responsibility for implementing sustainability measures lies with the client or the contractor.

Evaluation

Besides the generic and project-level approaches, another possibility for using the Ambitieweb is to evaluate a project, see Figure A.30. It might help, in terms of 'lessons learned' and 'organizational learning' to use it as an evaluation tool, so that it can be determined how sustainable the actual project was in reality. This can be used as a proof of evidence towards to client and can be used at its best after the end of the construction phase as part of the 'total evaluation'. Nevertheless, there are no opportunities to incorporate other lessons learned into the project itself. Another potential moment is to have an intermediate evaluation short after the procurement phase, this gives small gap in timeline to incorporate measures. During the evaluation the project team (and optionally with the contractor) can complete the Ambitieweb based on the contract information. A facilitator for this session is not essential to have since it is less intensive, but optional.

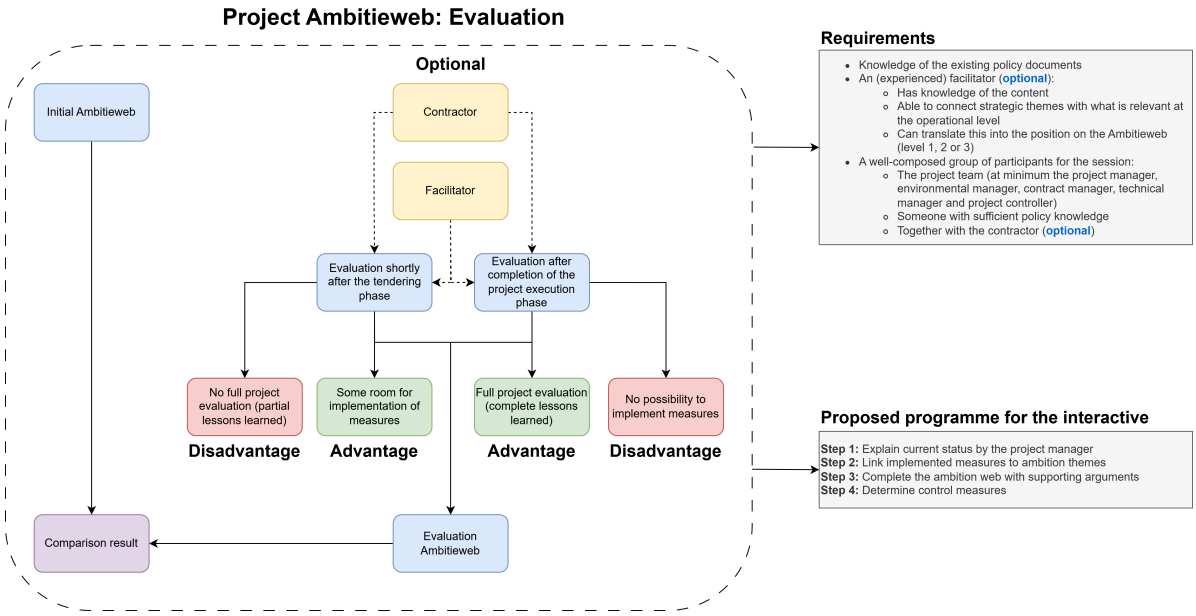


Figure A.30: *
Flowchart of the evaluation Ambitieweb during project development including requirements and a proposed program (source: Author)

Conclusively, the Omgevingswijzer estimates the impact of the project within the area/scope/environment by visualizing it and the Ambitieweb visualizes the ambition levels using the 12 themes as shown in Figure A.27. In order to define the ambitions, in the Dutch construction industry several metrics are introduced to measure and quantify these ambitions such as the $CO2_2$-emission of a project using the CO_2–Prestatieladder and the MKI-values (also ECI-values) of a project using DuboCalc, which a software application using a database. This will be elaborated in the next sections.

CO2-Prestatieladder

The CO_2-Prestatieladder is a Dutch sustainability instrument, developed by Prorail and since 2011 the ownership and management is transferred to 'Stichting Klimaatvriendelijk Aanbesteden en Ondernemen' (SKAO) (also 'Foundation for Climate-Friendly Procurement and Business Practices'). It enables both companies and public authorities to reduce CO_2-emissions internally, collaboratively and throughout the supply chain. As a management system, it supports structured emission reduction within the organization and its value chain. Additionally, the CO_2-Prestatieladder can be applied as a procurement instrument, allowing organizations to leverage their purchasing power to drive sustainable impact (Duurzaam GWW CROW, 2016).

The latter one, is how Rijkswaterstaat introduces the instrument, by using it as a way to formulate concrete and measurable (SMART) formulated agreements in the contracts for awarding projects. Contractors who submit a bid and demonstrate that they are genuinely working to reduce their CO_2-emissions receive an advantage on their initial tender submitted to Rijkswaterstaat. The ladder consists of 3 steps as shown in Figure A.31. Nowadays, the newest version of the CO_2–Prestatieladder is published, which is the 4.0 version.

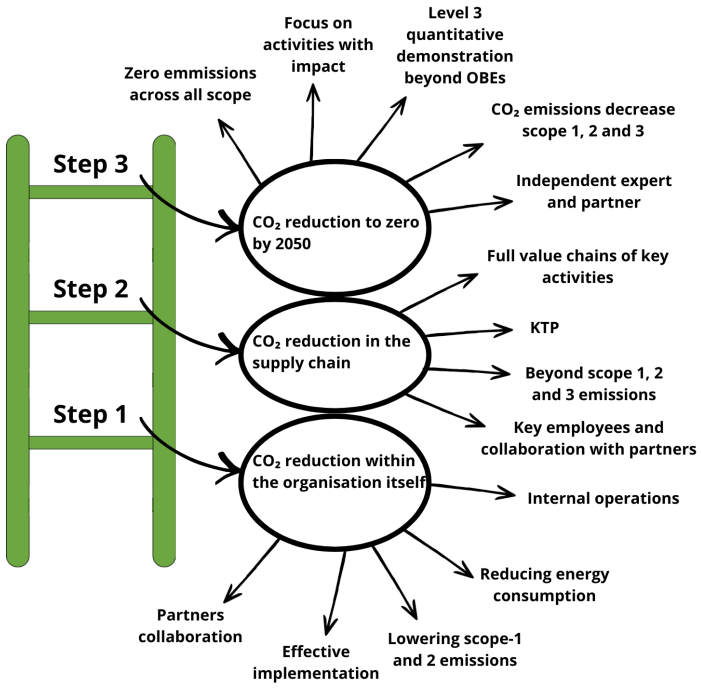


Figure A.31: * CO_2-Prestatieladder (made by Author using source (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b)

In essence, the ladder contains 3 steps of which:

- **Step 1**
  At Step 1, the organization brings its internal operations in order within one to three years. The organization focuses on reducing energy consumption and lowering its scope 1 and 2 emissions. In addition, the organization has insight into the employees in key positions for an effective implementation of the Ladder and understands which partners it can collaborate with effectively (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b).
- **Step 2**
  At Step 2, the organization focuses on the full value chains of its key activities. For this level, the organization must develop a Klimaat Transitie Plan (KTP), outlining a strategy for achieving CO_2 reduction in the medium term (5 to 10 years). It looks beyond scope 1, 2 and 3 emissions, supported by a partner who helps determine the most effective approach. Employees in key positions are actively involved and the organization works closely with various partners. Step 2 requires a similar level of effort as Level 5 of CO_2–Prestatieladder version 3.1 (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b).
- **Step 3**
  The long term objective for Level 3 is zero emissions across all scopes by 2050. For this level, the company must focus on all activities over which it can exert influence. Organizations seeking Level 3 certification must demonstrate quantitatively in their KTP how it will achieve CO□ reduction within their organization, across the value chain and where applicable beyond (OBE) on the path to 2050. Total CO_2–emissions in scopes 1, 2 and 3 decrease rapidly. The organization works together with an independent expert and a partner. Level 3 therefore requires the most ambitious goals and plans (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025b)

When bidding for infrastructure projects, the bidder indicates that the offer will be aligned with one of the first three levels of the Ladder. The higher the level, the greater the effort required and the more challenging it becomes to reduce CO_2–emissions. On the other hand, a higher level (if achieved) results in a higher fictitious discount on the tender price, thereby increasing the likelihood of winning the contract. The amount of this discount and the method by which it is calculated—together with the other qualitative elements of the tender are based upon the BPKV criteria (Rijkswaterstaat, 2026a). This criteria is related and computed from the EMVI criteria since 2016, RWS selects bidders based on the combination of price and quality. Quality includes aspects such as public engagement, sustainability and risk management. In this way, Rijkswaterstaat also aims to stimulate innovation within the civil engineering sector (GWW). RWS used a scale ranging from 2 to 10 in the sector, however since 2023 it was adopted a different (progressive) scale from 0 to 3, where 0 represents no added value and 3 represent 100% added value, see Table A.8. Submissions that are done with disadvantageous or posing risks, the letter code 'NR' is assigned, which results in a higher fictitious tender price (Rijkswaterstaat, 2026c).

Table A.8: *

Scoring system and corresponding percentage of maximum quality value for bidding (Rijkswaterstaat, 2026c)

Description of the score	Score	% of maximum quality value
Excellent (significant added value)	3	100
Good (clearly sufficient to considerable added value)	2	60
Fair (sufficient added value)	1	25
Neutral (little or no added value)	0	0
Adverse and/or risky	NR	-50

The BPKV methodology is applied within the civil engineering sector for engineering services that are covered by the agreement. Other procurement domains are generally using a point based BPKV model without applying monetization. During the tender, RWS elaborates the methodology for the specific project in the tender guidelines, these set out the objectives, the criteria on which RWS assesses them and the maximum value (expressed in monetary terms) are assigned to these criteria. The purchasing processes is as follows (Rijkswaterstaat, 2026c):

- Formulating criteria based on the project's objectives and risks
- Carrying out the actual procurement process by preparing the tender documents, evaluating the submissions and providing feedback to the bidders
- Safeguarding the EMVI added value offered during the execution phase

During the award of the project, the proposed level of the ambition becomes part of the contract and must be achieved during the execution of the project. This is a performance mandate for the contractor. In case it appears that after a while this won't be achieved, then a sanction will be assigned of 1.5 times the fictitious discount of the bid (Rijkswaterstaat, 2026c).

In case the CO_2-Prestatieladder 4.0 is used as a BPKV criterium, Table A.9 shows what rules apply to this (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a).

Table A.9: *

CO_2 ambition levels and corresponding award advantage (Stichting Klimaatvriendelijk Aanbesteden & Ondernemen, 2025a

CO_2 Ambition level	Award advantage
No CO_2 ambition level	0% or €0 or 0 points
CO_2 ambition level 1	5% or €37,500 or 50 points
CO_2 ambition level 2	10% or €75,000 or 100 points
CO_2 ambition level 3	15% or €112,500 or 150 points

Note: Using the absolute scoring method, the total award advantage ranges between €800,000 and €1.1 million, based on a total of 550 points.

Companies are able to bid using this methodology with the BPKV criterion in two ways, namely:

1. The first option is for the company to submit its 'CO_2 Awareness Certificate', which shows that the entire organization operates CO_2 consciously in line with the levels of the award criterion.
2. The second option is for the company to demonstrate at project level that, for this specific project, it meets the ambition level and underlying levels of its tender

In short, tenders that use the CO_2-Prestatieladder as a BPKV criterion, holding or obtaining a 'CO_2 Awareness Certificate' is not mandatory, it is simply one possible way to meet the criterion. The methodology can be applied to this specific domain in the procurement stage. However, it is essential to be aware of the consequences in case the performance on the long run does not meet the documented level during the bidding phase. A penalty might be assigned to, so overestimating might backfire (1.5 times). The core principle of the ladder is that demonstrable effort is rewarded.

DuboCalc

DuboCalc stands for 'Duurzaam Bouwen Calculator' (Sustainable Building Calculator) and was developed by Rijkswaterstaat to calculate and compare the sustainability and environmental costs of public tenders. DuboCalc is used by contracting authorities and potential contractors to analyze design variants and to prepare and assess BPKV/EMVI tenders for civil engineering (GWW) works (Rijkswaterstaat DuboCalc, 2025).

The tool can represent effects of the equivalent emissions into 'shadow' prices of which the summation is expressed in the MKI-value. The higher the MKI the more (the material) will harm the environment. The main goals is to significantly influence environmental advantage within the design, execution and bidding of civil engineering (GWW) projects, therefore

interesting for bids using the BPKV criterion. Environmental costs allow contracting authorities to assess tenders quickly and consistently, whereas potential contractors and third parties can use this info to improve their bids. Figure A.32 shows the MKI score of three variants. A higher score indicates a greater environmental impact in terms of total life cycle costs (LCC) (Duurzaam GWW CROW, 2016). A lower MKI-value often also results in CO_2 reduction and contributes to the objectives of the Circular Economy.

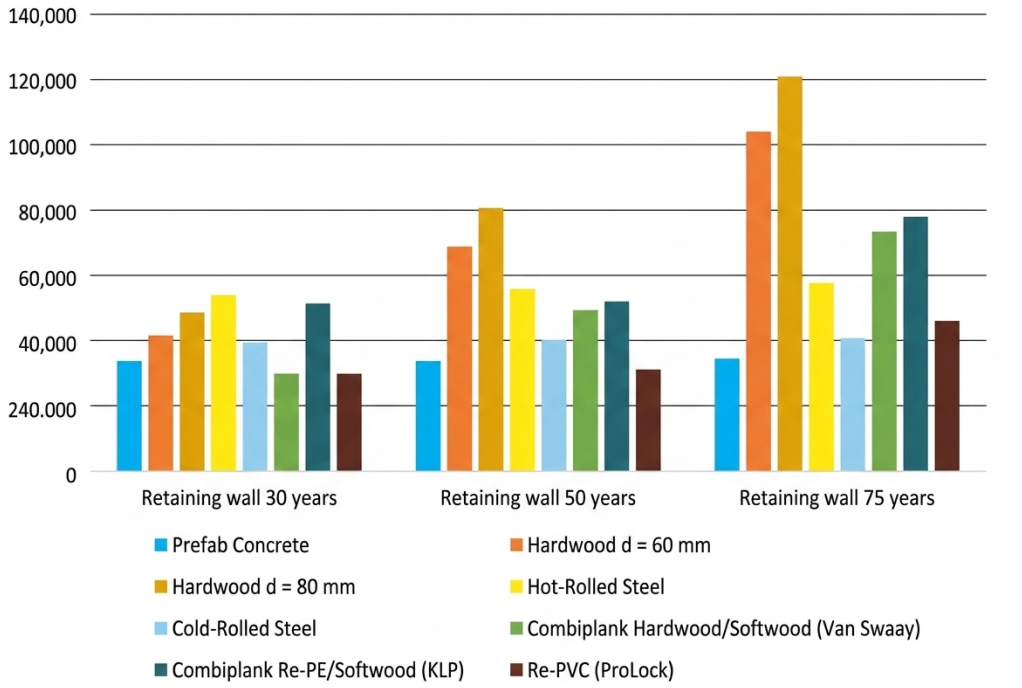


Figure A.32: *
Example of using DuboCalc for several cases and material use (Duurzaam GWW CROW, 2016)

B

Interview protocol

Interview template and invitation

Dear participant,

My name is Shahram Omary and I am currently completing my graduation project within the Project Management & Control group in Utrecht. For my thesis, I am investigating which PPS components (Processes, Products and Services) within the 10 PM domains have the greatest potential for integrating and measuring sustainability. Please see the image below:

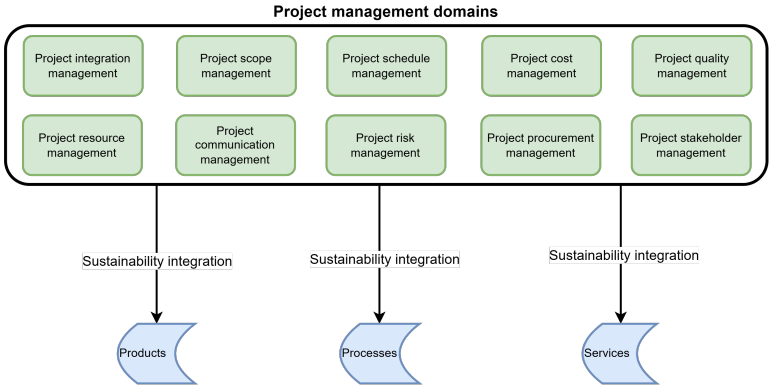


Figure B.1: Informal meeting thesis related diagram (source: Author)

Since you have expertise in one or several of these PM domains, I would like to schedule an informal meeting with you regarding Project ... Management domain (*see attachment*). I am very interested in hearing about your practical experiences and insights, as these will help me strengthen the foundation of my research.

During the conversation, I would like to ask you a few questions:

1. What tasks fall within your current role?
2. What sustainability-related activities do you already carry out within these responsibilities?
3. Which sustainability opportunities do you see that are currently not being utilized?
4. The attached document includes PPS components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?

If you wish, you are welcome to briefly prepare your thoughts on these questions. Besides that, I simply look forward to getting to know you.

I hope you are willing to share your knowledge with me and contribute to the value of my research.

Thank you in advance and I look forward to hearing when it would suit you to meet. If it does not fit your schedule, I would greatly appreciate it if you could recommend another colleague.

Kind regards,
Shahram Omary (Graduate Student)

PMC Construction Management – Project Control

Interview informed consent form

Dear participant,

You are being invited to participate in a research study titled “Developing a Semi-Quantitative Method for Integrating Sustainability into Infrastructure Project Management”. This study is being conducted by S. Omary as part of the Master’s program in Construction Management and Engineering at TU Delft and will serve as input for my master’s thesis in collaboration with Witteveen+Bos.

The purpose of this study is to develop and validate a method that integrates sustainability factors into project management practices, focusing on products, processes and services (PPS) during the planning and design phases of infrastructure projects. By analyzing current practices and collecting insights from experts, the research aims to bridge the gap between high-level sustainability ambitions and practical implementation.

Interviews and/or informal meetings will be conducted with project managers (PM), sustainability experts and related stakeholders to identify relevant PPS-factors and validate the proposed framework. Your insights will ensure that the method aligns with real-world practices and challenges.

Confidentiality and data handling

As with any digital activity, there is a minimal risk of data breach. However, I will ensure that your responses remain confidential to the best of my ability:

- The interview may be conducted online or face-to-face, depending on your preference and availability
- Only audio recordings will be made (no video) for transcription purposes
- You will receive a transcript of the interview for review and approval. If you wish, you may exclude or amend specific statements
- After approval, the recording will be deleted and the transcript anonymized.
- Any personally identifiable information (PII) will be permanently deleted once the anonymization process is completed
- Data will be securely stored on the Witteveen+Bos server and/or equipment and only accessible to me and my supervisors
- Only aggregated and anonymized results will be reported in my thesis and potential future publications

Voluntary participation

Your participation is entirely voluntary. You may withdraw at any time without giving a reason. Any data you provide can be withdrawn within one month after the interview upon request. After this period, the anonymized data will be processed and included in the analysis.

The interview will last approximately 60 minutes and will consist of open-ended questions regarding your experiences and perspectives on sustainability integration in project management.

By signing this informed consent form, you agree to participate under the conditions described above.

Please tick the appropriate boxes		
	Yes	**No**
1. I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves participating in an audio-recorded interview that will be textually transcribed before the recording is destroyed.	☐	☐
4. I understand that the study will end on the date the researcher graduates, now set at 3rd of June.	☐	☐
5. I understand that taking part in the study also involves collecting specific personally identifiable information (PII), such as name, e-mail, function, company, years of experience and associated identifiable research data (PIRD), such as personal experiences, with the potential risk of my identity being revealed.	☐	☐
6. I understand that the (identifiable) personal data I provide (excluding function, years of experience and statements during the interview) will be destroyed once the research concludes.	☐	☐
7. I agree that my responses, views, or other input can be quoted anonymously in research outputs.	☐	☐
8. I consent for the de-identified information that I provide to be archived in the TU Delft repository, which is open access.	☐	☐

Signatures
I, as a participant, have read and understood the details provided in this consent form and agree to participate in this research study.

Participant name	**Signature**	**Date**
_____	_____	_____

I, S. Omary, confirm that I have explained the purpose and procedures of this study to the participant and, to the best of my ability, have ensured that the participant understands what is involved.

Researcher name	**Signature**	**Date**
Shahram Omary		
_____	_____	_____

Contact details
Shahram Omary

C

ATLAS.ti

Data analysis process

ATLAS.ti is a qualitative data analysis software designed to help researchers systematically organize, code and interpret large volumes of textual or visual data. It is particularly useful for managing complex datasets collected through methods such as interviews, focus groups or document analysis. By allowing the creation of thematic codes, linking of data segments and visualization of relationships. ATLAS.ti supports rigorous, transparent and traceable analysis processes.

In this study, ATLAS.ti was used to analyze the insights gathered from 18 semi-structured interviews (SSIs) conducted with employees of the engineering consultancy company (W+B). The interviews were transcribed and imported into ATLAS.ti to facilitate coding and theme development. An initial coding framework was developed based on the research objectives and a preliminary reading of the transcripts. Through iterative analysis, new codes emerged inductively to capture recurring patterns, ideas and perspectives shared by all 18 participants. The codes were then categorized into higher-level categories and themes. By cross comparing participants and departments, the process ensured consistency and depth in qualitative interpretation. ATLAS.ti's visualization tools, such as code networks and co-occurrence tables are also used to identify interconnections between themes and to support the development of the final analytical process. This appendix includes data that excerpts from the ATLAS.ti project file to illustrate how themes were developed and validated throughout the analysis process. The questions asked during the SSIs are as follows:

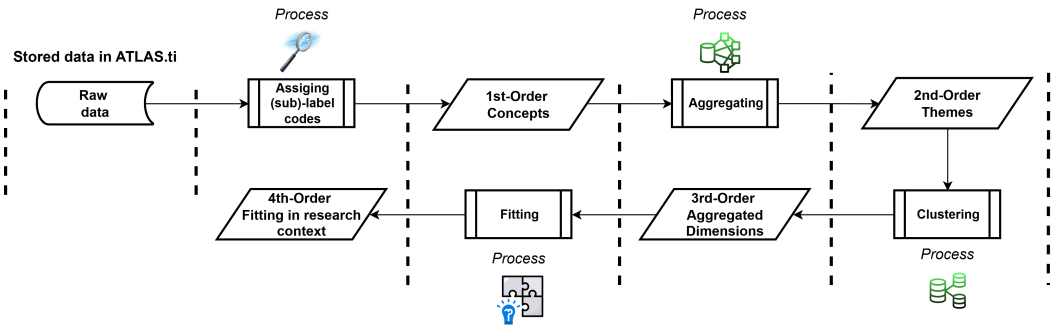
(SSI-Q1) What tasks fall within your current role?

(SSI-Q2) What sustainability-related activities do you already carry out within these responsibilities?

(SSI-Q3) What sustainability opportunities do you see that are not being utilized today?

(SSI-Q4) The attached document includes PPS-components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?

During analysis following the coding structure based on the process as shown in Figure **??**, these resulted in final fitted dimensions per SSIs-Q. The findings from the participants are written per question and elaborating on how the fitted dimensions are find and related including a flowchart diagram.



Flowchart of aggregation procedure in ATLAS.ti (source: Author)

Conclusively, in ATLAS.ti these levels are constructed by organizing individual, low-level codes into hierarchical structures (categories and sub-codes) or by grouping related codes together. These themes represent broader patterns or topics, where parent codes (categories) act as themes and child codes (sub-codes) act as specific, granular facets of that theme, facilitating thematic and dimensional analysis. These were defined per question (SSIs-Q1 to SSIs-Q4). Figure 4.3 describes the iterative analytical workflow applied in the qualitative data analysis using ATLAS.ti based on the Gioia

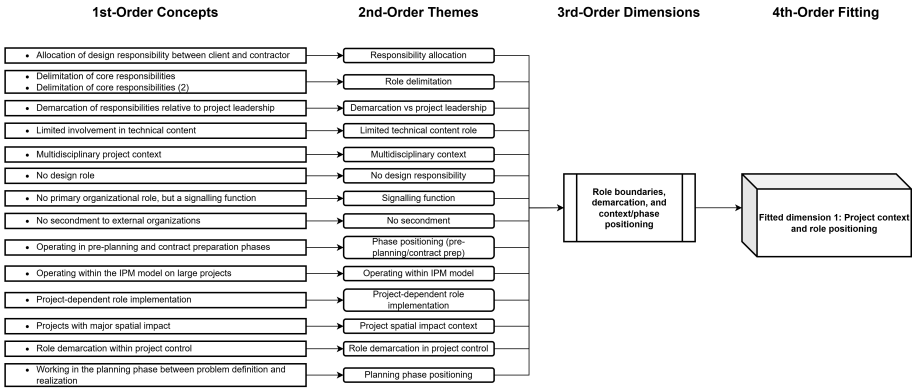
methodology. The procedure was carried out and recorded as a matrix in Excel for each question (SSIs-Q1 to Q4). Based on this matrix, a flowchart visualization was created to clearly and systematically show which quotes and topics were relevant in forming each fitted dimension. Regardless, in the next the paragraphs, the findings from SSIs-Q1 to SSIs-Q4 are elaborated, however SSIs-Q3 and SSIs-Q4 are most essential, since it covers the risks (negative risk = threat and positive risk = opportunity) and therefore the enablers and barriers for sustainability integration (considering current project management theories) are taken into account. Before this is done, the fitted themes per questions are elaborated and discussed on the answers from the participants and findings of the SSIs.

SSIs-Q1 - Roles and project context

The first question (SSIs-Q1) focused on identifying the participants' current roles and the activities they perform within W+B. Based on their responses, fitted dimensions were subsequently developed in accordance with the Gioia methodology described earlier.

Fitted dimension 1: Project context and role positioning

Fitted dimension 1 is formed based on role boundaries, demarcation and context or phase positioning. The participants emphasized that roles are primarily formed through clear boundary setting, contextual constraints and phase-specific positioning rather than direct technical involvement. The allocation and delimitation of responsibilities were highlighted, particularly when deciding whether design tasks are retained or delegated to the contractor ([P5],[P8]). This proofs the distribution of responsibilities and formal role boundary definition ([P5]). Additionally, participant indicate limited engagement with design activities ([P14],[P16],[P17]) and instead coordinating or signaling function ([P14]), which is referring to a non-technical role orientation, but more overarching and indirect influence. Also, the role is strongly contingent on project characteristics ([P17]), such as working with multidisciplinary, large-scale infrastructure project governed by the IPM-model (Rijkswaterstaat, 2026d) ([P11]) and influenced by spatial impact ([P9],[P16]). The data also highlight the temporal embedding of the role, particularly in early project phases such as plan development and contract preparation ([P1],[P10]). Together, these empirical insights are shown in Figure **??**, with the analogy of the Gioia methodology under '1. Project context and role positioning'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q1 (source: Author)

Fitted dimension 2: Project leadership and project control

Fitted dimension 2 is formed, based on project control aspects related to cost, schedule, risk and dashboards combined with project leadership, integration and governance. Aside from the project context and role position, in practice the findings indicate that leadership and control are increasingly supported by the use of advanced estimation and analytical practices, especially during the FEDP where strategic decisions are formed. Their involvement is often within the planning phase between problem definition and realization, where the analytical insights influence decision-making ([P1]). These decisions, influence other aspects as a consequence, like cost for example, which evolves beyond the deterministic approach towards a more sophisticated method that integrated environmental and probabilistic dimensions. Meaning that the life-cycle assessment (LCA) data is translated into cost structured combines with probabilistic techniques, such as Monte Carlo simulations, to account for uncertainties in quantities and unit prices ([P12]). This allows for a better understanding of risk and variability in project outcomes. Beside this, the Multi-Criteria Decision Analysis (MCDA) is used as a central (scoring)mechanism to reduce complexity within decision-making process, allowing decision-makers to compare alternatives on several criteria, including sustainability ([P1]). A cost engineer stated that, these approaches are operationalized even a step further through variant-based cost estimations, where different design or implementation scenarios are evaluated across both cost and environmental metrics (e.g. MKI), often using weighted criteria to reflect project specific priorities ([P12]).

In terms of cost and financial management, participants highlighted that cost estimation is a core activity within their role (as a cost engineer), closely linked to broader PM-domains and decision-making processes ([P12]). Their involvement spans from early conceptual phase (with only qualitative sketches or measures available) to highly detailed design phases, meaning that the estimation practices evolve parallel with project development and maturity. A challenge mentioned was providing cost estimates even when no design was available, relying only on expert judgment and iterative

refinements as projects progress ([P7]). Cost estimation is not a one-off activity it is done continuously throughout the project LC, depending on new updates and refinements across the phases which reflects new insights and project conditions ([P7]). Making it more complex when the project is a large-scale infrastructural project, where long term asset management and maintenance demands require sustained financial and analytical oversight ([P7]). This proves the importance of anticipatory and interpretative nature of estimation practices during early (strategic) project decisions (which also comes with experience). The cost engineers made clear, that cost estimation and financial control are different, the former is an analytical and advisory function/task while the overall budget control and financial steering remains the responsibility of the project manager or project leader ([P12]). Lastly, cost engineers are mainly responsible in assessing and safeguarding financial feasibility within project teams, meaning that they are ensuring that solutions/variants remain within budgetary constrains ([P7]). Often, during the tenders the variants are sub-categorized in sober (sober), appropriate (doelmatig) and luxuriance (luxe) in order to reduce high costs.

Project controlling systems and performance monitoring play a key role in project control, participants mentioned that dashboards and data-driven reporting are important as a tool that can be used to support project leaders and enabling informed decision-making ([P8],[P4]). These tools are supported by planning practices, like deterministic scheduling which provides a structured basis for controlling project timelines and progress ([P8]). Project controlling involves continuous financial monitoring and the implementation of insights into project expenditures, which allows for adjustments on time and reinforcing the link between analytical information and project steering ([P8]). Participants also stated that their involvement are across several key control domains, including scope, planning and risk as well as their responsibility regarding managing project control teams and making sure the teams perform well ([P14],[P17]). A project control manager and PMC leader (a leader of an entire business unit) highlighted the organizational embedding of these analytical practices, where main responsibilities include both team coordination and maintaining oversight of core control tasks, such as scope management and financial control ([P17],[P3]). Additionally, beside these main priorities, a project advisor stated that there is a need for adoption on LC perspective in project control, meaning that the project control thinking should shift beyond a sole focus on construction, towards a long-term performance and asset management ([P6]).

In order to simplify and adopt specific practices during project control. A cost engineer stated that internally, they use established cost estimation frameworks, such as 'Standaard Systematiek Kostenramingen' (SSK), which stands for 'Standard Cost Estimation Framework' used for infrastructural projects and NEN2699 for building related contexts, which provides a consistent approach forming the basis for calculating and comparing project costs ([P12]). These standards support uniformity and transparency in estimation practices across different project types. A sustainability advisor stated that sustainability metric (e.g. the MKI/ECI) are much more embedded as a standard component within these analytical frameworks, allowing cost engineers for instance to integrate environmental impact into cost-based assessments ([P4]). By incorporating such indicators into estimation practices, the analytical processes move beyond financial considerations towards a more comprehensive, sustainability informed evaluations that can be used for project control. These paragraphs all emphasized project control related to cost, schedule, risk and dashboards as shown in Figure **??**, which is situated under '2. Project leadership and project control'.

The next paragraphs delve into the project leadership, integration and governance. A contract manager highlighted that they function within a hybrid leadership role in early project (planning and design) phases, meaning they operate in a dual or combined role, balancing responsibilities like contract management, project leadership and early-phase advisory work ([P10]). Two project leaders emphasized that this dual role is particularly evident and occurs during the pre-planning and planning study phases ('planstudiefase'), where their contribution is delivered by acting as a project leader and simultaneously giving their input to strategic decision-making and advisory processes ([P1],[P16]). This role extends beyond traditional management, often before project structures are fully defined, states the contract manager ([P10]). A designer states that leadership is not only granted and seen by formal authority, but it comes with actively shaping decision-making by introducing alternatives, raising consideration and making complex information accessible to all stakeholders ([P18]). In parallel, a PMC leader who is also a technical manager, states that the role requires leadership on an analytical and strategical level embedded across the full project LC, linking early-phase insights into long term considerations ([P3]). This shows the differentiation in roles, responsibilities and forms of leadership that can be formed depending on (project) circumstances.

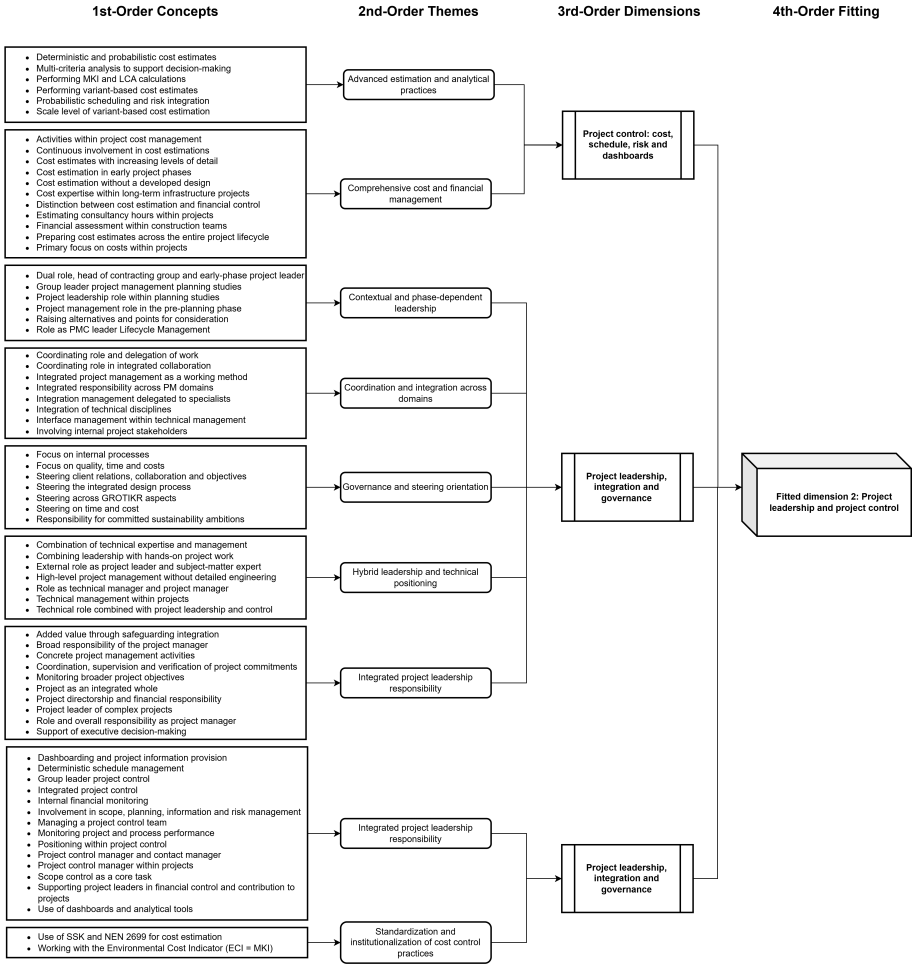
Besides contextual and phase-dependent leadership, some participants mentioned that they role involve coordination and integration across domains, meaning that they are actively coordinating work, delegating tasks and ensuring that relevant expertise is mobilized across the project organization ([P6],[P16]). Another technical manager said that the coordination in general is based upon a model called the 'Integrated Project Management (IPM) model (Rijkswaterstaat, 2026d), which provides a formal framework for organizing responsibilities and aligning different project domains ([P11]). In this model, the project leaders hold overarching responsibility across the domains (involved) while specific integration tasks are often delegated to specialized roles, such as the technical or environmental managers ([P16]). Eventually, effective project control depends on two main aspect, which is about the integration of technical disciplines (1) and the management of interfaces between them (2), in order to make sure that different (knowledge or project) domains come together at the right moment during the project LC, states a technical manager ([P3]). This is called 'interface management', which is a key element in maintaining project coherence, especially in complex multi-disciplinary contexts ([P11]). Impactful roles within this process are the internal stakeholders (e.g. technical (TM) and environmental managers (OM))

who play crucial role in the integrative process ([P4]).

In addition to coordination and integration across domains, governance and steering orientation play a big role in project leadership and control. It is suggested by a project control manager that internal processes are the primary structure through which project control is exercised, with sustainability and other objectives often embedded within the systems rather than addressed explicitly ([P14]). A project leader confirmed that this process-based orientation is complemented by the need to actively steer integrated design processes, bringing together technical, environmental and permitting perspectives within coordinated decision-making structures ([P16]). As a result of this, the project leaders operate across multiple control dimensions, such as the GROTIK (Geld = Money, Risico = Risk, Organisatie = Organization, Tijd = Time, Informatie = Information and Kwaliteit = Quality) aspects, ensuring alignment between scope, time, cost, risk and quality ([P14]). However, a noticeable statement by a project control manager, is that monitoring and steering practices remain anchored in tradition control variables, particularly time and costs, that continue to dominate PM and decision-making processes ([P17]). At the same time, a project manager indicated an increasing sense of responsibility for fulfilling sustainability commitments within these control structures, suggesting a gradual integration of sustainability into existing governance mechanisms ([P9]).

To make sure a full overview of the project is take into account, hybrid leadership and technical positioning is essential. A technical manager suggested that integration both technical and managerial perspectives is important, to make sure overall project integration and integral decision making are covered ([P11]). These roles often take form of 'hands-on' leadership, where individuals within this role not only manage teams and processes but also actively contribute to project content and delivery ([P13]). A project advisor verified this phenomena by stating that he operated across multiple levels of abstraction, combining strategic thinking with the coordination of analytical work that was carried out by specialized disciplines ([P6]). This reflects that currently within W+B, there is a division of labor in which project leaders (PL) guide and integrate analyses rather than performing them directly. On the other hand, technical managers (TM) and project managers (PM) are often combined or alternated depending on the size and context of the project, indicating the overlapping nature of responsibilities ([P3], [P11]). Another technical manager mentioned the result in practice of this, whereas these roles span project leadership, stakeholder management and control of project domains such as time, cost and quality (GROTIK aspects), while also integrating technical insights into decision-making processes ([P15]).

In terms of integrated project leadership responsibilities within these roles, their added value lies in safeguarding integration across disciplines and interfaces, ensuring that fragmented project components come together as a whole ([P11]). A project leader added, that the integrative role is reflected in a broad set of project management activities, including coordination, contract and planning management and alignment with client objectives ([P1]). In practice, project leaders actively coordinate, supervise and verify project commitments within teams, while maintaining oversight of both traditional and emerging project objectives, such as sustainability ([P9],[P17]). This highlights a shift towards broader performance monitoring beyond time and cost alone. At the same time, a technical manager stressed the importance of viewing projects as integrated systems, where individual components must ultimately align within a unified project outcome ([P11]). This shows the importance of the domain of 'Project Integration Management'. The full financial and organizational responsibilities lies in the hands of a project director or project manager, particularly in complex projects, strengthening the strategic and accountable nature of project leadership ([P3],[P16],[P9]). Lastly, within this context, the use of advanced analytical practices support decision-making, which allows project leaders to guide stakeholders and decision makers in evaluating and selecting between alternative solutions ([P1]). These paragraphs all emphasize project leadership, integration and governance as shown in Figure **??**, which is situated under '2. Project leadership and project control'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q1 (source: Author)

Fitted dimension 3: Stakeholder and environmental management

Fitted dimension 3 is formed based on stakeholder management, participation, permitting and environment. An environmental manager described that stakeholder analysis is a key analytical way to map the relevant actors in the project environment by creating a power and interest matrix ([P2]). It is worth mentioning that this is not the only format to get an idea of the involved stakeholders. The environmental manager stated that this analysis often serves as the foundation for developing participation strategies, translating stakeholder insights into structured engagement approaches ([P2]). Besides the analysis, stakeholder engagement tends to be embedded within project leadership roles, which highlights the importance of ensuring that there is alignment between project objectives and external (stakeholder) expectations ([P16]). The project advisor, stated that in order to create alignment, there are some structured ways, such as the Ambitieweb sessions which facilitate dialogue among stakeholders to help and identify opportunities for (sustainability) objectives within projects ([P4]). The designer stated that, not all roles are directly involved with external stakeholders, this participant indicated that he has a more indirect or supportive contribution and primarily indicating with internal teams while providing input to stakeholder related processes when required ([P18]).

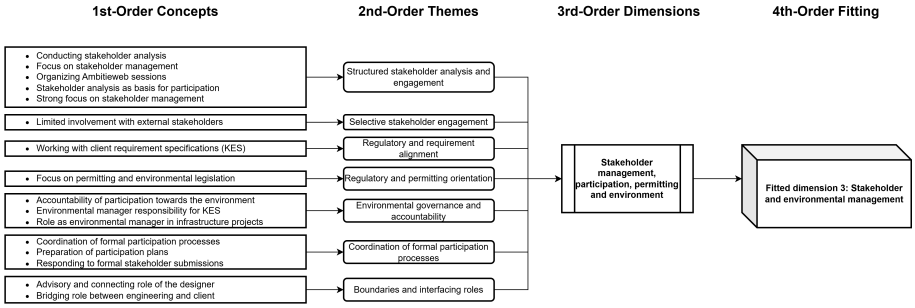
Related to the rules and regulations for obtaining permits, especially nature regulations, the environmental legislation plays a significant role in shaping project feasibility and decision-making, which requires continuous attention throughout the project LC ([P16]). No permit means also potential contingency and delay as an end result, impacting the timeline. In terms of requirements alignment, the environmental manager highlighted the importance of the client requirement specifications (KES) as a key instrument for structuring project objectives and translating stakeholder and client demands into concrete and actionable criteria ([P2]).

Besides the formal juridical part related to stakeholders, the environmental manager indicated that participants processes are not only conducted during the project but are also formally documented afterwards in participation reports, which justify what has been organized and how it contributed to decision-making ([P2]). This highlights a shift is in traceability and accountability of stakeholder engagement within projects. The responsibility for these processes is often explicitly assigned to the environmental or stakeholder manager, who takes ownership of both participation and compliance with client requirements such as KES ([P2]). This role is particularly noticeable in large-scale infrastructural projects, where environmental managers are actively involved in managing stakeholder relations, permitting and environmental considerations throughout the project LC ([P2]).

A more operational aspect, is the coordination of formal participation which is executed and maintained by the envi-

ronmental manager, this individual stated that this role is responsible for coordinating the entire participants process ('participatie'), ensuring that stakeholder input is properly collected, structured and addresses ([P2]). This procedure involves the preparation of participation plans in advance ('participatieplan'), elaborating on how and when stakeholders will be engaged throughout the project, as well as the documentation of these activities in reports. Besides these plans, another key element is that this role requires formal responding to formal stakeholder submissions, such as opinions or objections to project decisions. These inputs must be carefully reviewed and answered in a practical and valid way, confirming the formal and legally embedded nature of participation processes ([P2]). In order to fulfill this role successfully, it requires skill sets on how to approach the involved stakeholder while considering what kind of impact the submission might have on the project.

A permanent boundary condition from the perspective of an engineering consultancy firm, in this case W+B, it must be mentioned that designers and project members that are involved in projects during the planning and design phase are not the final decision makers. But rather operate in a connecting position where they gather, interpret and relay input from multiple resources both internal and external stakeholders ([P18]). This 'in-between' position allows them to capture diverse perspectives and ensure that relevant considerations are brought into the decision-making process, even if they do not directly determine outcomes. Besides that, this bridging function is useful in the translation of technical knowledge to clients and stakeholders. A project leader stated that they rely on technical experts for 'in-depth' knowledge but are responsible for communicating these insights in an accessible and understandable way, without overwhelming non-technical stakeholders with details ([P16]). This shows that stakeholder management is not only about engagement and coordination, but also about effective knowledge translation across disciplinary and organizational boundaries. These paragraphs all emphasize stakeholder management, participation, permitting and environment as shown in Figure **??**, which is situated under '3. Stakeholder and environmental management'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q1 (source: Author)

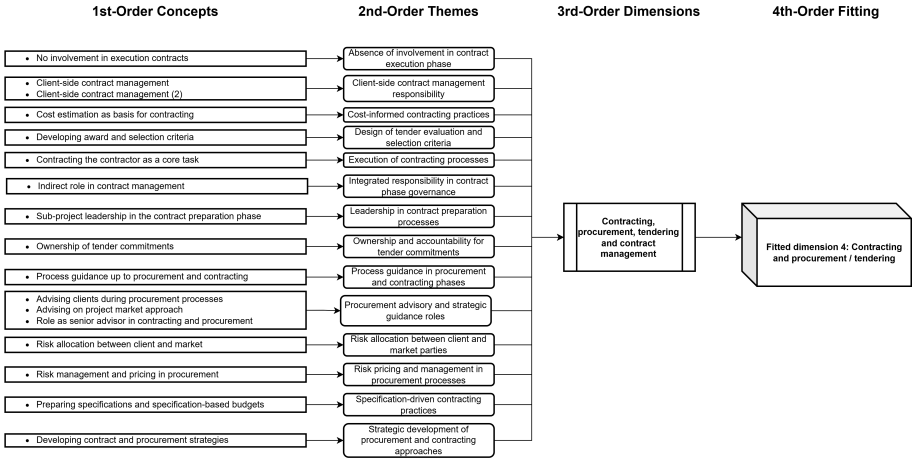
Fitted dimension 4: Contracting and procurement / tendering

Fitted dimension 4 is formed based on contracting, procurement, tendering and contract management. It is a subtopic interfacing multiple domains, that spans from early strategic advisory to the formalization of contracts and interaction with the market. A project control manager mentioned that his involvement is often within the pre-execution phases, with limited or no direct involvement in executing contracts themselves ([P17]). Instead, their contribution lies in shaping the conditions under which projects are brought to the market and contracted. A core element during this process is client-sides contract management, where professional engage in managing contractual relationships, including discussion on essential topics like scope changes and consequently additional or reduced work ([P8],[P17]). This role has an emphasis on controlling and managing the agreement with the client rather than executing the contract. The 'Cost Management' domain has an interface in this, since cost estimation plays a foundational role in contracting (e.g. the British NEC4 contract types), as estimates are used to approach the market and form the basis upon which contractors are engaged ([P7]).

This underscore the strong relation between financial analysis and procurement decisions. Additionally, a contract manager highlighted the importance of designing procurement strategies and tender procedures, which includes developing award and selection criteria (e.g. CO_2-Prestatieladder) to ensure the most suitable contractor is selected for the project ([P5]), as well as actively contracting the contractor as a core task ([P10]). The contract manager emphasized that often, in practice it is the case that roles extend across the full contract preparation phase, where colleagues may take on a sub-project leadership responsibilities and contribute to drafting contracts, guiding procurement processes and structuring tender strategies ([P5],[P10]). Another relevant aspect is the advisory role towards client, both in procurement processes and in defining market approaches. Participants indicate that they support clients in positioning projects effectively in the market and in making strategic decisions regarding contracting and tendering ([P5]). This does require senior expertise in contracting and procurement and especially during complex, large-scale and multi-disciplinary projects.

Risk allocation and pricing also come into play as critical considerations. It was stated by a contract managers that there appears to be a shift in market dynamics, especially for renovation and replacement (R&R) projects, since it requires careful balancing of risks between client and contractors ([P5]). This is highly related to the 'Risk Management' domain and pricing strategies within procurement processes (taking into account the awards e.g. for innovative solutions), suggesting a more strategic point of view on contracting and procurement. Finally, a cost engineer mentioned that the preparation of specifications and specification-based budget form a technical backbone of this topic, whereas

linking design requirements to contractual and financial frameworks is critical ([P12]). Taken altogether, these findings proof that contracting and procurement are not isolated and one-off tasks, but rather an integrated process that combines technical, financial and strategic expertise to guide projects from early definition to market engagement and contractual agreement. These paragraphs all emphasize contracting, procurement, tendering and contract management as shown in Figure **??**, which is situated under '4. Contracting and procurement tendering'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q1 (source: Author)

Fitted dimension 5: Engineering, design and data

Fitted dimension 5 is formed based on design, modelling and engineering output work (1), digitalization, data, tools and systems engineering (2) & technical assessment, safety and service-life decision support (3). Related to design, modelling and engineer output work, the designer described how 3D-modelling supports the alignment of structural designs by combining various technical inputs into a coherent representation of the design ([P18]). This includes modelling both existing situations and proposed interventions, allowing designers to visualize what needs to be replaced, strengthened or adapted. Besides the technical representation, 3D-models help in facilitating design discussions and they enable stakeholders to engage in conversations about potential solutions, alternatives and implications, even when they are not directly involved in detailed technical decision-making ([P18]). Therefore, model bridge the gap between disciplines and perspectives.

Besides the visual representation of a project, a model helps with critical assessment of design choices, where technical expertise is used to question and validate design decisions. A cost engineer spoke about actively challenging assumption, such as the necessity of additional materials or design measures and reflect on whether proposed solutions are justified based on past experience and actual need ([P7]). This shows that a critical stance contributes to a more efficient and practical design, preventing that decisions are not only technically sound but also proportionate. Additionally, design leadership was mentioned by a technical manager, especially in situations where existing assets no longer meet required standards. In such cases, they take on the role of design lead, responsible for developing solutions for replacement or new construction ([P15]). This shows the capacity of a technical manager, whereas the role extends beyond assessment and optimization of existing structures to include leading the design of new structures when required.

Apart from design visualizations and decisions, strong advisory and support during early design phases are critical. A cost engineer indicates that during sketch and design stages, their contribution often takes the form of advisory input rather than final decision-making, helping to shape design directions based on expertise ([P7]). The designer validates this and suggests that this role is internally oriented, with impact focused within the design team itself rather than externally. The designers supports the design process by making ideas and solutions visually accessible, thereby facilitating understanding and collaboration among team members ([P18]).

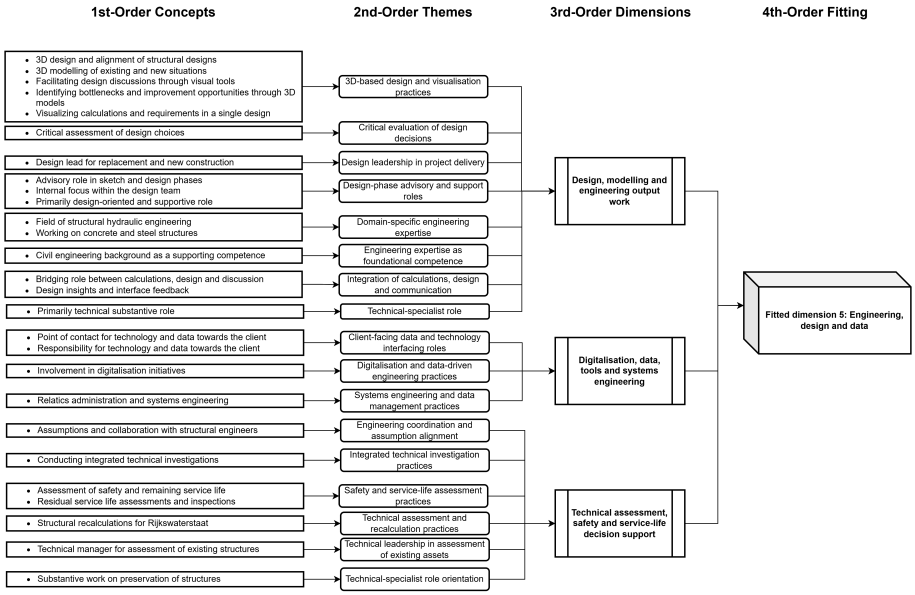
Having knowledge within a specific area as a project team member, can be a big benefit especially if it is technically oriented in which design and engineering work takes place. A technical manager highlighted that his specialization in structural hydraulic engineering, helps with providing relevant information to the design and thus obtaining a practical engineering output ([P11]). The other technical manager is a theme leader for the R&R projects for both concrete and steel constructions such as bridges and viaducts in the Netherlands ([P15]). This technical manager mentions that his role primarily remains technically and their contribution lies in the core engineering content itself, focusing on technical analysis, design and problem-solving rather than coordination or advisory functions. This shows how valuable technical specialization can be helpful for engineering, design and project end-result. The same counts for the statement of a project leader indicating that having a civil engineering background provides a strong foundation for understanding technical challenges and engaging effectively in design processes ([P16]).

Lastly, the designer emphasized that getting or providing feedback within the design process is essential. The contribution of the designer therefore lies in connecting calculations, design and discussion by translating technical outputs

into visual insights that can be shared across the project team ([P18]). By doing so, they enable meaningful dialogue between project leaders, engineers and other stakeholders, ensuring that different perspectives are integrated into the design process. This creates an iterative development of design which reveals new interfaces, constraints and potential issues that are not always visible in simplified models. Feeding these insights back into the process allows for continuous refinement and better informed decision-making ([P18]).

In terms of the digitalization, data, tools and systems engineering. A technical manager stated that within his role he is the main point of contact for technical and data-related matters towards the client, carrying responsibility for explaining justifying and report these aspects ([P3]). This responsibility is incorporated within the structured IPM project framework, where individuals are explicitly tasked with overseeing and being accountable for technology and data domains in relation to the client ([P3]). This highlights a representational role, where technical expertise is translated into accountability towards external stakeholders. A project control manager emphasized that his role covers involvement in digitalization initiatives and systems engineering practices, such as working with tools like Relatics, which support the structuring and management of project information ([P8]). In summary, this demonstrates that engineering roles increasingly extend into data management, digital tools and systems integration, proving the importance of digital competencies within modern project environments.

Additionally, regarding technical assessment, safety and service-life (related to LC) decision support, a cost engineer mentioned that their work often start in early stages with limited design information, requiring assumptions and close collaboration with structural engineers to develop initial insights and estimates ([P7]). This highlights the importance of expert judgment in situations where data is incomplete. In order to fulfill this data, a technical manager added to this, that his contribution is to conduct integrated technical investigations which include a combination of desk studies, inspections, material research and structural (re)calculations to assess the condition of assets ([P15]). He stated that these analysis help forming critical questions related to safety and reaming service life, which shapes the basis for decisions on whether structures (within projects) can continue to function or require intervention ([P15]). Adding to the service life, another technical manager stated that his role comes with determination of the residual service life assessment and inspections as a recurring activity ([P13]). This helps the structural engineers, in designing relevant and mitigating strengthening measure or replacement solution when necessary, making sure that the infrastructure continues to meet safety requirements ([P15]). Furthermore, this is complemented by more specialized tasks such as structural recalculations, particularly in context of RWS, where they are responsible for verifying the structural safety of assets as a core responsibility ([P15]). This is mainly involved in roles such as technical manager, with a strong focus on the assessment of existing structures and the preservation of infrastructural assets taking into account the operational and maintenance phase. ([P15],[P13]). These paragraphs all emphasize design, modelling and engineering output work (1), digitalization, data, tools and systems engineering (2) & technical assessment, safety and service-life decision support (3) as shown in Figure **??**, which is situated under '5. Engineering, design and data'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q1 (source: Author)

Fitted dimension 6: Organization, strategy and knowledge development

Fitted dimension 6 is formed based on organization, strategy, knowledge development and market positioning (1), sustainability integration in role tasks (2) and team leadership, coaching and capability development (3). Related to organization, strategy, knowledge development and market positioning, a project advisor mentioned that he is both active within his internal and external networks, where collaboration is key according to him. Meaning that some external partnerships are set-up (e.g. EcoShape) due to these networks, which facilitate knowledge exchange and innovations across organizations ([P6]). Working in such a collaborative project setting with multiple partners, it is common that this required

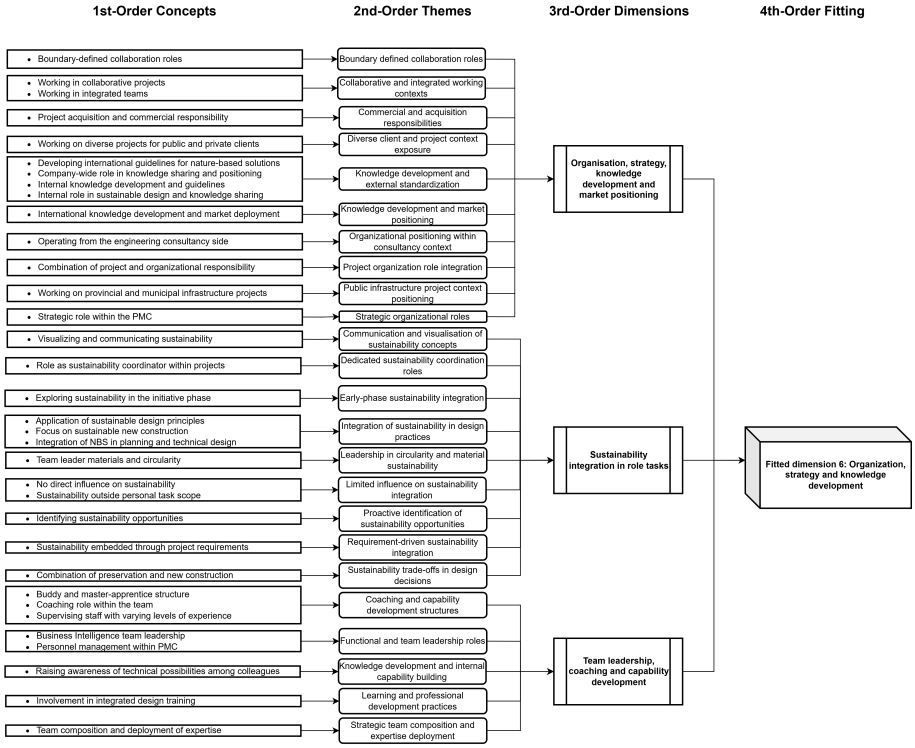
coordination across different stakeholders and contractual arrangements stated a project control manager ([P17]). This is even more strengthened by the use and forming of integrated teams, whereas solutions are created together across disciplines such as design, planning and environmental considerations ([P1]). In terms of project execution, a technical manager said that some roles also include organizational and commercial responsibilities, such as project acquisition and managing a practical workflow for their (project) teams ([P3]), as well as working across a diverse portfolio of public and private sector projects ([P4]).

In order to maintain a practical workflow, participants put the emphasis on internal knowledge development and transfer. This includes the development of (inter)national guidelines such as the Nature-Based Solution (NBS) for ministries abroad ([P6]), contributing to company wide positioning and knowledge strategies ([P13]) and creating internal guidance documents to support colleagues in integrating sustainability into projects ([P4]). An implemented and operational sustainability principle is the 'Sustainable Design Principles' (DOPs), which is developed mainly by the project advisor ([P6]). In summary, the participants state that their role can be dual, operating both across project- and organizational-level responsibilities. A project leader mentioned that some colleagues balance out project delivery with internal organization tasks, which indicates a dual focus that connects operational work with strategic development ([P1]). This is complemented by engagement in international markets and knowledge transfer, where expertise is both developed and applied globally ([P6]).

Also, in terms of sustainability integration in role tasks, the sustainability advisor stated that a big hurdle to sustainability integration is making sustainability tangible and understandable. For instance, her department is responsible for this and found a way to do so, by translating abstract ambitions (from the Ambitieweb sessions) into concrete visual representations ([P4]). Her role requires a big communicative skill, which is often formalized as a sustainability coordinator as well, who actively identify additional opportunities beyond contractual requirements and ensure sustainability is embedded broadly within projects ([P4]). Again, in order to identify the opportunities that fit within their ambitions, these ambitions must be defined, this is done in early project stage (FEDP). Whereas sustainability potential is explored in relation to client ambitions, where professional assess how there ambitions can be meaningfully integrated into project initiation and design ([P10]). During design, sustainability can be operationalized through the application of DOPs and/or NBS and technical approaches within planning and in collaboration between the designer(s) and structural engineer(s) for the design processes ([P6]). Despite the fact that there are several technical principles during design for sustainability integration, a technical manager mentioned that there is new growing focus on improving new solutions alongside traditional practices, such as preservation and life-cycle extension. Meaning that on organizational level, there are dedicated teams within W+B focusing on material and circularity, strengthening sustainability as a specialized or integrated domain ([P13]).

However, not everyone within W+B has an impact on sustainability integration and is therefore limited in influence and scope of role. A project control manager stated that sustainability falls out their direct responsibilities or is only embedded through project requirements (e.g. KES) or predefined work packages ([P14]). Indicating that sustainability is present but not actively steered upon, which highlights the added value of this research even more. However, as a sustainability advisor said, that opportunities are still identified by those in more dedicated roles, who actively seek to uncover and shape sustainability potential within projects ([P4]). It might be the case that opportunities of the project control manager has not brought up to daylight or has not been identified yet.

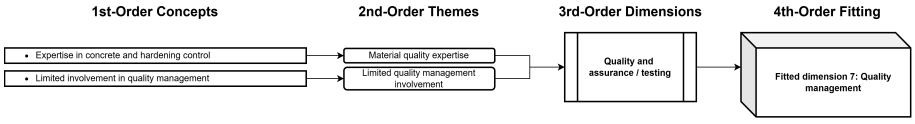
Lastly, related to team leadership, coaching and capability development, a technical manager stated that W+B has a buddy system and master-apprentice model, where experienced professionals guide junior and medior colleagues ([P13]). This provides room for development and guidance to next senior position and works as an incentive to work your way up (promotion). Additionally, the technical manager stated that, there is a more coaching oriented leadership style, where as team leaders see themselves not only as a manager, but also facilitators of individual growth and development within relative self-organizing (project) teams ([P13]). At the same time, these roles are responsible for active supervision, which remains necessary for teams with a wide range of experience levels, meaning that there is need for tailored guidance and regular alignment ([P13]). Beyond the individual coaching part, a technical manager mentioned that, leadership roles include a broader responsibility for team and organizational performance. This includes personnel management and making sure that teams are staffed and deployed with the right expertise at the right time ([P3]). Such as lead roles within the BI-group whereas they visualize on how knowledge and information management are organized to support project teams ([P8]). Additionally, it is important to raise awareness among other colleagues about technical possibilities and state-of-art practices (e.g. sustainability integration practices), in order to have an ongoing effort to elevate the overall knowledge base within W+B ([P13]). Training and knowledge transfer are essential, as stated by a project advisor, which is done by setting up trainings on integrated design (e.g. DOPs), resulting in the improvement of the internal distribution of expertise ([P6]). These paragraphs all emphasize organization, strategy, knowledge development and market positioning (1), sustainability integration in role tasks (2) and team leadership, coaching and capability development (3) as shown in Figure **??**, which is situated under '6. Organization strategy and knowledge development'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q1 (source: Author)

Fitted dimension 7: Quality and assurance / testing

Fitted dimension 7 is formed based on material quality expertise (1) and limited quality management involvement (2), both related to quality and assurance / testing. A technical manager mentioned that domain specific expertise, such as a focus on concrete performance and hardening control show that specialized knowledge area contribute to the technical quality and durability of infrastructure ([P13]). Indicating that certain roles are content wise driven with an emphasis on advancing and applying technical expertise within specific subdomains. However, there are some limitations to which all roles are involved in quality management. A project control manager, suggested that his involvement in quality related aspects is limited, with responsibilities on quality structuring, risks and organizations aspects being more associated with project managers instead ([P14]). This finding proofs that responsibilities are divided in which quality management is (not) uniformly embedded across all functions, but instead is allocated based on role definitions and project governance structures. These insights show that technical expertise might contribute to quality outcomes, but the formal responsibility for managing and organizing quality processes is separated, emphasizing the importance of role clarity and coordination within project teams. This paragraph emphasizes material quality expertise (1) and limited quality management involvement (2) as shown in Figure **??**, which is situated under '7. Quality management'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q1 (source: Author)

SSIs-Q2 - Current contribution to sustainability integration

The second question (SSIs-Q2) focused on identifying their current contribution related to sustainability integration within the responsibilities mentioned in SSIs-Q1. Again, based on their responses, fitted dimensions were subsequently developed.

Fitted dimension 1: Integrating sustainability in design and decision-making processes

Fitted dimension 1 is formed based on design and LC-integrated sustainability (1) and strategic steering and decision support (2) both related to integrating sustainability in design and decision-making processes. This reflects a move towards more flexible and resource efficient approaches to design. A technical manager mentioned that sustainability is not only about optimizing design but also about considering how performance is defined and managed. He gave an example, whereas monitoring is proposed as a viable alternative to over-dimensioning, where instead of 'over-engineering' solutions, uncertainties can be managed through adaptive monitoring methods. Resulting in a shift in norms and greater willingness to accept calculated risks ([P3]). Sustainability is also explicitly embedded through thematic priorities such as biodiversity and emission free construction (e.g. SEB (CROW Kennisplatform, 2026). A contract manager mentioned how projects more and more incorporate biodiversity considerations and try to include cleaner construction practices, which demonstrates a broader environmental scope beyond traditional engineering concerns ([P10]). A technical man-

ager stated that from a technical management perspective, integrating sustainability becomes a core responsibility, requiring alignment between technical decisions and sustainability objectives throughout the project LC ([P11]). Besides the fact that integration sustainability becomes a core responsibility, participants mentioned that seeking for synergies and co-benefits ('meekoppelkansen') during project development is essential to make bigger impact on sustainability integration. By putting efforts in identifying opportunities where sustainability gains can be combined with other project objectives, such as linking reuse flows between project or coupling projects to optimize resource use ([P2],[P15]). This is called systems thinking, which is fostered by questioning traditional requirements (e.g. strict availability and performance standards of materials) and considering whether potential lower thresholds could lead to more sustainability solutions without compromising core functionality ([P10]).

By optimizing design choices and reduce necessary resource/material use, the design phase contributes to sustainability integration. This is done, by preventing the cause of 'over-dimensioning', where alternative safety philosophies and evidence-based approaches are explored to prevent excessive material use (e.g. by reassessing standard design rules and applying concepts such as "proven strength"), project can then significantly reduce material inputs like steel or concrete, without compromising safety ([P3]). This requires a shift towards more efficient and critically assessed engineering practices. A technical manager stated that there are some ongoing explorations related to this, whereas there is a awareness of opportunities to improve sustainability through alternative materials and production techniques, especially in new-build contexts ([P13]). At the same time, W+B identifies and suggests mores sustainable execution methods and encourage reuse, although in practice they note that implementation remains challenging in practice ([P7]). On a material level performance requirements of material use also play an important role. Both a technical manager and cost engineer mentioned that they can influence design choices by proposing alternative materials such as different types of timber based (e.g. the Industrial, Flexible and Demountable (IFD) principle) on both cost and sustainability considerations, thereby steering design teams towards more sustainable outcomes ([P12], [P3]). This leads to opportunities for standardization and modularity improving sustainability during design phase ([P18]). By integrating these principles early in the design phase, the likelihood increases that they will be realized in execution and supports long term adaptability and reuse ([P10], [P11]).

Additionally, another important aspect worth mentioning is the analysis of sustainability ambitions (e.g using the Ambitieweb sessions). Projects that explicitly define their sustainability goals at the start are better able to make targeted decisions throughout the process ([P9]). This provides clarity at an early stage and helps to determine whether a project can truly add value and enables a thoughtful trade-off and prioritization. A technical manager mentioned that the recognition of design choices made in early phases, the FEDP, determine sustainability outcomes. Even aspects such as maintenance and LC performance are already influenced during the design stage, highlighting the long term impact of early technical choices ([P3]). This verifies the idea that sustainability is not something that can be "added later", but must be embedded from the beginning. A project leader even stated that the planning phase is decisive for sustainability impact. If sustainability is not taken into account during the plan development, the impact during execution becomes limited (e.g. due to regulatory constraints such as permits) ([P1]). Indicating that conducting thorough plan studies is a prerequisite for achieving meaningful sustainability outcomes. However, a project control manager stated that, sometimes sustainability is experienced as a boundary condition within planning, where practical constraints (e.g. space requirements for electrical equipment) can complicate implementation ([P8]). This highlights the tension between ambitions and feasibility during the FEDP.

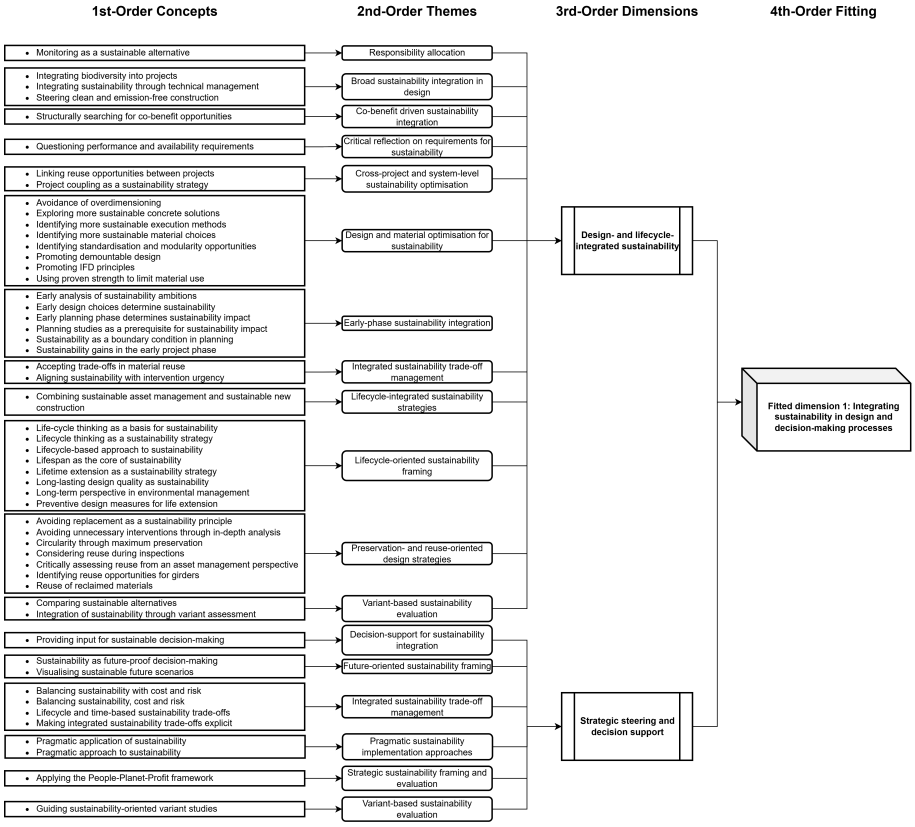
A challenge that comes with the implementation of sustainability solutions (e.g. material reuse) often requires acceptance form the client side that the outcomes may differ from expectations (alignment of expectations). An example is that reused materials may not have the same 'as-new' appearance, which can create a tension between aesthetic or performance demands and sustainability goals. Meaning that sustainability is not only a technical issue, but also a matter of stakeholder/client acceptance and decision making trade-offs ([P5]). Adding to this, opportunities for sustainability integration are also influences by project context and urgency. When replacements of assets are urgent, there is often limited time and room to explore additional sustainability measures ('meekoppelkansen'). In such cases, priorities shift towards speed and necessity instead of sustainability, which results in reducing the flexibility to integrate broader sustainability ambitions ([P15]).

Besides this, the 'LC perspective' is essential as well, in order to determine in which timeframe sustainability is measured or approached. A technical manager stated that sustainability should be approached from a full LC management perspective, which starts already during the design phase and extends through use and maintenance ([P3]). This means considering not only initial construction (CAPEX), but also operation, maintenance and eventual replacement (OPEX), ensuring that decisions are optimized over the entire lifespan rather than short term gains ([P6]). This is referred to as LC thinking as a strategy for sustainability. A technical manager highlighted the importance of finding the optimum over the total lifespan of the infrastructure project, rather than maximizing performance at a single moment. This includes ideas such as 'cradle-to-cradle' thinking and designing for an optimal service life ([P11]). However, during the realization it is of relevance that extending the lifespan of the asset is seen a core sustainability strategy, meaning that; demolition should be avoided, replacement frequency should be reduced and designing the asset should last longer (e.g. from 80 to 120 years) ([P3]). The earlier this approached is adopted within the Dutch construction industry by focusing on long lasting design quality, the more it contributes to a future proof infrastructure ([P2]). In practices this means that both preven-

tive and optimization measure, such as selecting better materials (e.g. more sustainable concrete solutions), applying protective measures (e.g. coatings) and making design choices that have minimal degradation over the lifespan ([P13]). Whereas the environmental manager stated that sustainability is also considered from a stakeholder and environmental perspective, where responsibility does not end at project delivery but continuous throughout the LC in its environment ([P2]).

A technical manager delved deeper into the context of sustainability impact, mentioning that most sustainable option is often to avoid replacement altogether. Replacing an infrastructural asset, especially concrete structures, immediately triggers CO_2-emissions, whereas existing assets already embody past emissions. Therefore, extending use rather than replacing is seen as a primary sustainability strategy ([P3]). An in-depth technical analysis can prevent unnecessary interventions. Understanding the actual structural performance, projects can avoid conservative strengthening or premature replacement, which means reducing material use and environmental impact ([P15]). This aligns well with the idea that maximum preservation sits at the top of the circularity ladder (referred to as the R-ladder), doing nothing is considered the most circular and sustainable outcome ([P15]). However, sustainability is operationalized in practice by the R-ladder analogy; assessing reuse potential already during inspections ([P3]), identifying opportunities to repurpose elements such as girders ([P15]) and actively working with reclaimed materials in projects ([P10]). In order to do so, reuse is not always as easy as it looks, there is a need for critical evaluation from an asset management point of view, where factors such as remaining lifespan, demand and practicality influence this decision ([P11]). Lastly, comparing alternatives helps finding the most sustainable option, by placing different design or execution options side by side allows project teams to make more informed (sustainable) choices ([P17]). This is supported by performing variant studies, where environmental impacts like the MKIECI are determined (e.g. a dike of steel or soil based dike) and considered during decision making ([P1]).

Regarding sustainability integration it is of essence that sustainability is considered primarily as a matter of strategic steering and decision support. This can be done by having sufficient input for decision making, whereas sustainability is explicitly taking into account alongside other criteria ([P12]). The environmental manager stated that, sustainability is also framed as a future proof, whereas PM-domains like environmental management or stakeholder management play a big role, meaning that decision in these domains are evaluated based on long term robustness and relevance ([P2]). A project leader supported this, that in order to translate this or communicate this it is helpful to visualize future scenarios, which assists stakeholders to understand what sustainable solutions could look like in practice. This makes future outcomes more tangible and supports project teams to better align on direction and ambition ([P16]). Decision making on sustainability is the consistent process of balancing out competing criteria (e.g. cost, risk, quality and performance). This is often done during asset management, where optimal solutions are those that achieve the highest 'acceptable' trade-off across these criteria ([P10], [P11]). However, time is another critical aspect that can not be neglected, since sustainability is also time dependent, which requires the earlier mentioned LC perspective. Solutions that have an up-front high impact, may still be preferable when evaluated over a longer period of time, emphasizing the importance of time based trade-offs in strategic decision making ([P13]). Additionally, a technical manager stated that these trade-off should be made explicit and conscious, depending on the project circumstances. Implicit prioritization of one criterium (e.g. cost or quality) does not capture the whole dynamic interplay of criteria related sustainability integration, since sustainability integration requires informed choices where consequences are clearly understood and communicated ([P13]). A technical manager mentioned that in practice there is a pragmatic boundary to sustainability, meaning that ambitions might come with practical constraints (e.g. technical, financial or organizational) and challenge project teams to apply sustainability in a realistic way suitable for the project context ([P3]). This can be realized, by evaluating the broader People, Planet and Profit framework which is required to balance out the environmental, social and economical values in decision making according to a project advisor ([P6]). A technical manager suggested that incorporating this framework to some extent within variant studies and comparative analysis, supports making sustainable decision. Since it helps to systematically evaluate alternative solutions, allowing project teams to identify the best options that perform the best across LC impacts, reuse potential (by using the R-ladder) and long term value ([P13]). This is all shown in Figure **??**, whereas design- and lifecycle-integrated sustainability (1) and strategic steering and decision support (2) are situated under '1. Integrating sustainability in design and decision-making processes'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q2 (source: Author)

Fitted dimension 2: Quantifying and substantiating sustainability

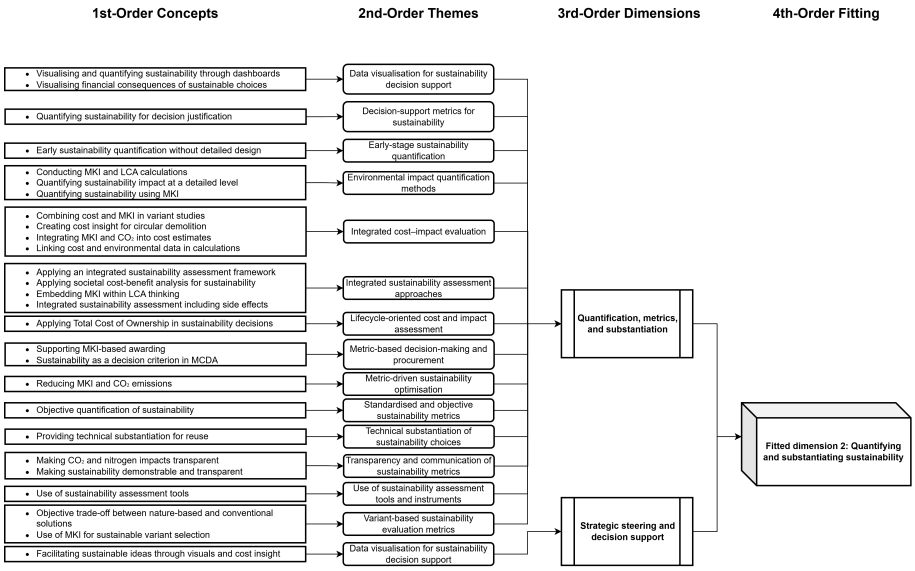
Fitted dimension 2 is formed based on quantification, metrics and substantiation (1) and strategic steering and decision support (2), both related to quantifying and substantiating sustainability. The findings indicated that sustainability can be better operationalized through quantification which allows to measure impacts, compare alternative and integrate sustainability into decision making. Using visuals help to communicate sustainability through quantitative tools, whereas a sustainability advisor mentioned that using a dashboard to compare MKI impacts across different design variants and baseline scenarios, makes sustainability performance explicit and accessible ([P4]). Adding to that, a cost engineer said that there is a need to better visualize financial consequences alongside environmental impacts, which indicates that sustainability should be communicated in both environmental and economic terms to support decision making, which is now done only by the MKI. However, a technical manager values that if more metrics could be identified and quantify sustainability (e.g. euros, CO_2 or material quantities) ([P11]). In terms of quantification in supporting and justifying decision, a cost engineer mentioned that for decision makers to make informed choices and to substantiate them afterwards, these decision makers require comparable data and quantified results ([P12]). An example or situation is that in case of a higher upfront cost it can be justified against sustainability benefits, such as reuse or reduced environmental impact, therefore it is not only evaluated but also argued through data (performing a CBA). Currently at W+B, the core of these methods that are used are MKI and LCA calculations, which are widely used to quantify environmental impact ([P4]). A technical manager stated that sometimes these methods are complemented with material flow analysis, but according to him it is more important that MKI should be incorporated within broader LCA thinking, in order to ensure that environmental impacts are addressed in a consistent way ([P13]).

An important note to quantifying, expressed by the cost engineers, is that there is distinction between early stage and detailed stage quantification. Detailed stage sustainability assessment are performed when design information is available, but it is recognized that early stage quantification (before detailed design) is both possible and underutilized ([P7],[P12]). Meaning that the opportunity to integrate sustainability considerations earlier in the project LC is not optimally used. Besides this, they desire the integration of sustainability with financial metrics, meaning that cost estimates should be combined with MKI scores in variant studies, allowing for direct comparison between alternatives on both environmental and financial performance ([P12]). Currently, W+B works on the integration of sustainability metrics in cost databases and procurement processes (e.g. by link CO_2 values to material costs or using MKI as a criteria during tender) ([P7],[P12]). As stated earlier, the LC perspective or approach is of importance, also during quantification which is emphasized by a technical manager, whereas total costs and impact over time should be expressed through 'Total Cost of Ownership (TCO)', which includes investment, maintenance, operation and end of life phase ([P11]). This guarantees that sustainability is evaluated not only at a single point during its LC, but across the entire lifespan of the asset. By including seconder effects, such as transport, demolition and reuse processes the approach becomes comprehensive ([P15]).

Apart from the metrics, there are also some evaluation frameworks used internally at W+B, a project advisor mentioned the 'Maatschappelijke Kosten-Baten Analyse' (MKBA), where both positive and negative societal impacts are considered

([P6]). In projects, a project leader stated that sustainability is also included in decision making through a 'Mutli-Criteria Decision Analysis' (MCDA), where it is used as one of several criteria alongside others (e.g. risk and costs) ([P1]). During tendering, sustainability is even operationalized directly within procurement by influencing tender outcomes through MKI-based scoring or 'discounts' on the bidding ([P12]). Besides internal use and process related use of sustainability, a project leader and project manager stated, that sustainability should also be framed as something that should be measured and made explicit (SMART-formulated), rather than discussed in abstract terms. Meaning that it can then be communicated transparently and presented towards (internal and external) stakeholders ([P1],[P9]), which improves the accountability and trust.

Currently, W+B use tools such as the MKI, Ambitieweb and Omgevingswijzer which are used to structure and support sustainability assessment ([P11]). However, there are still some gaps that can be fulfilled whereas a cost engineer mentioned that the use of integrated datasets and tools help to express sustainability on several fronts, where environmental indicators are directly linked to cost and material data ([P7]). These tools help to translate sustainability into standardized and operational metrics. These tools are helpful, as a technical manager stated that quantifying makes it easier to determine circularity and reuse (R-ladder) strategies. Identification of impacts and costs supports the project team to define the feasibility and reuse options and provide technical evidence required to convince clients and regulators ([P15]). This supports more circular decision-making processes. Remarkably, a project advisor stated that this data often reveals trade-off and non-intuitive outcomes. For example, a standard solution may sometimes sometimes perform better than a NBS when assessed against specific criteria ([P6]). This indicated the importance of objective, data based evaluation rather than relying on assumptions about what is 'more sustainable'. At last, the role of a project leader is essential in this, which comes with a more facilitative and exploratory role in strategic steering, where sustainability is supported through early idea development and decision support. Instead of making direct decisions, the role involves guiding a project team towards considering sustainable options by proposing interventions, making ideas concrete through visualizations, rough design and cost estimations ([P16]). By doing so, sustainability becomes easier to discuss, evaluate and communicate within the project team. These paragraphs all emphasize quantification, metrics and substantiation (1) and strategic steering and decision support (2) as shown in Figure **??**, which is situated under '2. Quantifying and substantiating sustainability'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q2 (source: Author)

Fitted dimension 3: Embedding sustainability through processes and project structures

Fitted dimension 3 is formed based on process- and governance-based embedding and is related to embedding sustainability through processes and project structures. According to a contract manager, for formalizing and structuring sustainability ambitions, it is observed that there are still challenges regarding the 'quality and clarity on these ambitions' when these are not formulated in a SMART way ([P5]). To tackle this, efforts are made (within W+B) to structure these ambitions into 'different tiers' aiming to distinguish between legal requirements, standard policies and additional (project) ambitions. This helps with alignment on expectations and creates a more structured approach to sustainability integration. The contract manager stated as well, that it is increasingly embedded in formal project structures (e.g. contract,s procurement and requirements). Whereas it is presented as a 'standard component' in contracts and tendering processes, meaning institutionalization within governance frameworks ([P5]). Furthermore, these sustainability requirements are included in project scopes and requirement specifications (e.g. KES), assuring that these become part of formal obligations within infrastructure projects ([P14]).

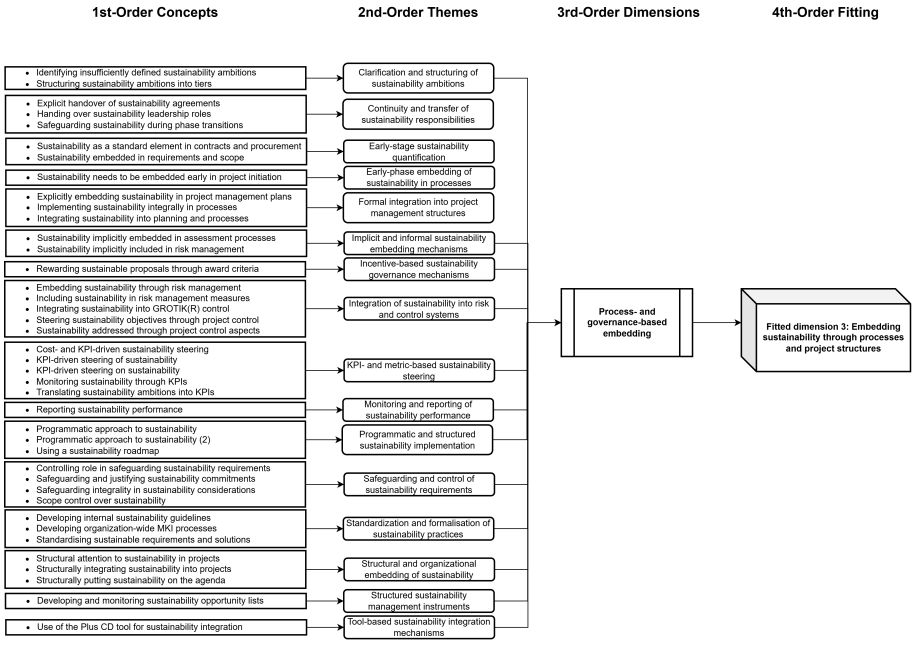
A challenging aspect of governance based embedding of sustainability is the continuity of sustainability across project phases. A project managers suggested that explicitly transferring sustainability related decisions, risks and ambitions between phases and teams should be maintained in order to prevent loss of information or 'down watering' of sustain-

ability goals ([P9]). This includes practical handover during project development and recognition that leadership roles related to sustainability might need to shift between individuals with different competencies over time ([P6]).

The designer stated that sustainability must be included early in the project LC, particularly in initiation documents and project definitions, since decision made at this stage (often by the project manager and project leader) tend to determine the extent to which sustainability is integrated later on ([P18]). Proving the importance of governance structures in the FEDP. This means that integration of sustainability within core project management processes are critical, rather than treating it as a separate or addition task. By doing so, sustainability should be taken into account in the planning, workflows and overall design, guaranteeing that it actively influences design decisions instead of being evaluated afterwards. This can be done by steering sustainability using sustainability objectives within frameworks such as GROTIK and managing them through project control mechanisms ([P17]). According to a technical manager and project control manager sometimes sustainability is addressed implicitly within assessment procedures or risk management, which can be effective but may also reduce visibility and accountability of sustainability ([P15],[P14]). Risk management is a key domain for governance mechanism to realize sustainability integration. This has to do with the fact that sustainability considerations are incorporated by defining risks and corresponding mitigating measures, such as staying within environmental limits or adopting cleaner technologies ([P8]). Including the translation of sustainability into metrics and linking this to risk frameworks, which allows for monitoring, evaluation and managing within existing control structures as was done by a study of Wong, 2024 ([P17],[P9]).

Potential leverage during the procurement and tendering phase, since they function as governance instruments should be utilized. This is because of the award criteria that reward sustainable proposals through fictive discounts or price-quality mechanisms (BPKV), which incentivizes sustainability ([P5]). this creates market competition and shifts sustainability from a voluntary consideration to a competitive advantage within procurement. Additionally, standardization and internal frameworks (at W+B) strengthens this, such as development of guidelines (e.g. DOPs), tools (e.g. +CD Tool) and standard approaches (e.g. Ambitieweb and Omgevingswijzer) ([P4]).

Besides all the tools, application and approaches, sustainability should also be incorporated within the organization and project teams through 'organizational learning' and 'programmatic approaches' (e.g. HWPB from the Water Authority). Rather than addressing sustainability on a project-by-project basis, this emphasized by a project manager that there is recognition and awareness that a programmatic approach (across multiple projects) allows for learning scaling and continuous improvement ([P9]). Confirmed by a project leader that uses road maps and long term strategies during projects, that provides direction and coherence across projects ([P16]). On top of that, a project control manager stated that contract managers and project control managers are responsible for ensuring that sustainability commitments are actually implemented, verified and justified. This involves checking whether agreed measures are included in design, if not, making sure that this is explained and documented (towards internal and external stakeholders) ([P14]). This highlights the importance accountability and intrinsic motivation in sustainability ambitions. On a higher organizational and system level, W+B makes sure that processes incorporate sustainability through MKI integration in decision making structures and through standardization efforts (e.g. IFD and DOP principles) ([P4],[P10]). Strategical, sustainability is positioned as a main priority to represent the image of the company and therefore receives sufficient attention within project and organizations (in this case W+B) ([P7]). Lastly, the responses of the participants showed that sustainability is also about actively maintaining focus and awareness, which is about continuously putting sustainability on the agenda, identifying opportunities and monitoring progress through tools (e.g. opportunity lists) and sessions ([P4], [P13]). If this is not brought to attention, within the governance structure, sustainability risks becoming fragmented or deprioritized. By doing so, sustainability becomes easier to handle, maintain and execute within the project team. These paragraphs all emphasize process- and governance-based embedding as shown in Figure **??**, which is situated under '3. embedding sustainability through processes and project structures'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q2 (source: Author)

Fitted dimension 4: Stakeholder- and participation-oriented sustainability

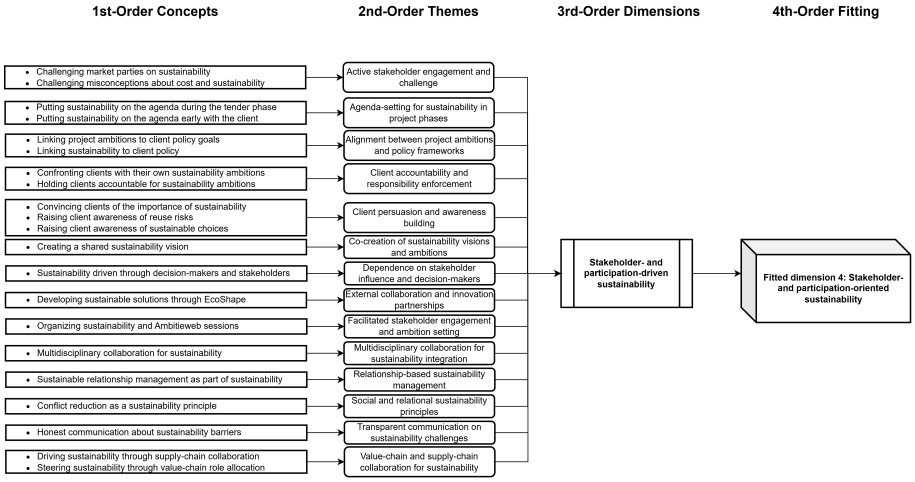
Fitted dimension 4 is formed based on stakeholder- and participation-driven sustainability and is related to stakeholder- and participation-oriented sustainability. The emphasis by participants on this, is that sustainability is shaped through interaction with involved stakeholders and the broader project environment, which means that sustainability is not only a technical or internal process, but more a social, relational and participatory process.

The impact of engagement and challenging external stakeholders (especially for market parties and contractors) is positively influencing sustainability integration. As mentioned earlier, the most sustainable bidding during the procurement process challenges bidders to contribute to sustainability integration with new ideas (e.g. opportunity plans or proposal for reusable materials or IFD principles) ([P5]). However, a cost engineer stated that assumptions and misconceptions on sustainability needs to be cleared, especially regarding costs and feasibility. The cost engineers actively correct 'misbelief' that sustainable alternatives are always more expensive, using their knowledge to propose equal prices but more sustainable solutions (on project or element level) ([P12]). This shows that knowledge is important in order to influence stakeholder interaction and steer towards sustainability. A project leader and project manager suggested that sustainability should be on the agenda at an early stage, especially when interacting with clients. This mainly happens already in the tender and initiation phase, where project members engage clients in discussion to better embed sustainability in project definitions ([P9], [P16]). Adding to that, realization of sustainability comes with relationship management and stakeholder dynamics in order to obtain a high 'goodwill factor', since this minimizes conflicts and maintains good relationships. Contributing to a smoother project development process and better integration of sustainability goals ([P2]). This comes with transparency and honest communication about challenges, barriers and trade-offs which enables stakeholders to make informed decisions and maintain trust ([P16]).

Existing client policies and ambitions also play a role in sustainability integration, both project leaders stated that they contribute to translating and strengthening these policies within projects, by referring back policy documents and previous stated ambitions ([P16],[P1]). Agreed the technical manager, by mentioning that clients should be confronted or reminded of their own sustainability goals when they risk being overlooked and becoming secondary ([P15]). Besides, alignment of expectations, a project leader said that client should be held accountable and influencing their decision making, by continuous dialogue, persuasion and awareness raising to make sure that sustainability is take seriously ([P16]). Sometimes, as is stated by a technical manager, this requires convincing clients to take risks or move beyond conservative approaches, indicating that risk aversion can hinder sustainability ambitions ([P15]).

Not only, the project team members need to be aware, but also clients and stakeholders. All involves participants should be conscious of the consequences of their choices, such as long term impacts, budget constraints or maintenance implications ([P6]). This means that sustainability should be considered which influences decisions. However, a technical manager suggested that a 'shared vision on sustainability' is lacking among stakeholders. without alignment on what sustainability actually means in a project, the project risks fragmentation and conflicting interpretations ([P11]). This proves that critical processes such as workshops and discussion are relevant to establish a collective understand and direction on sustainability (integration). This is often done through interactive and collaborative formats, such as Ambitieweb workshops, where multiple stakeholders jointly explore opportunities for improvement ([P4]). Despite this, sustainability integration or progress often depends on individual or decision makers who are willing to advocate for it and push boundaries and starts off at an individual level ([P16]). Meaning that stakeholder driven sustainability is not only insti-

tutional or organization, but also person dependent. Multidisciplinary collaboration is the nature of doing a project, this brings a challenge since sustainability integration requires input from different domains (e.g. engineering, ecology and financial) in order to actively involve different experts to improve the quality and feasibility of solutions ([P6]). However, determining and applying metrics that serve as fundamental sustainability measurement in these domains can support the assessment of how extensively sustainability has been integrated. The whole chain across the project realization is responsible for sustainability integration, verified a contract manager, therefore the value chain with different actors (e.g. contractors, engineers and clients) have different capabilities and influence. Effective sustainability integration requires, strategically assigning responsibilities to those best positioned to act ([P10]). This shows the importance of value chain coordination in achieving, sustainability outcomes. These paragraphs all explain stakeholder- and participation-driven sustainability as shown in Figure **??** which is situated under '4. Stakeholder- and participation-oriented sustainability'.



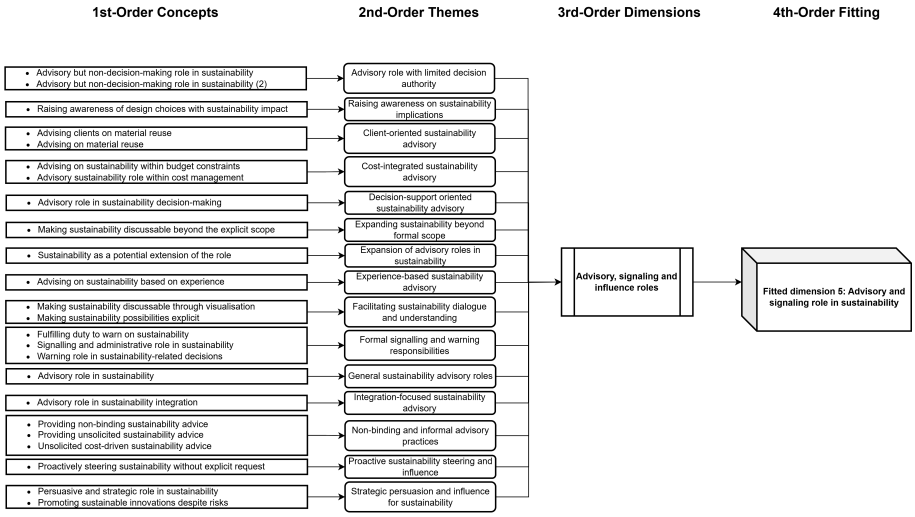
Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q2 (source: Author)

Fitted dimension 5: Advisory and signaling role in sustainability

Fitted dimension 5 is formed based on advisory, signaling and influence roles and is related to advisory and signaling role in sustainability. A main characteristic is that many actors have advisory but no decisive position. The designer and technical manager stated that they contribute to raising questions, providing input and structuring information, while decision remain at the client or key stakeholders ([P18],[P11]). This is related to raising awareness of sustainability implications, particularly during design. Even when the impact is potentially low, highlighting how early design decisions determine sustainability outcomes towards these decision makers ([P10]). This reflects and shows an important indirect leverage within their capacity. This advice is often focused on specific sustainability strategies within W+B (e.g. material reuse). The advise is given in concrete recommendations and reuse opportunities, whereas such options are often overlooked due to limited financial incentives or preference for new materials ([P7], [P5]). Showing that it is done, by bridging the gap between technical feasibility and decision making practice. The budget plays a big role, even when ambitions are present, the financial limitation can lead to rejection or more sustainable options, meaning that advisory input operates broader during project development which is stated by a contract manager ([P5]). Quantification of sustainability is valued by integrating it within advisory roles, where sustainability is made more tangible through cost calculations. Linking sustainability through specific metrics (e.g. MKI ECI)) helps the founding the argument of the advice and enables better decision making, since it is evidence based advise ([P12]).

Besides the quantifying effort, making sustainability also discussable by making it visible (especially when not explicitly included in the project scope), is important. A project manager suggested that, actively introducing sustainability topics into conversations, ensures that they are considered even when not formally required ([P9]). This is verified by the designer, stating that visualization is used as a tool to initiate the dialogue and support mutual understanding ([P18]). Additionally, the designer mentioned that experience plays a role in advisory input as well. Lessons learned from previous projects are used within W+B to inform current recommendations, which helps project teams to provide contextualized and practical advice ([P18]). This advisory role should be 'natural' as an employee of an engineering consultancy firm employee, since signaling and warning (duty to warn) for risks, overlooked aspects or suboptimal choices should be common ground trough formal roles or documents (e.g. risk registers) or communication like 'look at this again' ([P14],[P7]). This signaling acts as a safeguard for sustainability considerations. The 'duty to warn' responsibility indicated a more proactive behavior in flagging for more sustainable alternatives, even when not explicitly requested. This shows a proactive and ethical stance in promoting sustainability ([P12]). However, there exists a distinction between requested and unrequested advice, since advisory input is formally suggested. A project control manager and project manager mentioned the importance of providing informal sustainability advice, especially when opportunities for improvement are identified ([P9], [P17]). The proactive mindset, helps with steering sustainability without explicit mandates, particularly in projects where sustainability ambitions are not strongly defined. A project control manager mentioned that he tends to take initiatives to introduce alternatives and influence decision making indirectly ([P17]).

Furthermore, objectivity and neutrality is important as well, since another project leader often positions himself as a provider of 'balanced decision making', presenting multiple variants and their implications rather than favoring a single solution ([P1]). This is not the only way of working, another project leader stated that a more persuasive and strategic approach, actively helps in trying to convince stakeholders of the importance of sustainability and to influence outcomes beyond advice ([P16]). Lastly, a contract manager mentioned that advisors tend to encourage innovation at uncertain times (e.g. new technologies), despite that fact that perceived risks are not fully taken into account, requiring both technical justification and stakeholder persuasion ([P5]). This shows how advisory and signaling functions are operating in practice and what it means from the perspective of W+B. These paragraphs all explain advisory, signaling and influence roles as shown in Figure **??**, which is situated under '5. Advisory and signaling role in sustainability'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q2 (source: Author)

Fitted dimension 6: Organizational and knowledge-driven sustainability

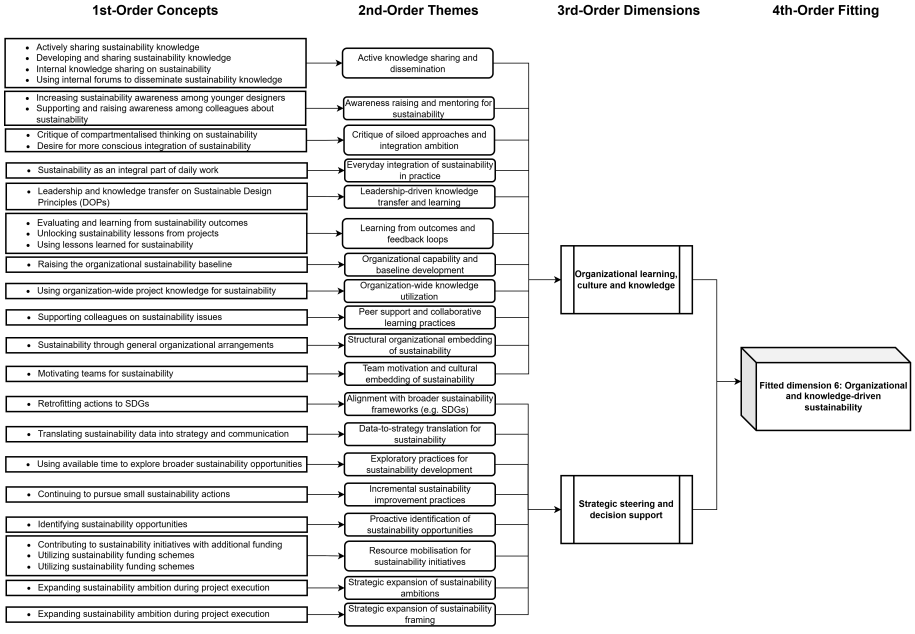
Fitted dimension 6 is formed based on organizational learning, culture and knowledge (1) and strategic steering and decision support (2), both related to organizational and knowledge-driven sustainability. An emphasized subtopic by that participants was that active sharing and spreading of sustainability knowledge. A technical manager highlighted that spreading insights across the organization is a must, for example through large internal meetings or discipline specific forums where experiences from projects are shared with broad groups of colleagues ([P13]). By sharing lessons within existing structures (e.g. discipline meetings), knowledge can reach large groups efficiently, strengthens a learning-oriented organizational culture. This helps with making individual project knowledge to become collective organizational knowledge. Adding to that, developing and institutionalizing knowledge, both internal and external, contributes to that as well. A contract manager emphasized that setting up standards, guidelines and knowledge platforms is essential to formalize sustainability practices and make the reusable across projects ([P10]). Providing a shift instead of ad hoc applications to a more structured and scalable approach, which is already being implemented, as a sustainability advisor mentioned that a tool she is working with the +CD Tool, is already used internally and used by other colleagues. Additionally, a technical manager mentioned that internally there are some internal knowledge exchange are currently done and supported through organized sessions and communities. Evaluating and discussing about a year plan or thematic meeting with experts that share insights on topics like biodiversity or climate neutral design ([P3]).

A notable statement by the designer, was that there is an increase in awareness of sustainability among younger employees at W+B, which is encouraged, since new perspective and expectations are considered into projects ([P18]). Indicating that the company culture change is driven by a generational shift for a part, within the current workforce. A technical manager mentioned that there is a need to move away from 'compartmentalized thinking', since sustainability integration and realization requires multidisciplinary collaboration and 'out of the box' thinking, indicating a more integrated perspective which challenges traditional way of working ([P15]). This eventually leads to a more multidimensional organizational mindset. However, for some roles, sustainability is already part of their integrative way of working, rather than a separate and additional task ([P4]). Whereas other express their wishes for having a more conscious and logical integration, showing that sustainability is not yet consistently embedded across all practices. A project advisor mentioned that taking leadership and ownership is essential for specific sustainability ideas. A project advisor mentioned that individuals who take on roles such as knowledge leader or ambassadors (e.g. for Sustainable Design Principles (DOP)) contribute to the continuous transfer and development of expertise within the organization ([P6]). Besides the ownership of a sustainable idea or approach, it is on individual level also important to learn from experience. A project manager said that sustainability outcome should be evaluated, successes and failures should be reflected on and apply those insights to future projects ([P9]). These can then be stored into a knowledge base for internal documentation of sustainability practices. This is part of lessons learned (repositories), whereas its potential can be unlocked by formalizing valuable project experiences in document and translating them effectively into organization knowledge, which is emphasized by a technical manager pointing out an opportunity for improvement ([P13]). As a next step in this, this can be used in order

to guide future projects and support continuous improvement ([P17]). This contributes to a more evidence-based and iterative approach to sustainability integration. This is needed, since the contract manager suggests that at a higher level, organizations in the Netherlands aim to raise the baseline of sustainability performance, meaning that they have to keep up to. Therefore, gradual increase of minimum standards and expectations across projects are needed, to ensure that sustainability is improved over time ([P10]). Additionally, being involved in various and big amounts of projects, brings value, since the availability of knowledge across these projects enables W+B to (re)use cross project insights, such as identifying opportunities or solutions between contexts ([P15]). Besides internal projects, a project advisor mentioned that colleagues seek advice and share expertise through informal knowledge networks. Meaning that they get easy access to expertise and peer supports within the organization and beyond ([P6]). However, at last, a project leader added that encouraging teams and creating awareness of small contributions, builds on a shared sense of responsibility, which is key to embedding sustainability in practice ([P16]).

Strategic steering and decision support was mentioned by several participants, whereas the first observation was that sustainability frameworks such as the SDGs are not always leading but sometimes used retrospectively. Meaning that decisions are adjust by the actions that are proposed with the goal to align with the SDGs after the fact, which creates a gap between strategic intent and operational steering ([P18]). Besides that, the sustainability advisor mentioned that translation of sustainability data into strategy and communication instead of only focusing on calculations and result interpretations is essential. This enables W+B to position sustainability within decision making and external communications (which is partially done by MKI calculations and the +CD Tool) ([P4]). However, time is important as well, since exploring sustainability opportunities also requires sufficient effort if the schedule allows this. Projects tend to be confronted with the estimated time span, whereas the participants mentioned that the scope can be broaden beyond immediate requirements (e.g. reuse, biodiversity and climate adaptation). A technical manager confirmed that it requires opportunity driven sustainability thinking that is flexible enough ([P15]). A contract manager added, that systematic mapping of where improvements can be made, supports more informed and strategic decision making ([P5]), reflecting the proactive behavior as explained earlier. This proactive identification forms the basis for targeted interventions. According to a project leader, sustainability is also done through smaller steps, meaning that even small interventions, pursued within projects and teams, contribute cumulatively to broader sustainability goals ([P16]).

According to the cost engineer, there are also some dedicated sustainability budgets from clients' side or other funding allows contractors or project teams to maximize sustainability impact. Reflecting that instead of focusing on cost minimization, the focus should be on the impact optimization within the given resources ([P7]). Understanding the budget based on sustainability funding, helps to create opportunities to implement ambitious measures, therefore awareness and accessibility are crucial since opportunities might remain unused if not actively recognized ([P5]). During execution, sustainability ambitions can still be expanded in collaboration with clients, which implies that strategic steering is an iterative process where ambitions evolve as new insights and opportunities arise ([P9]). A technical manager added that, broadening sustainability frameworks beyond traditional metrics, incorporating themes such as biodiversity or ecological value is a tendency within W+B ([P15]). These paragraphs all explain organizational learning, culture and knowledge (1) and strategic steering and decision support (2) as shown in Figure **??**, which is situated under '6. Organizational and knowledge-driven sustainability'.

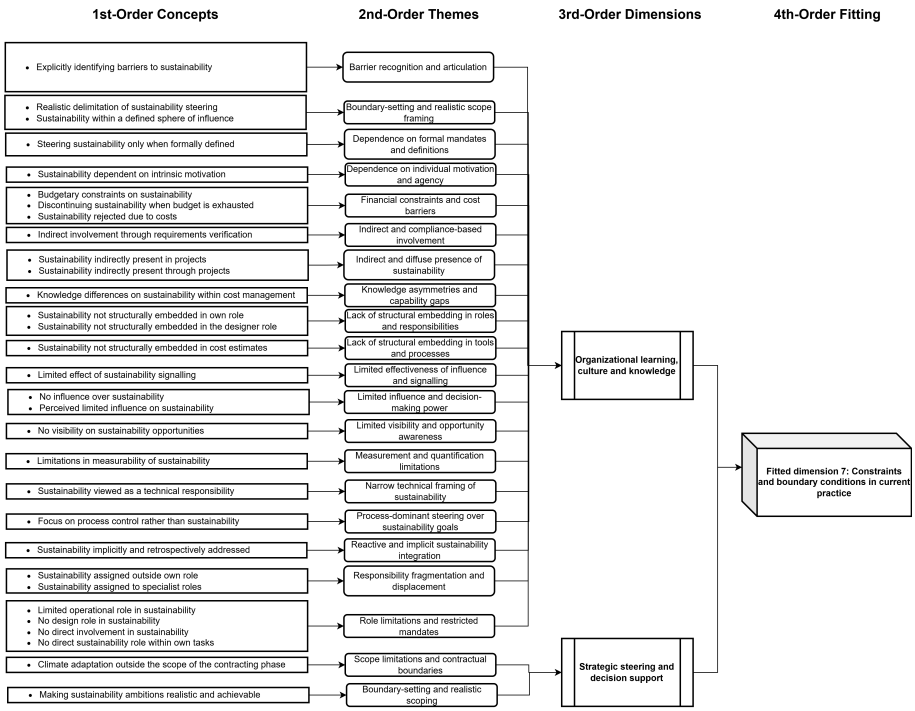


Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q2 (source: Author

Fitted dimension 7: Constraints and boundary conditions in current practice
Fitted dimension 7 is formed based on constraints, limitations and boundary conditions (1) and strategic steering and decision support (2), both related to constraints and boundary conditions in current practice. A project leader mentioned that there are explicit barriers to sustainability implementation, besides the fact that ambitions are expressed, they tend to fade over time when confronted with cost implications or stakeholder resistance. Proving that sustainability is not only a technical challenge but also a process of overcoming organization and financial barriers ([P16]). This is also related to and results into conditional or limited steering capacity, meaning that sustainability is no longer actively pursued (because of shifting priorities or constraints) which leads to minimization of monitoring, metrics tracking or further ambition setting. According to a project control manager, this is called pragmatic delimitation of sustainability efforts, where steering only occurs if boundaries are feasible to act upon ([P17]). Besides the practical aspect, another limitation is also the scope of influence of an employee. A technical manager mentioned that, contribution to sustainability is often bound to a specific domain of expertise (e.g. material choices within structural engineering), suggesting that sustainability is approached within predefined areas of responsibility rather than holistically ([P13]). Again, as mentioned earlier, a project manager also emphasized that sustainability is only actively managed when it is formally embedded as a project objective or work package. In case it is not explicitly defined, then it tends to receive limited attention, showing the importance of formalization related to strategic steering ([P17]). Besides the embedment, budget limitations often override sustainability ambitions according to project and technical manager, which leads to either downscale interventions or complete termination when budget runs out. This implies that sustainability is therefore treated as optional rather than integral, especially when additional investments are required ([P15],[P17]). Verified by a designer, stating that sustainability initiatives are regularly deprioritized due to the expected high costs or complexity even when initially included in project agendas ([P18]).

Sustainability sometimes is indirectly embedded through requirements (e.g. KES), work packages (e.g. WBS) or specialist roles. This based on a governance level and maintains some degree of inclusion, but it can also lead to fragmentation, where responsibilities are dispersed and not owned collectively ([P14]). A cost engineer and designer mentioned that there is a lack of structural embedding of sustainability within roles and processes. Sustainability is often dependent on individual awareness, expertise or (intrinsic) motivation rather than begin integration into job responsibilities or workflows. This creates differences in outcomes and limits consistency ([P12],[P18]). However, there exists a perception of limited influence and agency within the group of participants. A lot of them indicate that their ability to impact sustainability is constrained (e.g. organization hierarchies, contractual boundaries or lack of decision making authority). Whereas the earlier mentioned chapter of signaling and warning function is experiences as ineffective or ignored ([P14],[P18]). Experience is an additional gap, whereas particular domains such as cost estimation requires experience to understand where sustainability can be optimized according to the cost engineer ([P12]). This limits integration as well. A project control manager added that the presence of a dedicated sustainability expert can both support and potentially isolate sustainability from broader project responsibilities ([P14]).

Another constraint according to a technical manager is the limitation of measurability and uncertainty. Meaning that long term performance (e.g. lifespan of a project) is difficult to predict which makes decision making complex and reduces confidence in sustainability proposals ([P15]). This is strengthened if roles remain focused on control, compliance or specific technical domains which limits engagement in sustainability beyond their boundaries and leads to fragmentation of sustainability across disciplines ([P14]). The designer added that sustainability is sometimes addressed only implicitly or afterwards, rather than proactively embedded from the start. This is seen as a step forward compared to complete absence, which limits its transformative potential ([P18]). Lastly, a technical said that translating abstract ambitions into feasible, concrete measures can help to see them as a key contribution and especially in navigating the constraints described above ([P11]). These paragraphs all explain constraints, limitations and boundary conditions (1) and strategic steering and decision support (2) as shown in Figure **??**, which is situated under '7. Constraints and boundary conditions in current practice'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q2 (source: Author)

SSIs-Q3 - Sustainability integration opportunities

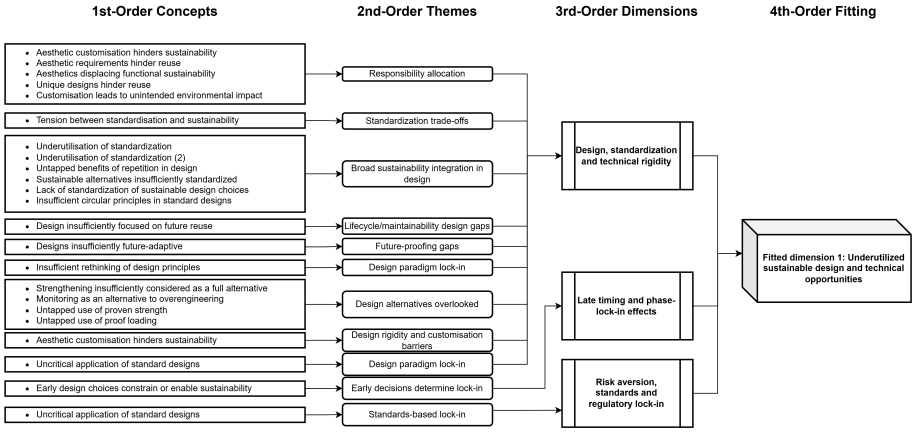
The second question (SSIs-Q3) focused on identifying opportunities related to sustainability integration within the responsibilities mentioned in SSIs-Q1 & Q2. Again, based on their responses, fitted dimensions were subsequently developed.

Fitted dimension 1: Underutilized sustainable design and technical opportunities

Fitted dimension 1 is formed based on design, standardization and technical rigidity (1), late timing and phase-lock-in effects (2) and risk aversion, standards and regulatory lock-in (3), all related to underutilized sustainable design and technical opportunities. A first subtopic brought to light by a technical manager and designer, is that there exists a tension between customization and standardization. Architectural preferences and aesthetic requirements often lead to unique and one-off designs, which hinder reuse potential, scalability and efficiency. Custom elements reduce the potential for circularity, as unique components are difficult to repurpose and often end up as waste ([P15],[P18]). Verified by a cost engineer, that aesthetic consideration can override functional sustainability and pushing resources towards visual quality rather than environmental performance ([P7]). Standardization (e.g. the IFD or DOP principles) offers a clear recognition towards sustainability benefits, such as easier reuse, efficient production and maintenance. However, these tend to remained underutilized due to cultural resistance, particularly from design oriented stakeholders. A more hybrid approach, whereas core elements of a structure or project are standardized combined with customization for non-critical elements, which can be promising but is currently insufficient explored ([P15]). This is related to the lack of structural standardization in sustainable design choices, in case these principles are used, it is of importance that they are made with awareness of its impact. Decisions are often made on the spot, depending on preferences rather than embedded design principles with the narrative on sustainability (one of the criteria). According to a contract manager this leads to inefficiencies and missed opportunities, when sustainable alternatives are not consistently considered or normalized ([P10]).

Additionally, during initial phases (e.g. conceptual or preliminary phase) the design choices made, tend to persist throughout the project even when they limit sustainability outcomes. The choices that are made then, can restrict disassembly (IFD) or reuse (DOP) that are often locked-in early during the FEDP ([P10]). This highlights the impact of phase lock-in effects. A cost engineer emphasized that current design approaches within W+B often lack a future oriented perspective. This has the do with the fact that infrastructure is frequently designed base on outdated assumption (e.g. past emission standards), instead of anticipating future developments. This results in solutions that are not adaptable or aligned with long term sustainability goals ([P7]). During the project development, there are still some insufficient explored strategies for alternatives. Options such as strengthening instead of replacing, monitoring instead of overdesigning or reusing existing materials are not always considered. This shows a bias towards solutions, even when more sustainable alternatives are available ([P12], [P3]). On a more detailed level, a technical manager mentions that some technical methodologies are still underused (e.g. proof loading or design based on proven strength), rather than conservative assumptions. These methodologies could help to reduce material use and avoid unnecessary interventions (despite the investment costs for the tests), but they are currently not embedded in practice ([P3]). This has to do with the uncertainty in performance and lifespan of a structure or project, which is a barrier to reuse and adaptive design (IFD). Again, difficulty in accurately predicting long term behavior leads to conservative decisions, which often leads to replacement rather than reuse ([P15]). This is mainly due to the strict and standardized lifespan requirements, which do not account for the remaining value of

existing materials or components ([P10]). Beside the approaches within the company, there are also some established regulatory frameworks and design standards that can create or limit lock-in effects. The established guidelines (e.g. ROK (Rijkswaterstaat, 2023)) and approved standards (e.g. NEN (NEN, 2025)) are followed without hesitation, limiting innovation and discouraging alternatives and more sustainable approaches. Designs bounded by rules and regulations thus becomes a barrier to sustainability improvements ([P13]). This indicates that there is need for rethinking design principles (e.g. using IFD and DOP). In practice, the main priorities are certainty, standard compliance and short term efficiency over adaptability, circularity and long term sustainability. Unlocking the opportunities requires a shift towards flexible, performance base and LC oriented design approaches. These paragraphs all explain design, standardization and technical rigidity (1), late timing and phase-lock-in effects (2) and risk aversion, standards and regulatory lock-in (3) as shown in Figure **??**, which is situated under '1. Underutilized sustainable design and technical opportunities'.



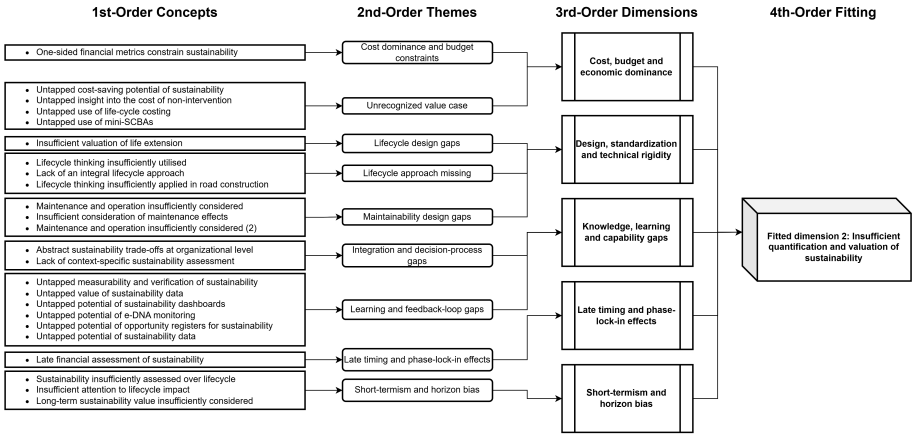
Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q3 (source: Author)

Fitted dimension 2: Insufficient quantification and valuation of sustainability

Fitted dimension 2 is formed based on cost, budget and economic dominance (1), design, standardization and technical rigidity (2), knowledge, learning and capability gaps (3), late timing and phase-lock-in effects (4) and short-termism and horizon bias (5), all related to insufficient quantification and valuation of sustainability. A central issue is the dominance of one dimensional financial metrics in decision making. When decisions are primarily based on direct costs, more sustainable options (e.g. circular demolition or reuse), are frequently dismissed. The choice of metric fundamentally shapes outcomes, what is not monetized or measured remains invisible in decision making ([P12]). At the same time, a project control manager stated that, there is evidence that sustainability can also generate cost savings, however this potential is not systematically recognized or exploited ([P8]). Related to this, a cost engineer mentioned, there is lack of insight into the cost of non-intervention. Projects typically assess the cost of building new solutions, but rarely evaluate the economic implications of maintaining, strengthening or not intervening at all. This leads to a bias toward conventional and often less sustainable solutions ([P12]). Another gap lies in the limited application of LCC and broader economic evaluation methods. Beside the fact that LC thinking is acknowledged as important, it is barely used in practice, particularly in long lifespan infrastructure projects where maintenance and replacement cycles are insufficiently incorporated into decision making ([P7]). Similarly, tools such as (mini) societal cost-benefit analyses (SCBAs) are not consistently applied, despite their potential to capture broader societal impacts ([P3]). This reflects a broader lack of LC oriented thinking in design and evaluation. Maintenance, operation and long-term performance are often insufficiently considered, leading to suboptimal sustainability outcomes. Decisions are frequently made within project boundaries, without adequately accounting for downstream effects such as maintenance burdens or operational impacts ([P7],[P8]).

A sustainability advisor even mentioned that sustainability trade-off are often handled in a highly abstract or strategic level, without being translated into concrete, actionable criteria (SMART-manner). This limits their practical impact on project level decisions ([P4]). Moreover, a technical manager mentioned that, sustainability assessment are often not context specific, applying uniform approaches across different environments despite varying local conditions and impacts ([P3]). Another challenge is the limited measurability and usability of sustainability data. Although metrics and monitoring tools exist within W+B, the application is inconsistent and collected data is not always integrated into organizational systems or decision making processes. As a result, valuable sustainability insights remain underutilized ([P9], [P3]). Related to this is the untapped potential of dashboards, monitoring tool (e.g. e-DNA) and opportunity registers, which could support more proactive and data driven sustainability management but are not widely implemented ([P8],[P3]). Timing also plays a crucial role. Sustainability considerations are often introduced too late in the project lifecycle, particularly in financial evaluations. Early stage decisions (during FEDP) largely determine sustainability outcomes, yet cost-benefit analyses (e.g. SCBAMKBA) of sustainable options are frequently postponed until later phases, when flexibility is already reduced ([P17]). Related to time, there is strong indication of short-termism and horizon bias in decision-making, meaning that sustainability benefits often appear over longer time horizons (potentially causing ambition erosion (Veen, 2023)), while costs are immediate, visible and tangible. This mismatch or phenomena leads to underinvestment in sustainable solutions, especially when long term impacts like maintenance, LC emissions or durability are not accounted for ([P2],[P12]). These paragraphs all explain cost, budget and economic dominance (1), design, standardization and technical rigidity

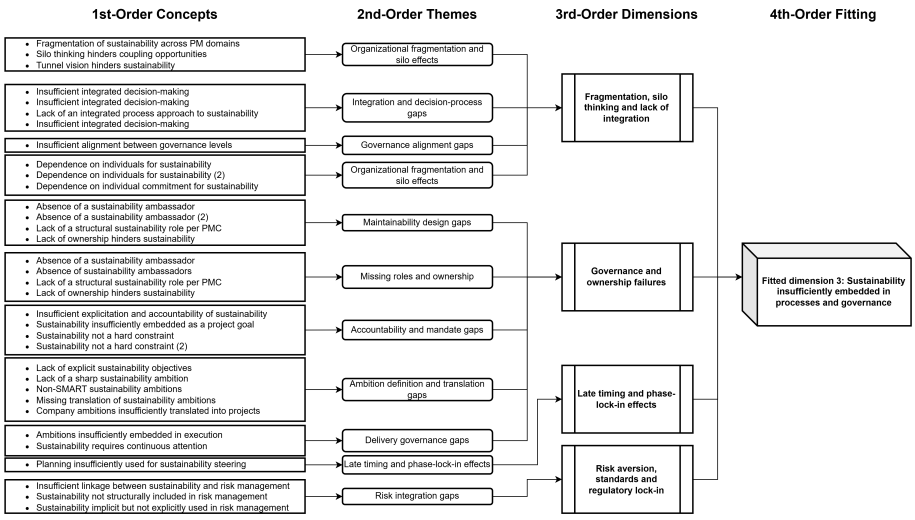
(2), knowledge, learning and capability gaps (3), late timing and phase-lock-in effects (4) and short-termism and horizon bias (5) as shown in Figure **??**, which is situated under '2. Insufficient quantification and valuation of sustainability'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q3 (source: Author)

Fitted dimension 3: Sustainability insufficiently embedded in processes and governance

Fitted dimension 3 is formed based on fragmentation, silo thinking and lack of integration (1), governance and ownership failures (2), late timing and phase-lock-in effects (3) and risk aversion, standards and regulatory lock-in (4), all related to sustainability insufficiently embedded in processes and governance. A issue highlighted by a project manager was that sustainability tends to fragment across multiple project management domains, which diminishes rather than strengthening it ([P9]). This is even boosted by the phenomena of silo thinking, where actors remain bound by their own budgets, standards or organization routines which leads to the limitation for opportunities coupling ('meekoppelkansen') and integrated decisions making ([P15], [P13]). The project control manager stressed out that sustainability should be integrated more explicitly into the planning and should be connected to other design and project teams, rather than treated as a parallel or isolated topic ([P17]). A more humanoid aspect is that there is strong dependence on individuals within W+B. Participants informed that sustainability progress often relies on intrinsically motivated people who keep pushing the topic, rather than on organizational arrangements ([P16],[P18],[P13]). Whereas was mentioned that there is a need and absence of a clear sustainability ambassador or structurally embedded roles within the PMC, which weakens ownership, accountability and continuity ([P16],[P4],[P2]). In practice, this means that sustainability is frequently not a hard project constraint, but remains secondary to other priorities unless explicitly considered in project goals, scope and responsibilities ([P1],[P11]). This comes with ambitions that may exist at organizational or client level, but are often insufficiently translated into concrete project objectives, planning decisions and execution arrangements ([P14],[P17],[P15]). Lastly, a project control manager expressed that sustainability is not weakly embedded in formal governance instruments, especially in planning and risk management, whereas for the latter a research by Wong, 2024 had developed a method for integrating sustainability within risk management domain. The participants note that sustainability needs to be built into project planning much earlier if it is to steer decisions effectively ([P17]). Although sustainability is sometimes implicitly present in risk management, it is rarely treated as an explicit and structurally monitored risk category in its own right ([P8],[P14]). This has now been done during a tender project of W+B. The findings suggest that sustainability is not completely absent from projects, but is still insufficient institutionalized, whereas it depends too much on personal initiative and is not completely anchored in project management and control practices. These paragraphs all explain fragmentation, silo thinking and lack of integration (1), governance and ownership failures (2), late timing and phase-lock-in effects (3) and risk aversion, standards and regulatory lock-in (4) as shown in Figure **??**, which is situated under '3. Sustainability insufficiently embedded in processes and governance'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q3 (source: Author)

Fitted dimension 4: Governance, client behavior and institutional barriers

Fitted dimension 4 is formed based on cost, budget and economic dominance (1), fragmentation, silo thinking and lack of integration (2), governance and ownership failures (3), knowledge, learning and capability gaps (4), late timing and phase-lock-in effects (5), risk aversion, standards and regulatory lock-in (6) and short-termism and horizon bias (7), all related to governance, client behavior and institutional barriers. Altogether, participants showed that sustainability is not only blocked by a lack of ideas, but by the way a project is governed, commissioned and steered.

According to a project leader and technical manager in practice sustainability ambitions are among the first aspects to be dropped when budgets are insufficient or when choices are framed as unessential compared to core delivery tasks ([P15],[P16]). This is emphasized by maintenance budget cuts, sober and efficient procurement frameworks and the perception that sustainability primarily adds cost rather than value ([P3],[P8]). In practice, functionality, safety and stakeholder demands have the main priority first, while sustainability is treated as secondary and pursued only if the budget allows this ([P11]). Also, current contractual and financial arrangements often fail to reward long term value creation, making it difficult to justify investments that save costs or reduce impacts only over longer time horizons ([P18],[P7]). Even where tender incentives exist, such as fictive discounts or award criteria, their steering power is experienced as limited, especially when cost pressure or resistance emerges later during project development ([P5],[P16]). Another barrier is about fragmentation due to silo thinking and weak integration across actors and levels within W+B. According to a project leader, sustainability is often insufficient prepared, poorly framed or steered in participation and project processes, resulting in promised ideas that fall apart once they encounter competing interests or resistance from stakeholders ([P16]). Separate budget and a fixed organizational routine hinders development and identification of coupling opportunities (’meekoppelkansen’), leading to poor integration between disciplines. The planning processes and governance levels limit the ability to treat sustainability as part of the integral project ([P15],[P16]). This fragmentation is made worse by the fact that sustainability implementation often depends on the motivation and commitment of individual actors rather than on stable institutional structures within W+B ([P16],[P18],[P13]).

Related to the broader governance and ownership failures, according to a project leader and designer, the sustainability ambitions often remain at the policy, strategy and organizational level, without begin translated into had project or company goals, assigned accountability or operational requirements ([P16],[P18]). In practice, the experience has been that sustainability is often driven only when clients explicitly ask for it, when it is part of the procurement request or when it is tied to EMVI criteria, otherwise opportunities are easily overlooked ([P17],[P9]). The participants emphasized there there is little room for influence within their own roles and a lack of administrative or managerial courage to make sustainable choices. Whereas they tend to have more conservative decision making under political or organizational pressure ([P14], [P16], [P1]). Therefore, these governance related barriers are not isolated on a process level, but comes with institutional and behavioral aspects, such as; unclear ownership, insufficiently sharp ambitions whereas sustainability is too rarely treated as a unnegotiable project objective. ([P1],[P5],[P14]).

Concerns regarding late timing and phase lock-in effects, is that sustainability is often introduced too late. Meaning that after final design, contractual or permitting decision have already been made, which narrows any room for change ([P1],[P6],[P17]). A project leader stated that, once a specific technical solution or option has been chosen and embedded in contracts, permits and stakeholder communications and design assumptions, it becomes hard to shift towards a more sustainable alternative ([P1]). Sustainability must therefore be included as early as possible in planning and design, rather than added afterwards. If not, the available room for sustainability decreases as the project progresses and is confronted with execution realities, the timeline and budget constraints that further obstruct sustainability to delivery ([P18],[P7],[P1],[P17]).

The findings show that risk aversion, standards and regulatory lock-in also is seen as an institutional barrier. According to a contact and environmental manager, sustainability opportunities are sometimes seen as threats, because they might lead to delay, uncertainty, procurement risk or lack of market response ([P2],[P5]). This leads to a more safe behavior whereas projects often fall back on conventional solutions and minimum compliance, rather than experimenting with more ambitious or innovative options ([P5],[P4]). However, in general these overly conservative lifespan assumptions, strict availability requirements and spatial constraints for zero emission construction (e.g. SEB) and permitting procedures all delay the processes and reduces room for sustainable choices ([P10],[P8],[P1]). As a matter of fact, the rules and regulations with the corresponding standards used in practice often delay or are applied rigidly, while guidelines for specific sectors such as those of RWS can unnecessarily limit the design freedom and increase environmental impact when these are uncritically copied within another project context ([P13],[P11],[P10],[P15]). This way of working creates a culture where deviation from the 'usual' standards requires unusual courage, while on the other hand project teams are trained to think in terms of risk minimization rather than sustainability maximization ([P3],[P8]).

Lastly, related to short termism and horizon bias. Sustainability is still too often assessed through a short-term lens, whereas many sustainable solutions only prove their value when evaluated over a longer period ([P13],[P11]). Some options may appear sustainable in the short run but perform less over time, while others require higher upfront investment yet deliver better long term outcomes ([P2]). This shows that current governance and procurement practices within W+B and perhaps even other engineering consultancy firms insufficiently account for long term value, LC performance and delayed benefits, which weakens the institutional position of sustainability in practice. In summary, sustainability is not only hindered by technical limitation, but by institutional arrangements that favor other aspects as mentioned in previous paragraphs over long term integrated value creation. As a result, many sustainability opportunities remain available in theory but are not activated in practice, because governance systems do not yet consistently reward, require or protect them. These paragraphs all explain cost, budget and economic dominance (1), fragmentation, silo thinking and lack of integration (2), governance and ownership failures (3), knowledge, learning and capability gaps (4), late timing and phase-lock-in effects (5), risk aversion, standards and regulatory lock-in (6) and short-termism and horizon bias (7) as shown in Figure **??**, which is situated under '4. Governance, client behavior and institutional barriers'.



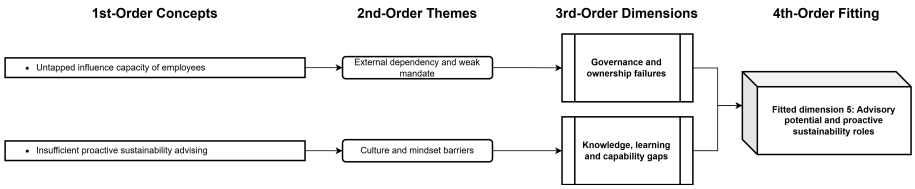
Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q3 (source: Author)

Fitted dimension 5: Advisory potential and proactive sustainability roles

Fitted dimension 5 is formed based on governance and ownership failures (1) and knowledge, learning and capability gaps (2), both related to advisory potential and proactive sustainability roles. Aside from sustainability opportunities being limited by formal structures within the company, but also by the extent to which an employee uses the room for influence they already have (capacity). A sustainability advisor mentioned that some employees remain within their comfort zone, while other may have to capacity to make the playing field bigger, meaning that part of the unrealized sustainability potential remains untapped in influence capacity of employees themselves ([P4]). This points to the governance challenges

that role may not determine outcomes, but rather that sustainability progress can also depend per individual and if they are willing and able to stretch their mandate and act more strategically.

Another aspect relates to the mindset and cultural barrier around proactive handling. A cost engineer mentioned that he did not brought up a potential better idea towards the client to raise the alternative of strengthening a bridge and extend its lifespan by 50 years. He could have raised this more proactively and boldly towards the client ([P12]). This indicates that advisory roles contain more sustainability potential than is currently being used within W+B, but in order to realize this potential it requires a more proactive, confident and forward leaning attitude. These paragraphs all explain governance and ownership failures (1) and knowledge, learning and capability gaps (2) as shown in Figure **??**, which is situated under '5. Advisory potential and proactive sustainability roles'.



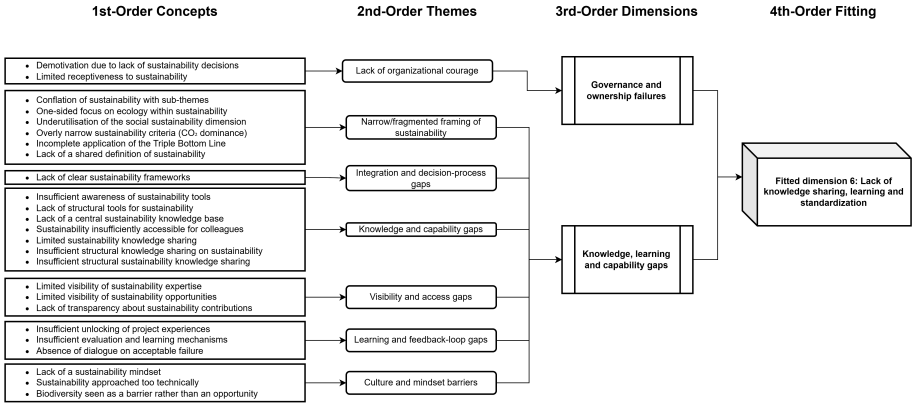
Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q3 (source: Author)

Fitted dimension 6: Lack of knowledge sharing, learning and standardization

Fitted dimension 6 is formed based on governance and ownership failures (1) and knowledge, learning and capability gaps (2), both related to lack of knowledge sharing, learning and standardization. A mentioned subtopic was about ambitions without follow-up, which leads to disengagement. A project leader said that how extensive effort is put into developing sustainability ideas ('schematizing'), yet nothing really is set in stone afterwards, which is feeling very demotivating towards a project team ([16]). This reflects that decision making and ownership are insufficiently aligned with earlier ambitions, resulting in promising sustainability initiatives to fail before implementation. Not having clear decisions or commitment at later stages undermines not only outcomes but also future motivation of the project team to invest in sustainability thinking. This is related to limited openness to sustainability within the organization and among project stakeholders. A project advisor mentioned that not every colleague or partners is equally open to sustainability arguments, even when it is framed through broader People, Planet and Profit Prosperity framework ([6]). Therefore, governance challenges are not purely structural, but also involve different levels of acceptance and prioritization, which impacts the decision whether sustainability considerations are taken on board or not. Besides this, sustainability integration is constrained by fragmented understanding and inconsistent conceptualization. The same project advisor stated that there is a confusion between sustainability and sub-themes (e.g. climate or biodiversity), as well as the absence of a balanced consideration of the People, Planet and Profit Prosperity framework ([P6]). This results in a narrow interpretation of sustainability (e.g. CO_2 becomes the dominant decision criteria) while broader societal impacts are overlooked ([P3]). Also related is the lack of a shared definition of sustainability, which leads to divergent interpretations across individuals and teams ([P11]).

Apart from the conceptual issues, participants emphasized that there are deficiencies in tools, structures and accessibility of knowledge. There is a lack of clear frameworks, limited availability of practical tools and a missing central knowledge base that could support more consistent application of sustainability ([P18],[P17]). Sustainability knowledge within W+B is often described as difficult to access, insufficiently shared or hidden. This results in low visibility of both expertise and opportunities ([P4],[P3]). This is a challenge to improve on internally, which also makes it hard for motivated individual to act, as they lack the necessary support to translate intent into practice. Furthermore, there is a weak learning and feedback mechanism. A project manager and technical manager mentioned that there is limited transparency about sustainability outcomes, insufficient evaluation of what works and a lack of systematic learning from past projects ([P9],[P13]). No evaluation and having an open dialogue (particularly during failure), further restricts collective learning and improvement ([P10]). This results into missing valuables experiences and underused opportunities for scaling successful practices.

A more cultural and mental gap to this, is that sometimes sustainability is approached too technically or seen as an add-on rather than an integral mindset ([P14],[P7]). In some cases it is even seen as a barrier rather than an opportunity, particularly in relation to biodiversity ([P3]). This means that improving knowledge alone is not enough, since a shift towards a shared sustainable mindset is also required, supported by accessible knowledge, frameworks and stronger organizational learning processes. These paragraphs all explain governance and ownership failures (1) and knowledge, learning and capability gaps (2) as shown in Figure **??**, both related to '6. Lack of knowledge sharing, learning and standardization'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q3 (source: Author)

Fitted dimension 7: Missed system-level and programmatic sustainability opportunities

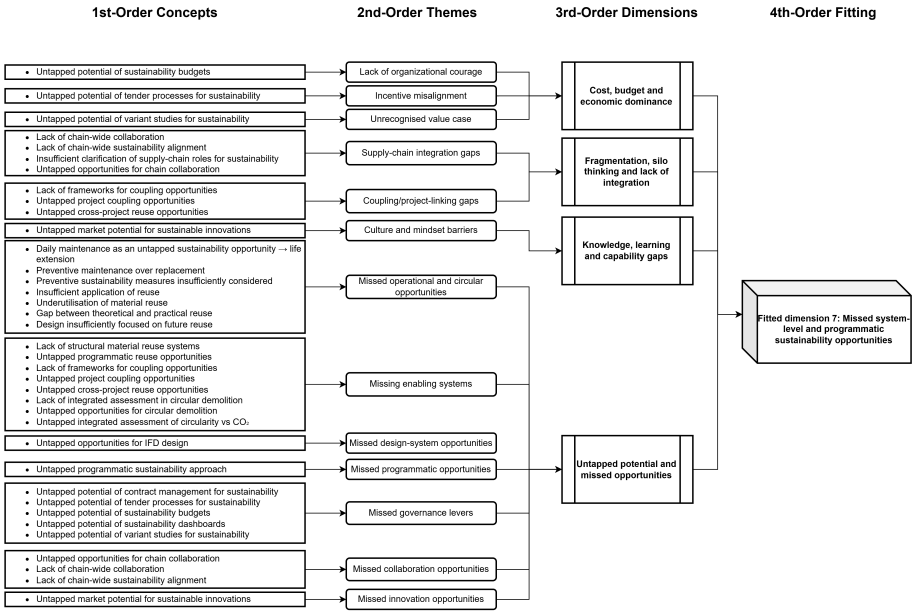
Fitted dimension 7 is formed based on cost, budget and economic dominance (1), fragmentation, silo thinking and lack of integration (2), knowledge, learning and capability gaps (3) and untapped potential and missed opportunities (4), all related to missed system-level and programmatic sustainability opportunities. A more strategic use of financial and contractual instruments is the first opportunity since a contract manager explained that dedicated sustainability budgets can create room for additional measures, but that these funds are not always allocated or structurally present in projects ([P5]). Similarly, according to a project control manager, during procurement and tendering the levers are underused to steer strongly in offer and tender trajectories which could push sustainability earlier and more explicitly into project choices ([P17]). A project leader mentioned that variant studies tend to be promising but underused, since this technique can compare alternatives not only on cost and time, but also on environmental impact (e.g. MKI ECI), constructability, sustainability performance and policy fitness. All of this suggests that budgets, tenders and comparative evaluations can boost system-level sustainability if they are used strategically rather than just as procedures.

Another missed opportunity subtopic concerns chain collaborations, cross-project coupling and programmatic coordination. A contract manager and technical manager highlight that sustainability gains depend on whether actors in the chain 'speak the same language', whether responsibilities across the supply chain are clearly defined and whether contractors are enabled to contribute from their own strengths ([P15],[P10]). This relates to 'play to everyone's strength'. Currently, chain alignment is often lacking, while frameworks for coupling opportunities between project or governance levels remain too weakly developed ([P6],[P16]). This can be observed in the discussion and phenomena of 'meekoppelkansen' (coupling opportunities), despite the fact that these opportunities are recognized, they are still difficult to realize in practice because they require coordination, financing and (shared) ownership across projects and organizations, as stated by the environmental manager ([P2]). Participants emphasized that developing markets, databases or programmatic coordination mechanisms could help reuse of material from one project in another, but these ideas are still underdeveloped ([P7],[P12]). This proofs that sustainability opportunities are not lost because they are technically impossible, but because of institutional and organizational infrastructure for linking projects, actors and resources is underdeveloped.

Additionally, a missed opportunity mentioned by the participants is related to reuse, circularity and lifespan extension strategies. In practice, there is more room for preventive maintenance, life extension and reuse of existing components, circular demolition and IFD or DOP design that is currently not optimally used ([P3],[P15],[P10]). The technical managers stated that preventive measure are not considered early enough, while maintenance and durability are undervalues compared to replacement oriented thinking ([P3],[P13]). The participants referred to material reuse as 'a neglected child', with barriers such as absence of reuse systems, material libraries and integrated coordination between demolition and new projects ([P10],[P7],[P12]). Participants also identify that there is a gap between the theoretical circular potential and the practical implementation, especially when these circular options score well on sustainability but poorly on financial calculations (e.g. the case of circular demolition) ([P11],[P12]). Additionally, a technical manager said that circularity and CO_2 are not always aligned, which means that more integrated system-level assessment is required instead of separate evaluation of each principle ([P3]). Furthermore, the untapped potential in designing for disassembly and future reuse through IFD principles, as well as in using standardization and programmatic thinking to make reuse practically feasible across projects has been brought to light by a technical manager and project manager ([P15],[P9]).

Lastly, the participants highlighted missing opportunities in organizational and informational system support. Project control managers mentioned that dashboards, central sustainability databases and accessible knowledge platforms would allow project teams to compare alternative, identify reuse opportunities and build on lessons learned from earlier projects ([P8],[P17]). Additionally, contract management, tender processes and market engagement contain much more leverage towards sustainability potential than currently is being used within W+B. Since they are all linked to programmatic and chain management approaches ([P14],[P5]). In summary, the findings show that many sustainability opportunities are already visible in practice, but remain underused since it requires coordination across project, sectors, budgets, governance levels and time horizon. Combined, the essence comes to the missed opportunities not primarily being technical,

but systemic whereas sustainability is still handled and organized at individual project level, while the largest gains lie in programmatic steering, cross-project learning, chain collaboration and integrated system-level planning. These paragraphs all explain cost, budget and economic dominance (1), fragmentation, silo thinking and lack of integration (2), knowledge, learning and capability gaps (3) and untapped potential and missed opportunities (4) as shown in Figure **??**, which is situated under '7. Missed system-level and programmatic sustainability opportunities'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q3 (source: Author)

SSIs-Q4 - Evaluation PPS-components

The second question (SSIs-Q4) focused on evaluation of the PPS-components obtained from the PMBoK project management guideline and its effectiveness on sustainability integration. Again, based on their responses, fitted dimensions were subsequently developed.

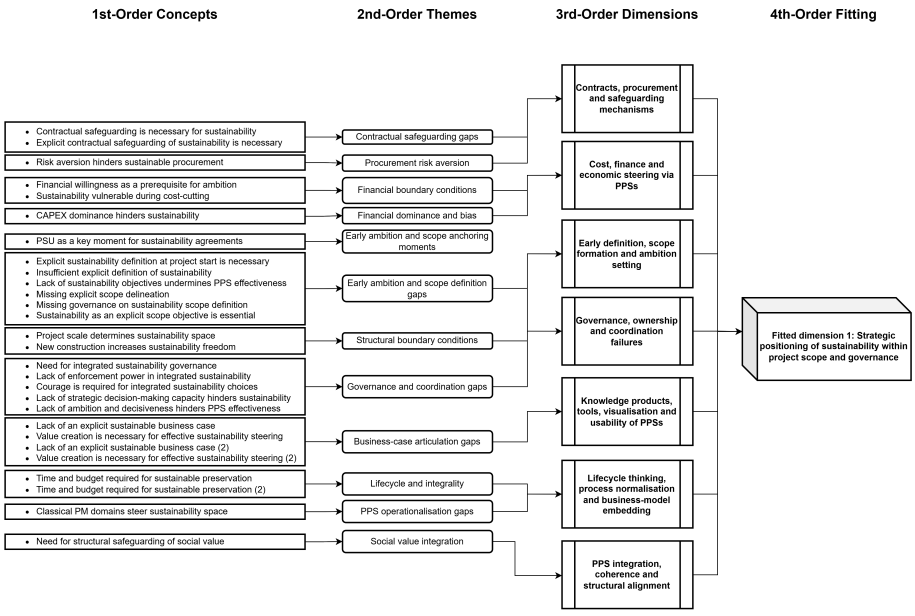
Fitted dimension 1: Strategic positioning of sustainability within project scope and governance

Fitted dimension 1 is formed based on contracts, procurement and safeguarding mechanisms (1), cost, finance and economic steering via PPSs (2), early definition, scope formation and ambition setting (3), governance, ownership and coordination failures (4), knowledge products, tools, visualization and usability of PPSs (5), LC thinking, process normalization and business-model embedding (6), PPS integration, coherence and structural alignment (7) and stakeholder PPSs, participation and social value (8), all related to the strategic positioning of sustainability within project scope and governance. A clear statement by the contract managers, was that contractual safeguarding is essential for sustainability delivery. Actors tend to deliver only what is contractually required, nothing more nothing less. Meaning that when sustainability is explicitly included in the assignment, it quickly disappears and becomes secondary ([P5],[P10]). This is increased when projects become uncertain or risky, resulting in stakeholders to go for safe and conventional choices, leading to deprioritization of sustainability ambitions ([P5]). Therefore, sustainability integration should not be only reliant on goodwill or informal intentions, but it must be formally anchored, measurable and legally bound within contractual agreements. A project leader, highlights that economic steering mechanisms within the PPS context, shape sustainability outcomes. Since sessions like the Ambitieweb session, only function when there is actual financial room and willingness to realize the ambitions defined ([P16]). A cost engineer verified that in practice, sustainability is the first aspect to be reconsidered when budgets are constrained, showing a vulnerability of sustainability integration during cost cutting processes ([P7]). Additionally, a tunnel vision focus on CAPEX rather than LC value limits sustainability choices, proving that even when sustainability is included, it remains highly depended on financial commitment ([P7]).

Also, early scope formation and ambition setting are important as leverage points for sustainability integration. A technical manager said that, the Project Start-Up phase (PSU) is a critical moment where sustainability agreements can and should be embedded ([P13]). Because, if sustainability is not made explicit at the beginning (in both terms of objectives and scope), then it erodes due to 'ambition erosion' over the course of the project ([P9]). Whereas initially, the definition of sustainability should be made clear and shared, since this is often lacking in practice ([P14]). On top of that, the unclarity of scope boundaries across organizational levels and project phases form a hurdle for the implementation of sustainability, as was stated by a project control manager ([P17]). This altogether shapes the governance gap, that in practice it is unclear who is responsible for making sure that sustainability is included and maintained within the project scope ([P1]). This is the main task for sustainability integration and for that reason anchoring sustainability within project scope management is essential, as this is where core (company or project) objectives are formally defined and safeguarded. Besides that, the potential for sustainability integration is also defined by project characteristics. Larger projects and framework contracts offer more room for sustainability discussions and integration due to their scale and

stakeholder complexity, according to a technical manager ([P13]). On the other hand, new build projects offer more flexibility compared to existing asset interventions ([P15]). Showing that sustainability is not only related to intent or capability, but also to project context and flexibility. Apart from project structures, governance and leadership shortcomings were mentioned by a technical manager highlighting that sustainability integration requires someone to maintain oversight and make trade-off across competing project objectives. This is not a lack of knowledge within W+B, it is a lack of action and decisiveness ([P3]). Including insufficient strategic decision making capacity, especially in LC based approaches (e.g. NPV or LCCA) instead of focusing only on upfront costs ([P12]). A contract manager added that sustainability integration is not often failing because it is impossible, but because it is not prioritized, mandated and courageously followed up within the governance structures ([P5]).

A practical barrier also lies in the lack of integrated knowledge products and decision support tools. A project control manager mentioned that there is no need for an entirely new project management domains, but perhaps develop tools that integrate sustainability into existing ones, for example through a for tools sustainable business case that connects scope, quality risk, resources and planning ([P8]). Furthermore, without a clear definition of sustainability, it risks to become a 'nice to have' rather than a steering principle, indicating how important it is to create value as the basis for sustainability governance ([P8]). On top of that, LC thinking and normalization of sustainability within processes is essential, since a technical manager mentioned that sustainable solutions often require additional time and budget to properly assess and utilize hidden value (e.g. residual strength), which is not always present in current project structures ([P15]). In general, sustainability remains constraint by the classical project management domains of scope, time and cost which continue to dominate decision making ([P15]). Showing that sustainability is still treated as an additional and separate task, rather than being included within core project control and management. Lastly, the findings show that stakeholder related safeguarding mechanisms are lacking, especially for long term social value. The Social Return On Investment (SROI) related benefits still require additional aspects to make sure that their long term effects are realized maintain beyond initial project delivery, according to a project leader ([P16]).In short, sustainability integration within projects is fundamental matter of institutionalization. It depends on a variety of elements as elaborated above, if these elements are absent or weak within projects, sustainability remains fragile, deprioritized and dependent on individual effort rather than systemic assurance. These paragraphs all explain contracts, procurement and safeguarding mechanisms (1), cost, finance and economic steering via PPSs (2), early definition, scope formation and ambition setting (3), governance, ownership and coordination failures (4), knowledge products, tools, visualization and usability of PPSs (5), LC thinking, process normalization and business-model embedding (6), PPS integration, coherence and structural alignment (7) and stakeholder PPSs, participation and social value (8) as shown in Figure **??**, which is situated under '1. Strategic positioning of sustainability within project scope and governance'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 1 for SSIs-Q4 (source: Author)

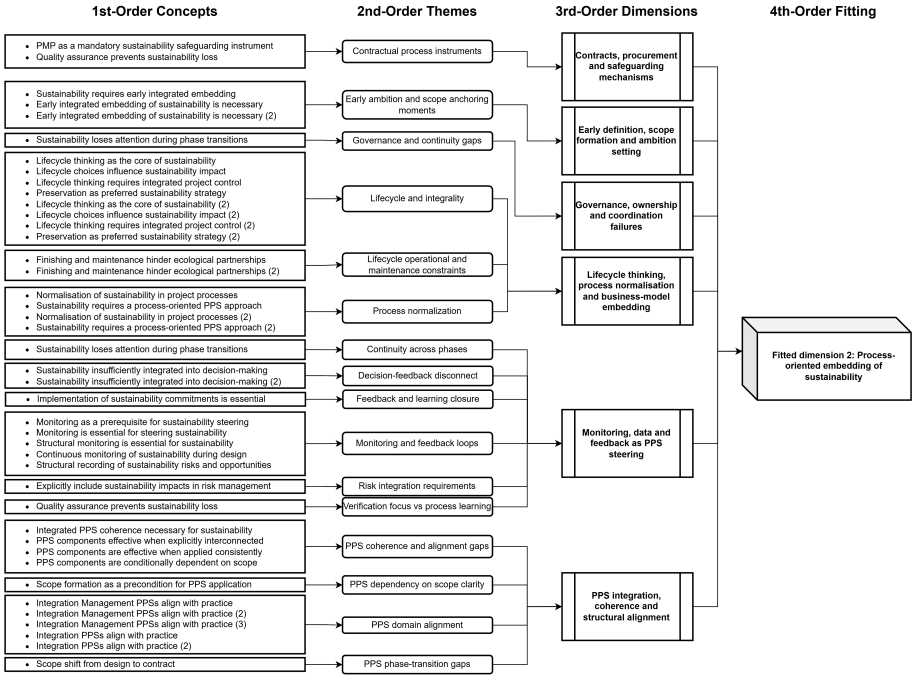
Fitted dimension 2: Process-oriented embedding of sustainability

Fitted dimension 2 is formed based on contracts, procurement and safeguarding mechanisms (1), early definition, scope formation and ambition setting (2), governance, ownership and coordination failures (3), LC thinking, process normalization and business-model embedding (4), monitoring, data and feedback as PPS steering (5) and PPS integration, coherence and structural alignment (6), all related to process-oriented embedding of sustainability. A notable aspect from a technical manager, was that the use of existing management document and control mechanisms such as the PMP was seen as a suitable place to anchor sustainability, for example by including a dedicated sustainability section in larger projects ([P13]). Within the narrative, quality assurance is not seen as a competing part, but rather as a way to prevent sustainability loss by making sure that agreed ambitions are preserved in execution and verification ([P15]).

Suggesting that sustainability can more anchored when it is linked to already institutionalized project controls instead of being treated as a separate ambition. A second topic brought to light by participants, was that early definition and embedding are essential process conditions, because topics like sustainability, operation and management and long term considerations begin in the design phase and should therefore be included from the outset of a project ([P3],[P6],[P11]). If sustainability is not taken along at the beginning, it quickly becomes something that is added too late or only partially considered ([P11]). This is even more boosted, when agreements tend to weaken during phase transitions or handovers if not clearly transferred ([P9]). Showing that processes are essential for anchoring sustainability during the FEDP of project, where ambitions, scope and long term implications are initially defined.

LC thinking is essential for sustainability integration as participants argue that sustainability should be understood in long term preservation, extended lifespan and performance across its whole LC rather than only the construction phase ([P3],[P6],[P15]). According to a technical manager, preservation is explicitly described as the highest step on the sustainability ladder ([P15]), while a cost engineer stated that small LC choices (e.g. replacement for components) can materially affect sustainability outcomes ([P12]). At the same time, sustainability should not be an isolated specialist topic, but normalized for everyone within W+B to incorporate it in their ways of working in broader project processes ([P11],[P1]). This is a challenge and remains difficult if financing and maintenance structures do not support sustainability ambitions, as noted in relation to environmental management ([P16]). This means that sustainability here requires not only technical awareness but also processes that connect design, maintenance, finance and long term value altogether. Besides this, participants highlighted that monitoring, data and feedback should be used as a core steering mechanism within W+B. A project advisor and technical manager argued that sustainability must be followed just as seriously as planning and budget if it is to remain visible and steerable during projects ([P11],[P6]). If sustainability is not measured, monitored or recorded, then it will disappear from view ([P6],[P8],[P9]). This indicates the need for continuous monitoring during design (e.g. through dashboards like +CD Tool) as well as recording of risks (e.g. risk registers) and opportunities (e.g. opportunity lists) related to sustainability ([P4],[P8]). A project control manager emphasized that risk management has big potential in realizing sustainability impacts more explicitly, as is done by Wong, 2024 ([P8]). Thus, process oriented embedding is not only about setting ambitions, but also about creating feedback loops that keep those ambitions active throughout project development and implementation ([P10],[P15]).

Lastly, the participants expressed real value in the PPS coherence and structural alignment across all 10 project management domains when shown Table 3.35, especially within Project Integration Management. A project control manager commented that sustainability only works when PPS-components are viewed in relation to one another and explicitly connected to value, risk and business logic ([P8]). A contract manager highlighted procurement techniques and tools (e.g. sustainable purchasing (Stichting Nationale Milieudatabase, 2020), contractual metrics, incentives and stakeholder engagement are useful, but only when they are applied consistently and in an integrative way ([P10]). Other participants explicitly recognized the relevance of integration management instruments (e.g. Project Charter, Project Management Plan, Sustainable Management Plan) as logical places to anchor and safeguard sustainability in practice ([P3],[P9],[P11],[P18]). At the same time, Project Scope Management is still decisive in sustainability integration, the PPS-components mentioned in Table 3.35, only become effective when sustainability is explicitly anchored in the project scope. As a project leader and project control manager mentioned that scope creep and expansion can occur over the project timeline (e.g. from design to contract phase) which creates shifts and impact sustainability ambitions and integration ([P1],[P17]). These paragraphs all explain contracts, procurement and safeguarding mechanisms (1), early definition, scope formation and ambition setting (2), governance, ownership and coordination failures (3), LC thinking, process normalization and business-model embedding (4), monitoring, data and feedback as PPS steering (5) and PPS integration, coherence and structural alignment (6) as shown in Figure **??**, which is situated under '2. Process-oriented embedding of sustainability'.

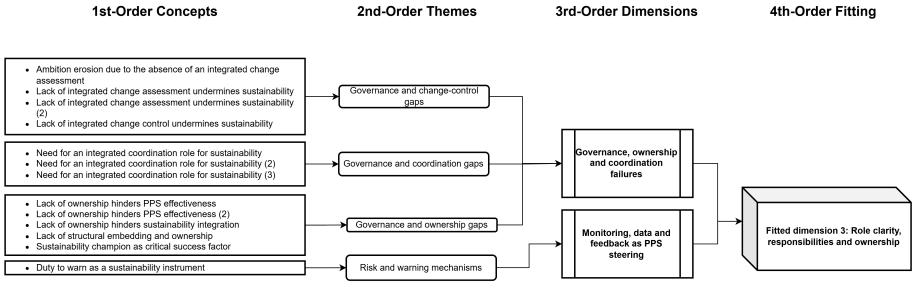


Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 2 for SSIs-Q4 (source: Author)

Fitted dimension 3: Role clarity, responsibilities and ownership

Fitted dimension 3 is formed based on governance, ownership and coordination failures (1) and monitoring, data and feedback as PPS steering (2), both related to role clarity, responsibilities and ownership. As mentioned earlier, a concert for the first one is that sustainability ambitions erode during project (scope) changes. Participants commented that every change or adjustment within a project, results in sustainability shifting backwards in priority or is even the first aspect to be sacrificed ([P11],[P6],[P9]). Whereas the observation of a technical manager enforces this, stating that each small decision shifting away, gradually counts up to undermine sustainability outcomes over time ([P3]). This put an emphasis on the need of a strong integrated change control and assessment, where sustainability is safeguarded when trade-offs are made. Besides that, clear coordination and integrative oversight is missing, since a technical manager said that without someone actively maintaining the overview and safeguarding coherence, sustainability risks 'falling between between two stools' ([P11]). Even the project advisor verified that there is a need for coordinating person, who monitors the interdependencies and ensures alignment across teams as it is explicitly mentioned as a key condition for maintaining sustainability ambitions throughout the project LC ([P6]). This shows that sustainability integration is not something that gets done naturally within the organization, but requires (pro)active governance through coordination roles and mechanisms.

As mentioned earlier, again here the lack of ownership and accountability on sustainability is present. A project manager stated that sustainability is not clearly assigned to a specific individual or role, it remains non committal and therefore loses priority in practice ([P9]). Someone must be explicitly responsible and actively steer on sustainability, otherwise ambitions will dilute over time ([P10],[P11]). In addition, when sustainability is not embedded in processes, it remains vulnerable to shifting priorities and external pressures ([P6]). Thus, embedding is effective when both formal ownership and procedural anchoring are in place. Not only is ownership a formal issue, but also a matter of leadership. A project leader pointed out that it is of importance to have an individual who is motivated and an influential sustainability champion who drives the agenda and has sufficient authority to steer on decisions ([P16]). This is a critical success factor in practice, since the governance structure on its own is insufficient without such an individual who takes initiative and maintains sustainability. Again, monitoring and advisory responsibilities also seem to be part of governance and ownership within this dimension, as a cost engineer mentioned that a 'duty to warn' helps on how project team members actively signal risks and provide advice when sustainability is at stake ([P12]). Through expert judgment and feedback loops, the responsibilities of individuals extend beyond their basic tasks to actively safeguard sustainability. In short, sustainability integration depends on clear role allocation, explicit ownership and continuous coordination across project processes, without these elements sustainability ambitions are prone to erosion during changes and fragment across responsibilities and eventually loses its priority. These paragraphs all explain governance, ownership and coordination failures (1) and monitoring, data and feedback as PPS steering (2) as shown in Figure **??**, which is situated under '3. Role clarity, responsibilities and ownership'.

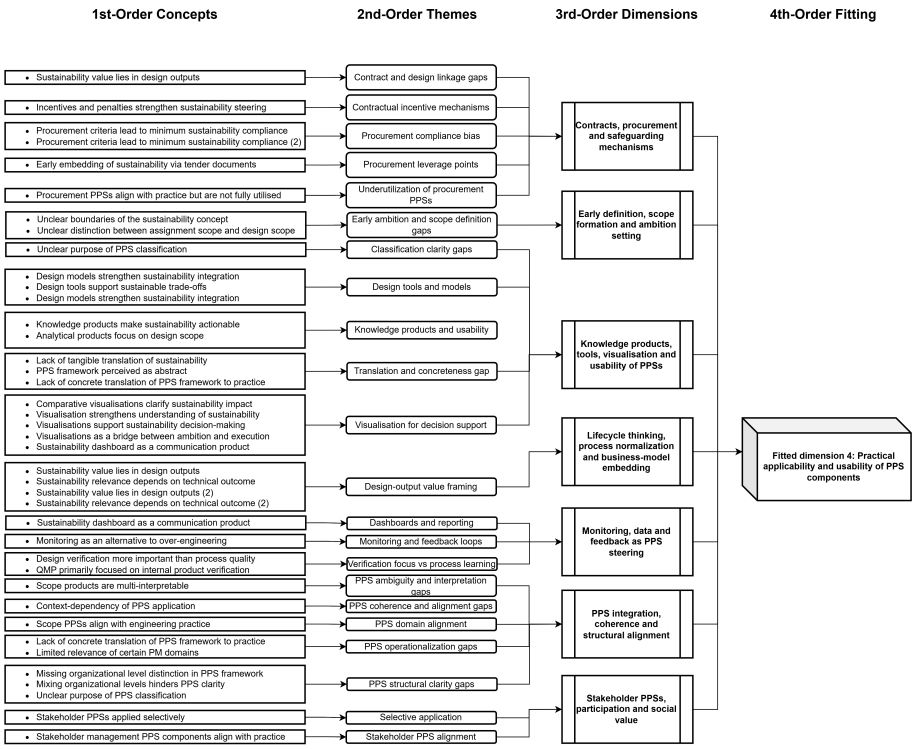


Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 3 for SSIs-Q4 (source: Author)

Fitted dimension 4: Practical applicability and usability of PPS components

Fitted dimension 4 is formed based on contracts, procurement and safeguarding mechanisms (1), early definition, scope formation and ambition setting (2), Knowledge products, tools, visualization and usability of PPSs (3), LC thinking, process normalization and business-model embedding (4), monitoring, data and feedback as PPS steering (5), PPS integration, coherence and structural alignment (6) and stakeholder PPSs, participation and social value (7), all related to practical applicability and usability of PPS-components. The first insight from the findings show that the in practice the design phase is seen as the primary leverage point for sustainability, instead of the procurement phase alone. A project control manager indicated that the real sustainability gains are achieved in design outputs (from the structural engineer and designer), where choices directly shape long term impact ([P17]). Showing that procurement and contractual aspects should not be treated separately, but instead be used as instruments to steer and safeguard (sustainable) design decisions. Another notable statement of the contract managers, was that without incentives, sustainability keeps being voluntary. The absence of a reward or penalty mechanism leads to situations where sustainability is treated just option rather than integral ([P10]). In fact, organizations and contractors tend to do only what is required to comply, but do not go beyond minimum criteria in practice ([P5], [P10]). This shows that procurement frameworks mainly focusing on compliance based criteria, may end up with minimum performance behavior instead of competitiveness and ambitions.

During the FEDP, the early stage procurement procedures can play a positive role when properly used to its advantage within W+B. A technical manager mentioned that sustainability is already anchored in some cases through tender documents, templates and predefined design principles (e.g. IFD or DOP), which allows to be addressed at the FEDP of infrastructural projects ([P13]). Therefore, procurement can function as an early safeguarding technique, when sustainability requirements are defined and operationalized from the outset. Additionally, participant recognized that the shown PPS related instruments in Table 3.35 within procurement (e.g. sustainable procurement practices, MEAT criteria, contractual metrics and sustainable contract management) are in principle effective ways to incorporate sustainability ([P5]). The main issue is not the absence, but the inconsistent and incomplete application in practice, whereas this gap reveals a broader implementation challenge, since sustainability is possible within procurement but not yet systematically leveraged to W+B's advantage. In short, contract and procurement mechanisms currently function as a baseline compliance tool rather that drivers for sustainability ambition which can be transformed by tackling the three conditions; linking them to design outcomes, embedding incentives and accountability structures and ensuring consistent application throughout the project LC. These paragraphs all explain contracts, procurement and safeguarding mechanisms (1), early definition, scope formation and ambition setting (2), Knowledge products, tools, visualization and usability of PPSs (3), LC thinking, process normalization and business-model embedding (4), monitoring, data and feedback as PPS steering (5), PPS integration, coherence and structural alignment (6) and stakeholder PPSs, participation and social value (7) as shown in Figure **??**, which is situated under '4. Practical applicability and usability of PPS components'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 4 for SSIs-Q4 (source: Author)

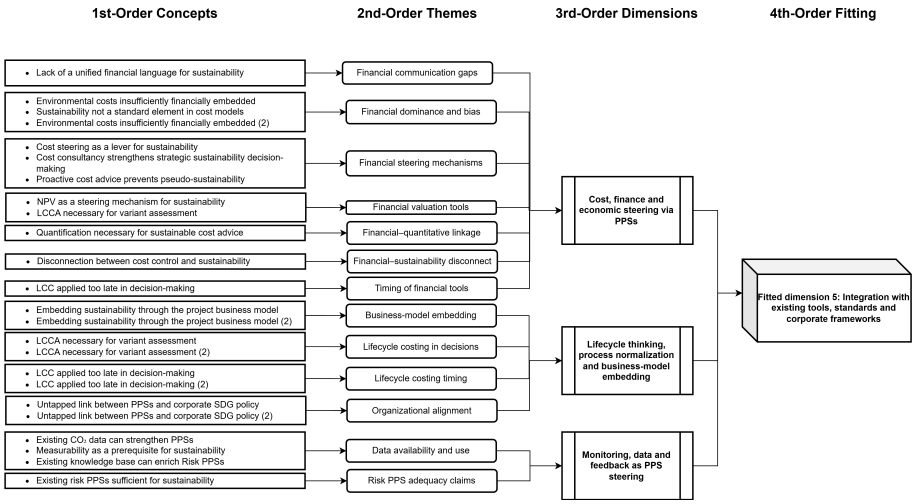
Fitted dimension 5: Integration with existing tools, standards and corporate frameworks

Fitted dimension 5 is formed based on cost, finance and economic steering via PPSs (1), LC thinking, process normalization and business-model embedding (2) and monitoring, data and feedback as PPS steering (3), all related to the integration with existing tools, standards and corporate frameworks. A repeated aspect was that sustainability is only taken serious when it is expressed in financial terms. A cost engineer mentioned that sustainable alternative gain traction only when they become comparable within standard cost assessments. Currently this is not the case, whereas environmental impacts are known like emissions, but not incorporated as costs or included in standard calculations ([P7]). Meaning that as a result of this, sustainability is still an external aspect to financial decision making. This leads to a disconnect between cost control and sustainability considerations, being completely separated from each other. As the cost engineer added to it, that without integration into financial models, sustainability is not a decision criteria but instead an additional consideration, which is often overridden when trade-offs are made ([P7]).

Transparency is valued within project teams and towards stakeholders, this is emphasized by the cost engineer meaning that financial transparency can act as a powerful steering technique. If sustainability impacts are made financially explicit, then it can influence or even force decision making ([P7]). This indicates the role of cost-based PPS-components as potential leverage for sustainability integration. Several aspects are identified and discussed with the participants, to create this such as cost consultancy for green procurement, which supports objective comparison of design variants, avoids misleading cost perceptions and integrates sustainability into strategic decision making using LCCA and NPV analogy ([P12]). Similarly proactive cost advice helps to prevent 'false sustainability' by assessing assumptions behind material and execution choices ([P12]). Therefore, these techniques can be used to bridge the gap between sustainability ambitions and financial decision making. However, often these techniques are applied too late in the process, for example LCCA insights are introduced after key design decisions are made, which limits the influence the technique ([P7]). The timing of this financial evaluation in earlier project phases can lead to better outcomes.

Additionally, a cost engineer highlights the importance of quantification and measurability. This has to do with making sustainability into tangible and cost related metrics which allows for better advisory and comparison between alternatives ([P12]). Lacking quantification goes hand in hand with abstract sustainability and difficulty incorporating it within economic approaches. Aside from project level calculations, on a broader organizational and strategic level, the embedment of sustainability is still a challenge. Regardless of existing tools like sustainability focused business model canvas ([P8]) and links to internal W+B's SDGs strategies ([P14]), these are not integrated yet into PPS driven decision making. Another point to note is that data availability is not a primary constraint. Since CO_2 data and existing knowledge bases are already present within W+B ([P17]), besides that measurement is recognized as essential for maintaining trust and steering ([P8]). A main challenge related to this lies in embedding this data into financial and decision making structures, making sure it informs trade-offs rather than remaining descriptive. In short, there are current tools that exist for economic steering on sustainability (integration), but their impact is limited because of lack of integration into financial logics, applied late in project phases and is insufficiently translating sustainability into economic metrics for decision making. These paragraphs all explain cost, finance and economic steering via PPSs (1), LC thinking, process normalization and business-model embedding (2) and monitoring, data and feedback as PPS steering (3) as shown in Figure **??**, which is situated under

’5. Integration with existing tools, standards and corporate frameworks’.

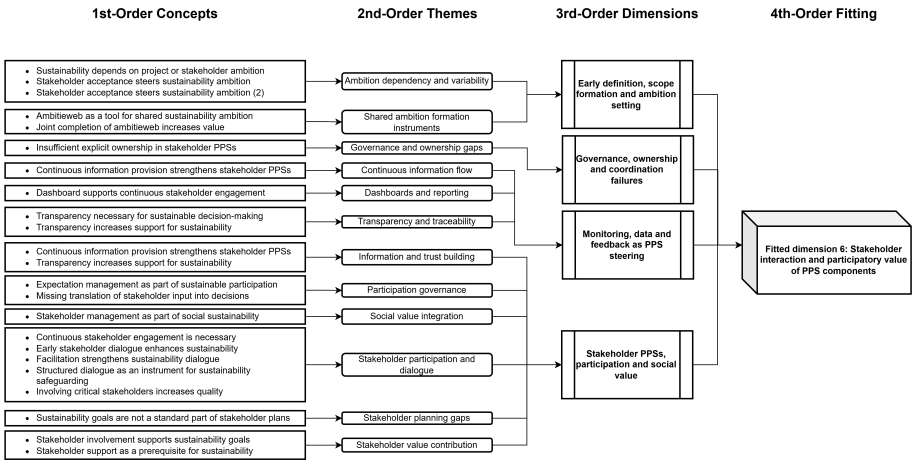


Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 5 for SSIs-Q4 (source: Author)

Fitted dimension 6: Stakeholder interaction and participatory value of PPS-components

Fitted dimension 6 is formed based on early definition, scope formation and ambition setting (1), governance, ownership and coordination failures (2), monitoring, data and feedback as PPS steering (3) and stakeholder PPSs participation and social value (4), all related to stakeholder interaction and the participatory value of PPS components. A notable pattern from the findings was that sustainability only becomes dominant when it is explicitly driven by either project objectives or stakeholder ambitions. Sustainability surfaces mainly when it strongly included in the project goal or actively pushed by the involved stakeholders ([P16]). If these drivers are not present, then it becomes secondary, meaning that sustainability in practice is not yet structurally anchored in early project definition, but rather dependent on circumstances. Furthermore, the contract managers commented that, what is considered acceptable by the environment (which emphasizes scope boundaries importance), determines how far sustainability ambitions can go ([P5],[P10]). Therefore, ambition setting is not only an internal project decision, but also a negotiated outcome during project development on a social and political level meeting stakeholder expectations. All of this, indicates that sustainability ambitions is often bounded rather than maximized (if not clearly defined at an early stage). A process that is helpful for this, is the Ambitieweb sessions for creating alignment on sustainability ambitions early on ([P13]). However, a project leader emphasized that the effectiveness of these session depend on how they are performed. These tools like the Ambitieweb gain value only when they are created together with the stakeholder, instead of applied separate ([P16]). This indicates that early ambition setting is a collaborative and shared process, instead of a technical and internal exercise. At the same time, despite doing this collectively, the environmental manager commented that there still exists a lack of explicit ownership in translating stakeholder input into concrete scope decisions. On top of that, responsibility for collecting, processing and integrating stakeholder input are unclear, which leads to fragmentation and reduced impact and weakens the link between early ambition setting and project scop definition ([P2]).

In order to steer it is essential to engage and create transparency between involved stakeholders for maintaining alignment between their ambitions and project execution. Participants mentioned that techniques like ongoing stakeholder communication, dashboard and clear justification of decisions help to sustain involvement and support ([P4],[P5],[P10]). These techniques helps to make sure that early ambitions are not only documented or formulated, but also supported throughout the project LC. Lastly according to an environmental manager, ambitions setting also requires more than initial consultation, since it depends on continuous participation, early dialogue and integration of stakeholder input into decision making ([P2]). Not doing so, means that participation is just symbolic rather than sincere. So, involving the stakeholder, including their critical voices, improves the value and reliability of sustainability ambitions ([P16]). In short, early sustainability ambitions are not incorporated with the discussed PPS-components Table 3.35, but is moreover shaped by stakeholders, context and presence or absence of clear ownership and participatory processes. These paragraphs all explain early definition, scope formation and ambition setting (1), governance, ownership and coordination failures (2), monitoring, data and feedback as PPS steering (3) and stakeholder PPSs participation and social value (4) as shown in Figure **??**, which is situated under ’6. Stakeholder interaction and participatory value of PPS components’.

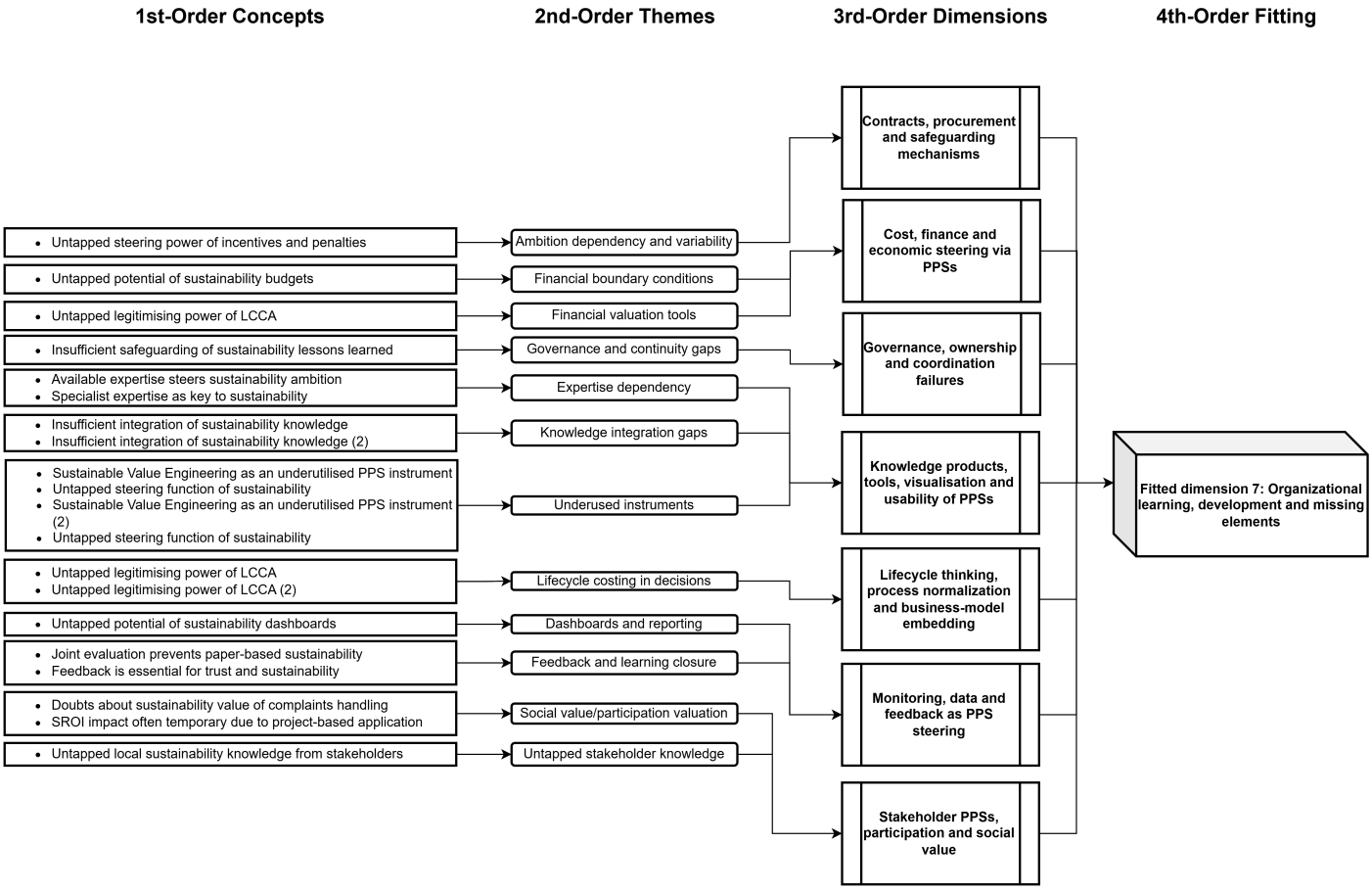


Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 6 for SSIs-Q4 (source: Author)

Fitted dimension 7: Organizational learning, development and missing elements

Fitted dimension 7 is formed based on contracts, procurement and safeguarding mechanisms (1), cost, finance and economic steering via PPSs (2), governance, ownership and coordination failures (3), knowledge products, tools, visualization and usability of PPSs (4), LC thinking, process normalization and business-model embedding (5), monitoring, data and feedback as PPS steering (6) and stakeholder PPSs, participation and social value (7), all related to organizational learning, development and missing elements. A relevant aspect mentioned is the untapped potential of incentive structures as a governance mechanism within W+B. A contract manager mentioned this, making clear that sustainability performance could be more effective if a system of reward and accountability was included (e.g. contractual incentives and penalties) which can shift behavior from compliance to performance-driven sustainability ([P5]). Additionally, financial resources do exist, but not always made available ([P5]). Meaning that the barrier this creates is not only due to financial scarcity, but rather a lack of prioritization over available budgets. Parallel to this, it is recognized a cost engineer, that economic methods such as LCCA, have strong legitimizing power. Implying that if sustainability is properly quantified and calculated through, it proves with evidence to be the most logical option ([P7]). This shows that the main challenge is not about proving the value of sustainability, but lies more in systemic integration of these calculations into decision making processes.

In terms of organizational learning and knowledge transfer, a project manager identified that although project generate valuable sustainability insights. The gained lessons of these projects are insufficiently transferred to future projects ([P9]), showing a lack of structural mechanisms for capturing, safeguarding and reusing knowledge, which prevents continuous learning and improvement. In order to capture relevant information from projects, which is related to this, the sustainability performance is also dependent on who is involved in the project and what expertise is available (group or project team capacity) ([P8]). A technical manager mentioned that senior structural engineer tend to unlock more advanced sustainability opportunities, such as leveraging hidden structural capacity of a structure or project ([P15]). In practice, the technical manager mentioned that even existing knowledge is not always accessed or integrated into practice ([P3]), even when PPS components (e.g. Sustainable Value Engineering), as shown in Table 3.35, are recognized as valuable, they are still not structurally incorporated in project routines ([P7]). A project manager emphasized that these components can help to achieve a greater potential and improve decision making than is currently done ([P9]), which reflects an implementation gap. A cost engineer LC thinking which is part of the LCCA technique, helps to provide a strong and rational base for sustainable choices, but remains underused in practice ([P7]). Showing that LC based financial reasoning is recognized, but not yet normalized within standard operating procedures (SOP) of project development. Lastly, to close the loop between ambition, execution and learning, the designer suggested that joint evaluation is seen as a crucial way to prevent sustainability from remaining a paper ambition, by actively reviewing progress and implementation together ([P18]). In the collaborative narrative, it is also appreciated by stakeholders, to provide them feedback when things are done with their input, as is mentioned by the environmental manager ([P2]). Not only does this create trust, but also fosters engagement which boosts potential sustainability outcomes. In short, the findings indicate that a wide range of the PPS-components, as shown in Table 3.35, exists across various elements (e.g. contracts, finance, knowledge and monitoring) of which the impact is limited due to different causes (e.g. active behavior, weak integration and insufficient organizational learning within W+B). The problem here is not the absence of tools, but the need to incorporate them structurally and connect them integrative with consistent application across the projects and different teams/divisions. These paragraphs all explain contracts, procurement and safeguarding mechanisms (1), cost, finance and economic steering via PPSs (2), governance, ownership and coordination failures (3), knowledge products, tools, visualization and usability of PPSs (4), LC thinking, process normalization and business-model embedding (5), monitoring, data and feedback as PPS steering (6) and stakeholder PPSs, participation and social value (7) as shown in Figure **??**, which is situated under '7. Organizational learning, development and missing elements'.



Extended Gioia methodology application and its corresponding levels in order to obtain fitted dimension 7 for SSIs-Q4 (source: Author)

FD	(SSIs-Q1)	(SSIs-Q2)	(SSIs-Q3)	(SSIs-Q4)
FD 1	Project context and role positioning	Integrating sustainability in design and decision-making processes	Underutilized sustainable design and technical opportunities	Strategic positioning of sustainability within project scope and governance
FD 2	Project leadership and project control	Quantifying and substantiating sustainability	Insufficient quantification and valuation of sustainability	Process-oriented embedding of sustainability
FD 3	Stakeholder and environmental management	Embedding sustainability through processes and project structures	Sustainability insufficiently embedded in processes and governance	Role clarity, responsibilities and ownership
FD 4	Contracting and procurement / tendering	Stakeholder- and participation-oriented sustainability	Governance, client behavior and institutional barriers	Practical applicability and usability of PPS components
FD 5	Engineering, design and data	Advisory and signaling role in sustainability	Advisory potential and proactive sustainability roles	Integration with existing tools, standards and corporate frameworks
FD 6	Organization, strategy and knowledge development	Organizational and knowledge-driven sustainability	Lack of knowledge sharing, learning and standardization	Stakeholder interaction and participatory value of PPS components
FD 7	Quality and assurance / testing	Constraints and boundary conditions in current practice	Missed system-level and programmatic sustainability opportunities	Organizational learning, development and missing elements

FD = Fitted Dimension

Overview of the fitted themes across the four interview questions (source: Author).

The analysis consists of 28 themes and 4 questions, with each question containing 7 themes. These themes can be visualized in ATLAS.ti using the Code–Document Analysis tool, either as a Sankey diagram or a table. The initial diagram is difficult to interpret, as it potentially displays 486 connections (18 participants × 28 themes. Therefore, a table was used instead, supported by a heatmap that illustrates the relative intensity of associations between (sub)codes, themes and participants, as shown in Table C.1. It presents the most relevant question and its corresponding theme. From this heatmap visualization, it becomes clear that the following items are of particular interest for further elaboration within the scope of this study:

- (SSIs-Q3) Which sustainability opportunities do you see that are currently not being utilized?
  - Theme 1: Underutilized sustainable design and technical opportunities
  - Theme 4: Governance, client behavior and institutional barriers
  - Theme 6: Lack of knowledge sharing, learning and standardization
  - Theme 7: Missed system-level and programmatic sustainability opportunities
- (SSIs-Q4) The attached document includes PPS components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?
  - Theme 1: Strategic positioning of sustainability within project scope and governance
  - Theme 2: Process-oriented embedding of sustainability
  - Theme 5: Integration with existing tools, standards and corporate frameworks
  - Theme 7: Organizational learning, developments and missing elements

The process leading up to the creation of the heatmap depends on the aggregation model applied to the raw data derived from the transcripts, this participant quotations. This aggregation workflow has been visualized in Figure **??**, which leads to the overall themes/clusters as provided in Table **??**.

Theme	SSIs-P01-PL-6/10	SSIs-P02-OM-6/10	SSIs-P03-TM->10	SSIs-P04-DA-0/5	SSIs-P05-CM->10	SSIs-P06-PA->10	SSIs-P07-CE->10	SSIs-P08-PC-6/10	SSIs-P09-PM->10	SSIs-P10-CM-6/10	SSIs-P11-TM->10	SSIs-P12-CE-0/5	SSIs-P13-TM-6/10	SSIs-P14-MPB->10	SSIs-P15-TM->10	SSIs-P16-PL->10	SSIs-P17-MPB->10	SSIs-P18-BIM->10	Total
(SSIs-Q1) FD 1	3	2	5	3	3	2	4	6	3	4	3	4	4	3	2	4	6	4	65
(SSIs-Q1) FD 2	3	1	3	0	1	2	0	1	1	0	3	1	1	5	2	5	6	0	35
(SSIs-Q1) FD 3	0	9	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	2	17
(SSIs-Q1) FD 4	0	0	0	0	9	0	2	1	1	5	0	2	0	0	0	1	2	0	23
(SSIs-Q1) FD 5	0	1	1	3	0	2	2	1	1	0	2	2	3	1	5	0	0	6	30
(SSIs-Q1) FD 6	1	0	1	3	0	4	1	1	0	0	0	0	4	1	0	1	0	0	17
(SSIs-Q1) FD 7	1	0	0	0	0	0	1	0	0	0	2	2	0	1	0	0	0	0	7
(SSIs-Q2) FD 1	3	1	8	2	2	3	1	0	1	3	5	2	5	1	6	0	2	1	46
(SSIs-Q2) FD 2	2	0	1	5	0	1	4	0	3	1	3	6	2	0	1	1	4	0	34
(SSIs-Q2) FD 3	3	1	1	3	3	3	2	2	5	2	3	1	1	4	3	2	7	1	47
(SSIs-Q2) FD 4	1	4	0	1	0	2	0	0	1	0	1	0	1	0	2	7	0	1	21
(SSIs-Q2) FD 5	1	1	2	0	6	0	3	1	1	1	2	4	0	1	2	2	2	3	32
(SSIs-Q2) FD 6	0	0	2	4	1	6	0	0	1	5	0	0	4	3	7	3	2	1	39
(SSIs-Q2) FD 7	0	0	2	0	1	1	1	3	1	4	1	2	1	8	4	1	5	7	42
(SSIs-Q3) FD 1	0	1	8	0	1	0	4	1	1	4	2	2	3	0	5	0	1	7	40
(SSIs-Q3) FD 2	1	1	4	0	0	1	3	2	1	0	2	5	0	0	1	0	2	1	24
(SSIs-Q3) FD 3	3	1	0	0	0	2	1	2	2	1	3	0	2	3	1	0	6	1	28
(SSIs-Q3) FD 4	3	1	2	0	4	2	1	3	0	1	2	0	1	1	3	7	2	1	34
(SSIs-Q3) FD 5	0	1	0	3	0	0	0	0	1	0	0	1	0	1	0	4	0	0	11
(SSIs-Q3) FD 6	8	6	18	9	8	8	10	9	8	10	10	10	12	8	14	12	14	14	188
(SSIs-Q3) FD 7	1	1	2	2	3	3	2	1	2	3	0	2	4	3	4	3	1	2	39
(SSIs-Q4) FD 1	5	0	2	0	1	1	2	4	2	0	2	2	2	6	1	2	2	0	34

Sankey diagram

Another result was the Sankey diagram which visualizes how all 18 interview participants are connected to the 28 themes that emerged across the four interview questions, each of which generated seven themes. In the diagram, each participant is represented on one side and each theme on the other, with the green flows indicating which themes were coded in each participant's transcript. The density and thickness of the lines make it possible to see which themes recur most frequently and which are more participant-specific, thereby highlighting patterns of convergence and divergence in the data. This figure (obtained from the Code-Document Analysis feature) thus serves as a compact overview of the coding structure, showing the breadth of thematic coverage per participant and shows how the thematic framework was applied consistently throughout the dataset.

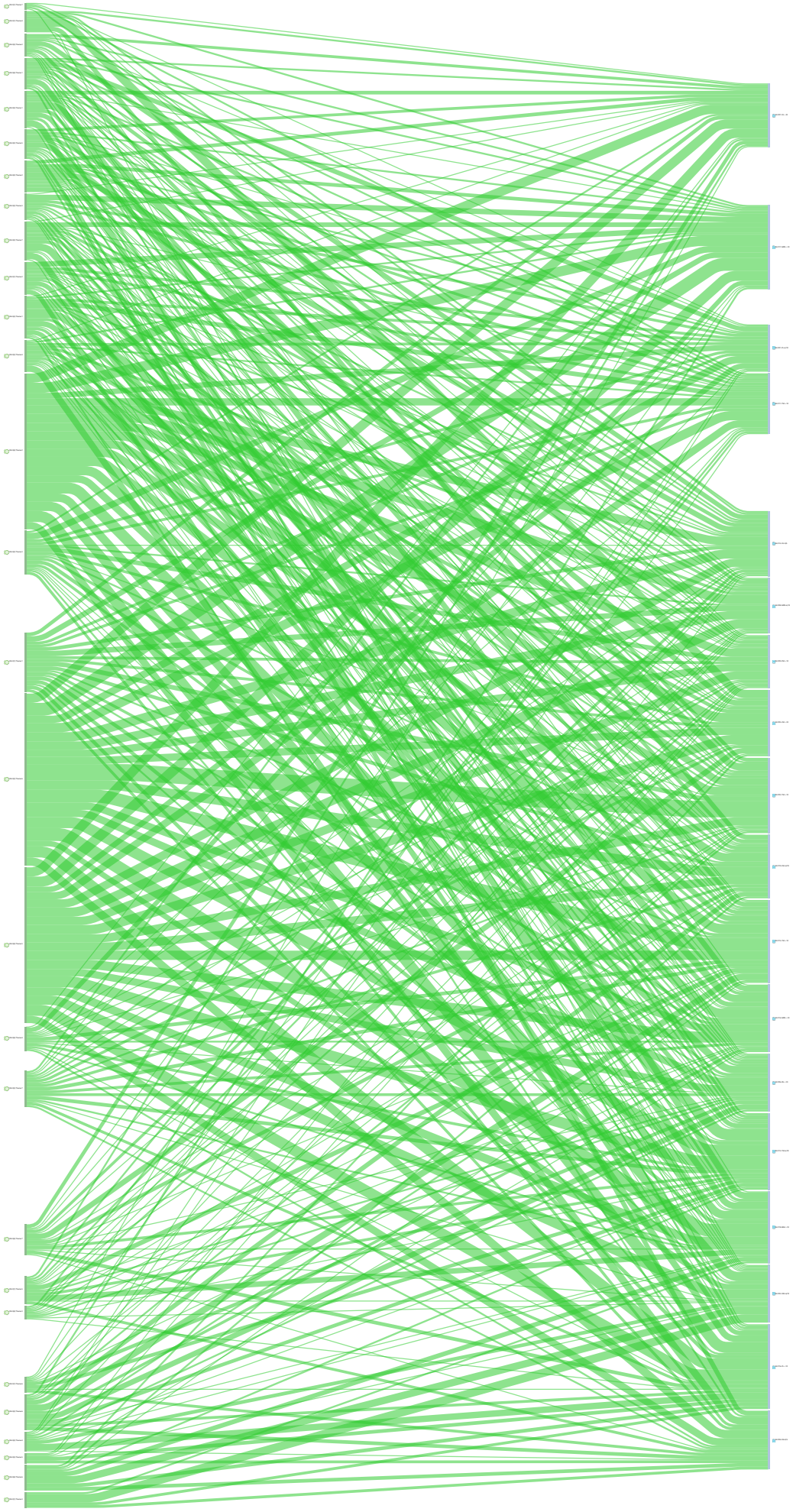


Figure C.1: Sankey diagram of all themes and participants in ATLAS.ti (Author)

At first glance, the diagram may appear dense and difficult to interpret, which is understandable. By clustering the data into broader categories and reviewing it once more, the most relevant subtopics for this study become more apparent. To facilitate this process, a table was created for each theme, listing all subcodes linked to the corresponding participant statements or quotations, after which they were categorized again. This procedure aligns with the data analysis approach described in the previous chapter.

Table

Before this thematically table is done, another strong feature of ATLAS.ti is the Table function, instead of the Sankey diagram. This table uses a heatmap visualization which indicates relative intensity of code associations (with themes) rather than statistical correlation coefficients, with darker shading indicating higher frequencies of co-occurrences between participants and questions with related themes. Do note, Figure C.2 is turned compared to the one the in the actual report.

	65	35	17	23	30	17	7	46	34	47	21	32	39	42	40	24	28	34	11	26	39	34	27	14	26	15	28	33	Totals
1: IM-P01-... 30	3	3				1	1	3	2	3	1	1				1	3	3		8	1	5	6			6			51
2: IM-P02-... 32	2	1	9		1			1		1	4	1			1	1	1	1	1	6	1		10	1		10	8	1	62
3: IM-P03-... 50	5	3			1	1		8	1	1		2	2	2	8	4		2		18	2	2	9		1	9		1	82
4: IM-P04-... 38	3		3		3	3		2	5	3	1		4						3	9	2		8		2	8	4	1	64
5: IM-P05-... 39	3	1		9				2		3		6	1	1	1			4		8	3	1	10		1	10	2	6	72
6: IM-P06-... 38	2	2			2	4		3	1	3	2		6	1		1	2	2		8	3	1	8	2	1	8		1	63
7: IM-P07-... 40	4			2	2	1	1	1	4	2		3		1	4	3	1	1		10	2	2	10		1	10		4	69
8: IM-P08-... 35	6	1		1	1	1				2		1		3	1	2	2	3		9	1	4	10	1		10		1	60
9: IM-P09-... 32	3	1		1	1			1	3	5	1	1	1	1	1	1	2		1	8	2	2	9	2	1	9			57
10: IM-P10... 38	4			5				3	1	2		1	5	4	4		1	1		10	3		9	1		9	2	4	69
11: IM-P11... 40	3	3			2		2	5	3	3	1	2		1	2	2	3	2		10		2	8	2	1	8		1	66
12: IM-P12... 44	4	1		2	2		2	2	6	1		4		2	2	5			1	10	2	2	9	1	1	9		3	71
13: IM-P13... 49	4	1			3	4		5	2	1	1		4	1	3		2	1		12	4	2	12	1	3	12	2	3	83
14: IM-P14... 42	3	5			1	1	1	1		4		1	3	8			3	1	1	8	3	6	10	1	2	10			73
15: IM-P15... 52	2	2			5			6	1	3	2	2	7	4	5	1	1	3		14	4	1	10	1	4	10	1	1	90
16: IM-P16... 52	4	5	3	1		1			1	2	7	2	3	1				7	4	12	3	2	12	1	1	12	4	4	92
17: IM-P17... 57	6	6		2				2	4	7		2	2	5	1	2	6	2		14	1	2	11		5	11		1	92
18: IM-P18... 48	4		2		6			1		1	1	3	1	7	7	1	1	1		14	2		9		2	9	5	1	78
Totals	65	35	17	23	30	17	7	46	34	47	21	32	39	42	40	24	28	34	11	188	39	34	170	14	26	170	28	33	1294

Figure C.2: Table intensity of associations of all themes and participants in Atlast.ti (Author)

As can be seen in Table 4.4, some fitted dimensions (rows) for SSIs-Q3 (underutilized opportunities) and SSIs-Q4 (PPS-components) are highlighted. In this research, the selection of the fitted dimensions is based on the principle that at least 50% of the collected data must be analyzed. This approach was applied to both questions, out of the 7 available fitted dimensions, 4 were selected, which exceeds the required minimum. Additionally, the top 4 largest fitted dimensions (the dimensions to which the highest number of quotations were linked in ATLAS.ti, see summation at the most right column) were selected for further analysis, making sure that the analysis focuses on the most relevant data. From this heatmap visualization in Table 4.4, it becomes clear that the following fitted dimensions are of particular interest for further elaboration within the scope of this study:

- (SSIs-Q3) Which sustainability opportunities do you see that are currently not being utilized?
  - Fitted Dimensions 1: Underutilized sustainable design and technical opportunities
  - Fitted Dimensions 4: Governance, client behavior and institutional barriers
  - Fitted Dimensions 6: Lack of knowledge sharing, learning and standardization
  - Fitted Dimensions 7: Missed system-level and programmatic sustainability opportunities
- (SSIs-Q4) The attached document (see Table 3.35) includes PPS components that were identified in advance as promising for sustainability integration. What is your view on these? Do you think anything is missing from a practical perspective?
  - Fitted Dimensions 1: Strategic positioning of sustainability within project scope and governance
  - Fitted Dimensions 2: Process-oriented embedding of sustainability
  - Fitted Dimensions 5: Integration with existing tools, standards and corporate frameworks
  - Fitted Dimensions 7: Organizational learning, developments and missing elements

D

Multi-Criteria Decisions Analysis (MCDA)

This appendix contains all the results regarding the scoring of the Multi-Criteria Decision Analysis (MCDA), using Python. These are all shown per PM-domain:

1. Project Integration Management
2. Project Scope Management
3. Project Time Management
4. Project Cost Management
5. Project Quality Management
6. Project Resource Management
7. Project Communications Management
8. Project Risk Management
9. Project Procurement Management
10. Project Stakeholder Management

The 10 PM domains are examined individually using the same procedure, while the following decomposition of PPS-components associated with each opportunity is identified, as shown in Table D.2:

Nr.	PM-domain	Product	Process	Service	Total
1	Project Integration Management	17	17	11	45
2	Project Scope Management	13	9	10	32
3	Project Time Management	8	9	5	22
4	Project Cost Management	9	8	7	24
5	Project Quality Management	11	12	12	35
6	Project Resource Management	8	7	8	23
7	Project Communications Management	10	10	11	31
8	Project Risk Management	9	11	10	30
9	Project Procurement Management	10	9	9	28
10	Project Stakeholder Management	11	13	11	35
	TOTAL	**106**	**105**	**94**	**305**

Table D.2: Number of identified sustainability integration opportunities across the 10 PM-domains and corresponding division into PPS-components (source: Author).

These findings of opportunities, both theoretical (PMBoK) and practical (SSIs), are all analyzed an assessed using the Weighted Sum Model (WSM) applied in this MCDA, defined as:

$$V(a) = \sum_{i=1}^{n} w_i \cdot s_i(a)$$

Where:

- $V(a)$ = Total weighted score of sustainability integration potential of an opportunity a related to a corresponding PPS-component within a PM-domain
- w_i = Weight of criterion i
- $s_i(a)$ = Score assigned to opportunity a on criterion i
- Each criterion is scored on a 1–3 scale as shown in Table D.4

Criterion	Score 1	Score 2	Score 3
MaQ	The opportunity is vague, qualitative or not verifiable.	The opportunity produces some indicators or partial evidence, but it is incomplete or hard to compare.	The opportunity produces clear, trackable and verifiable output such as a metric, calculation, audit result or dashboard value.
DL	The opportunity does not materially influence a choice, approval or contract decision.	The opportunity informs decisions indirectly or only occasionally.	The opportunity directly changes what is selected, approved, contracted or prioritized.
E	The opportunity depends on one person or remains an informal suggestion.	The opportunity is partly embedded, but not consistently anchored in formal processes or controls.	The opportunity is formally anchored in a plan, contract, baseline or governance process and is likely to survive personnel changes.

Score 1 = Low contribution; Score 2 = Moderate contribution; Score 3 = Strong contribution

Table D.4: Scoring criteria used for evaluating sustainability integration opportunities (source: Author).

The opportunities that were initially identified through the SLR and subsequent SSIs are now evaluated using the insights gained from both theoretical and practical perspectives. By applying the MCDA, all opportunities will be rated, acknowledging that this assessment is subjective (based on personal expertise gained from both theory and practice), as the outcomes may depend on personal judgment. In parallel with this, the reason that the range of scores are limited from 1 to 3, is because to prevent score inflation (risk of high scoring), limited cognitive overload (easy to understand) and makes the methodology more intuitive especially for big amounts of data which is the case in this research.

Project Integration Management

The amount of identified PPS-component related opportunities are in total 45, as shown in Table D.4.

Scoring heatmap

All of these 45 components are scored and shown as a heatmap visualization in Figure D.1 showing the total score, presenting $V(a)$ per opportunity.

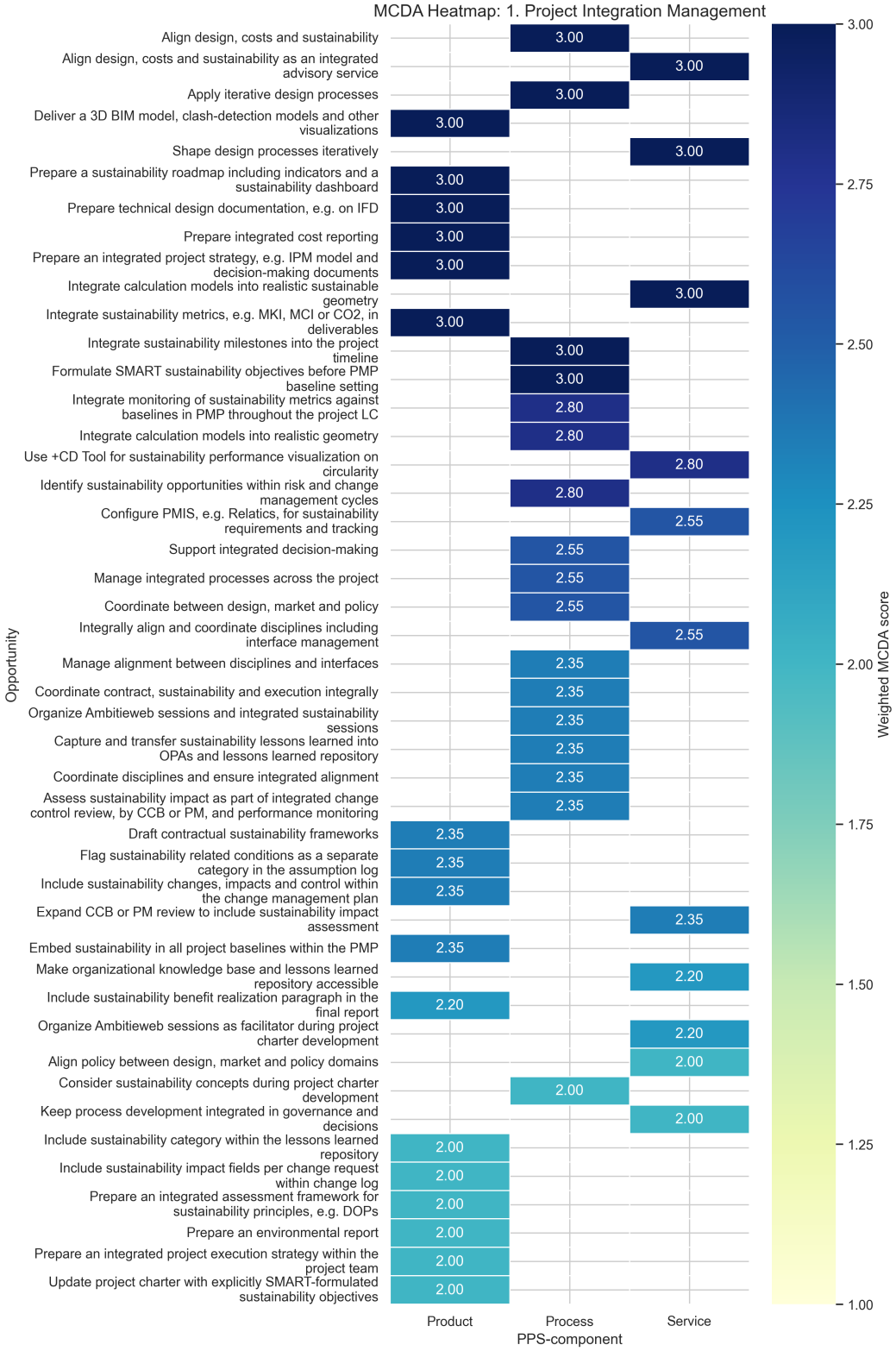


Figure D.1: Overview of the MCDA scoring results for sustainability integration opportunities within Project Integration Management across the PPS-components using Python (source: Author).

Top PPS-components

Besides these heatmaps, only the opportunities (and corresponding PPS-components) with the biggest potential, meaning opportunities with total scores of 3.0 are listed for further analysis in this research, see Table D.6. Eventually this helps in identifying the most prominent PM-domain(s) dependent on the final ranking.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	PMBoK-based	Formulate SMART sustainability objectives before PMP baseline setting	3.00
2	Process	PMBoK-based	Integrate sustainability milestones into the project timeline	3.00
3	Process	SSI-based; (PA)	Apply iterative design processes	3.00
4	Process	SSI-based'(CE)	Align design, costs and sustainability	3.00
5	Product	PMBoK-based	Integrate sustainability metrics, e.g. MKI, MCI or CO_2, in deliverables	3.00
6	Product	SSI-based; (BIM)	Deliver a 3D BIM model, clash-detection models and other visualizations	3.00
7	Product	SSI-based; (DA, MPB)	Prepare a sustainability roadmap including indicators and a sustainability dashboard	3.00
8	Product	SSI-based (PL)	Prepare an integrated project strategy, e.g. IPM-model and decision-making documents	3.00
9	Product	SSI-based (TM)	Prepare technical design documentation, e.g. on IFD	3.00
10	Product	SSI-based (CE)	Prepare integrated cost reporting	3.00
11	Service	SSI-based (BIM)	Integrate calculation models into realistic sustainable geometry	3.00
12	Service	SSI-based; (PA)	Shape design processes iteratively	3.00
13	Service	SSI-based; (CE)	Align design, costs and sustainability as an integrated advisory service	3.00

Table D.6: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Integration Management based on the MCDA analysis (source: Author).

Project Scope Management

The amount of identified PPS-component related opportunities are in total 32, as shown in Table D.4.

Scoring heatmap

All of these 32 components are scored and shown as a heatmap visualization in Figure D.2 showing the total score, presenting $V(a)$ per opportunity.

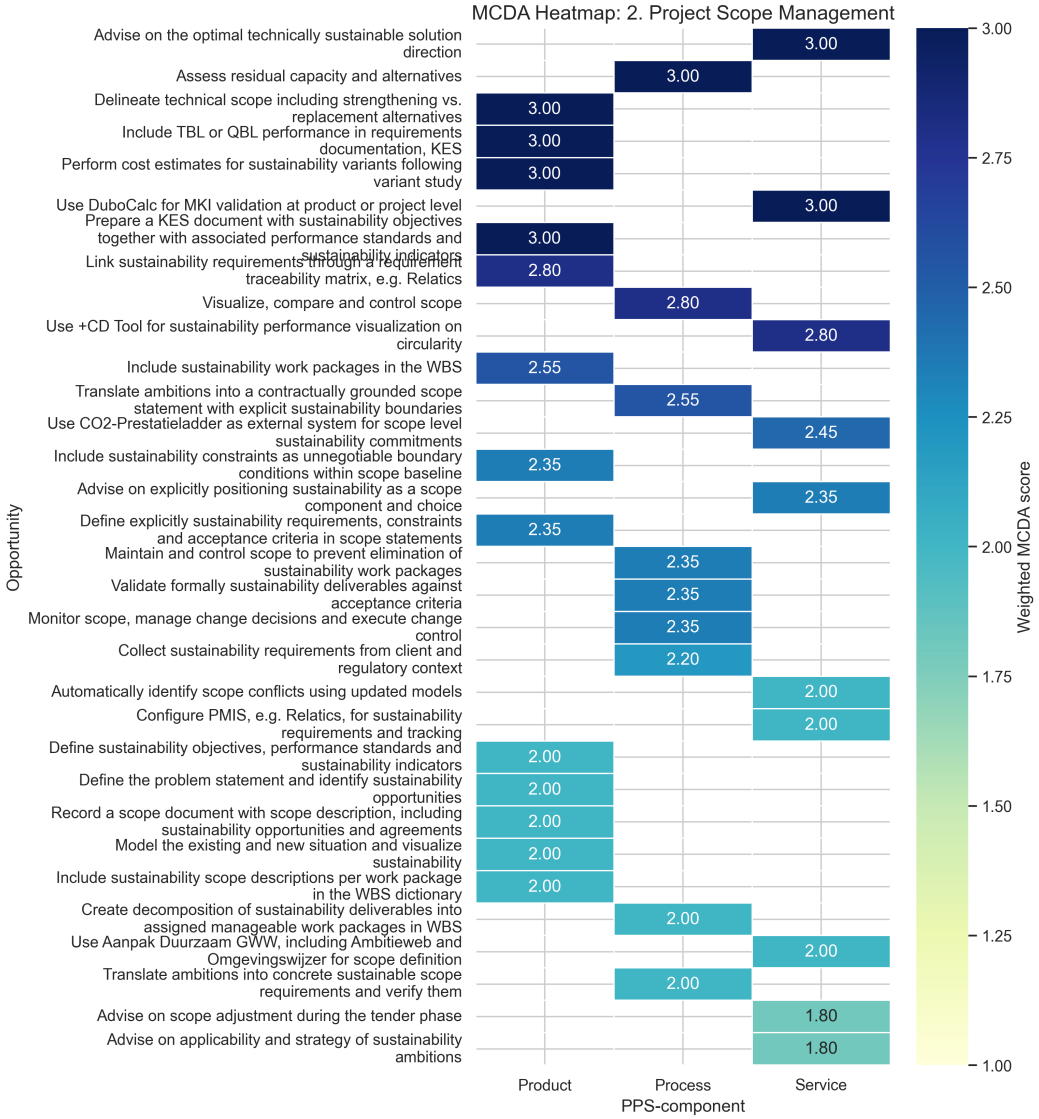


Figure D.2: Overview of the MCDA scoring results for sustainability integration opportunities within Project Scope Management across the PPS-components using Python (source: Author).

Top PPS-components

Again, the biggest potential of opportunities with a score equal to 3.0 are listed in Table D.8, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	SSI-based; (TM)	Assess residual capacity and alternatives	3.00
2	Product	PMBoK-based	Include TBL or QBL performance in requirements documentation, KES	3.00
3	Product	SSI-based; (DA, MPB, OM)	Prepare a KES document with sustainability objectives together with associated performance standards and sustainability requirements	3.00
4	Product	SSI-based; (TM)	Delineate technical scope including strengthening vs. replacement alternatives	3.00
5	Product	SSI-based; (CE)	Perform cost estimates for sustainability variants following variant study	3.00
6	Service	PMBoK-based	Use DuboCalc for MKI validation at product or project level	3.00
7	Service	SSI-based; (TM)	Advise on the optimal technically sustainable solution direction	3.00

Table D.8: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Scope Management based on the MCDA analysis (source: Author).

Project Time Management

The amount of identified PPS-component related opportunities are in total 21, as shown in Table D.4.

Scoring heatmap

All of these 21 components are scored and shown as a heatmap visualization in Figure D.3 showing the total score, presenting $V(a)$ per opportunity.

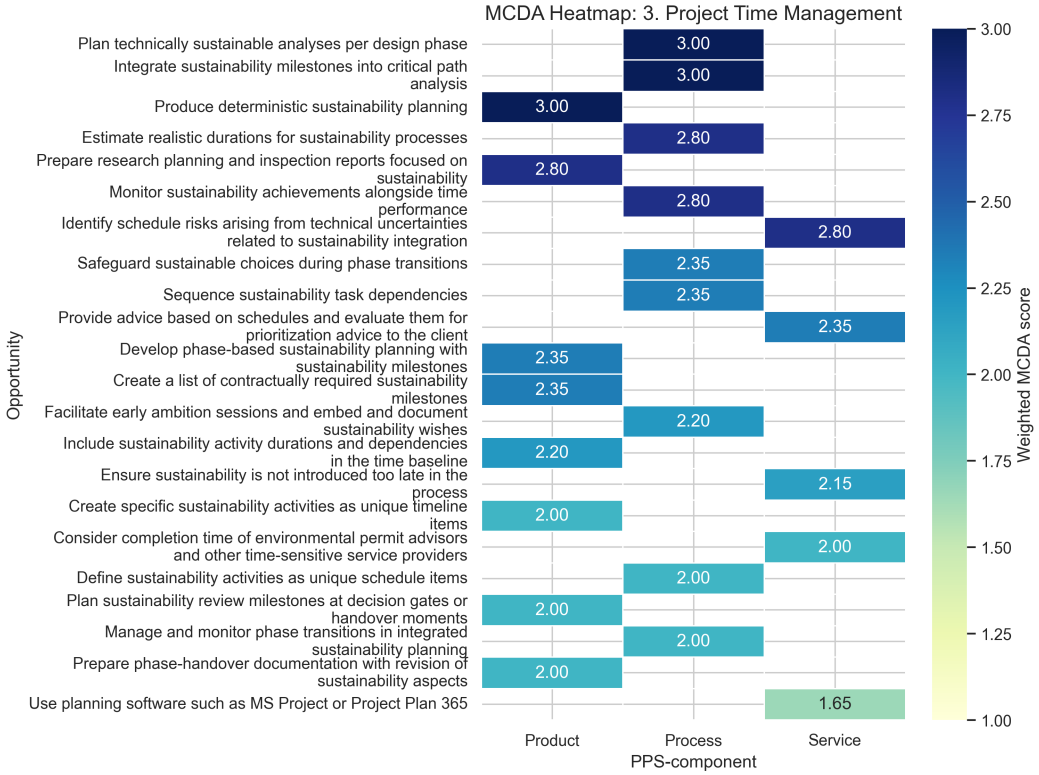


Figure D.3: Overview of the MCDA scoring results for sustainability integration opportunities within Project Time Management across the PPS-components using Python (source: Author).

Top PPS-components

Again, the biggest potential of opportunities with a score equal to 3.0 are listed in Table D.10, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	PMBoK-based	Integrate sustainability milestones into critical path analysis	3.00
2	Process	SSI-based; (TM)	Plan technically sustainable analyses per design phase	3.00
3	Product	SSI-based; (MPB)	Produce deterministic sustainability planning	3.00

Table D.10: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Time Management based on the MCDA analysis (source: Author).

Project Cost Management

The amount of identified PPS-component related opportunities are in total 24, as shown in Table D.4.

Scoring heatmap

All of these 24 components are scored and shown as a heatmap visualization in Figure D.4 showing the total score, presenting $V(a)$ per opportunity.



Figure D.4: Overview of the MCDA scoring results for sustainability integration opportunities within Project Cost Management across the PPS-components using Python (source: Author).

Top PPS-components

Again, the biggest potential of opportunities with a score equal to 3.0 are listed in Table D.12, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	SSI-based; (MPB, CM, PA, PL, PM)	Make trade-offs for each sustainable solution based on budget, financial monitoring, progress control and LCC	3.00
2	Process	SSI-based; (DA)	Integrate MKI into variant studies	3.00
3	Process	SSI-based; (TM)	Substantiate costs from a technical perspective	3.00
4	Process	SSI-based; (CE)	Prepare deterministic and probabilistic cost estimates for variants using Monte Carlo simulations	3.00
5	Product	SSI-based; (TM, DA, CE)	Perform MKI calculations, LCA analyses and LCC substantiations for each sustainable design	3.00
6	Product	SSI-based; (TM)	Conduct variant studies comparing strengthening vs. replacement options	3.00
7	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00
8	Service	SSI-based; (TM)	Provide advice on cost-effective technical choices	3.00

Table D.12: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Scope Management based on the MCDA analysis (source: Author).

Project Quality Management

The amount of identified PPS-component related opportunities are in total 35, as shown in Table D.4.

Scoring heatmap

All of these 35 components are scored and shown as a heatmap visualization in Figure D.5 showing the total score, presenting $V(a)$ per opportunity.

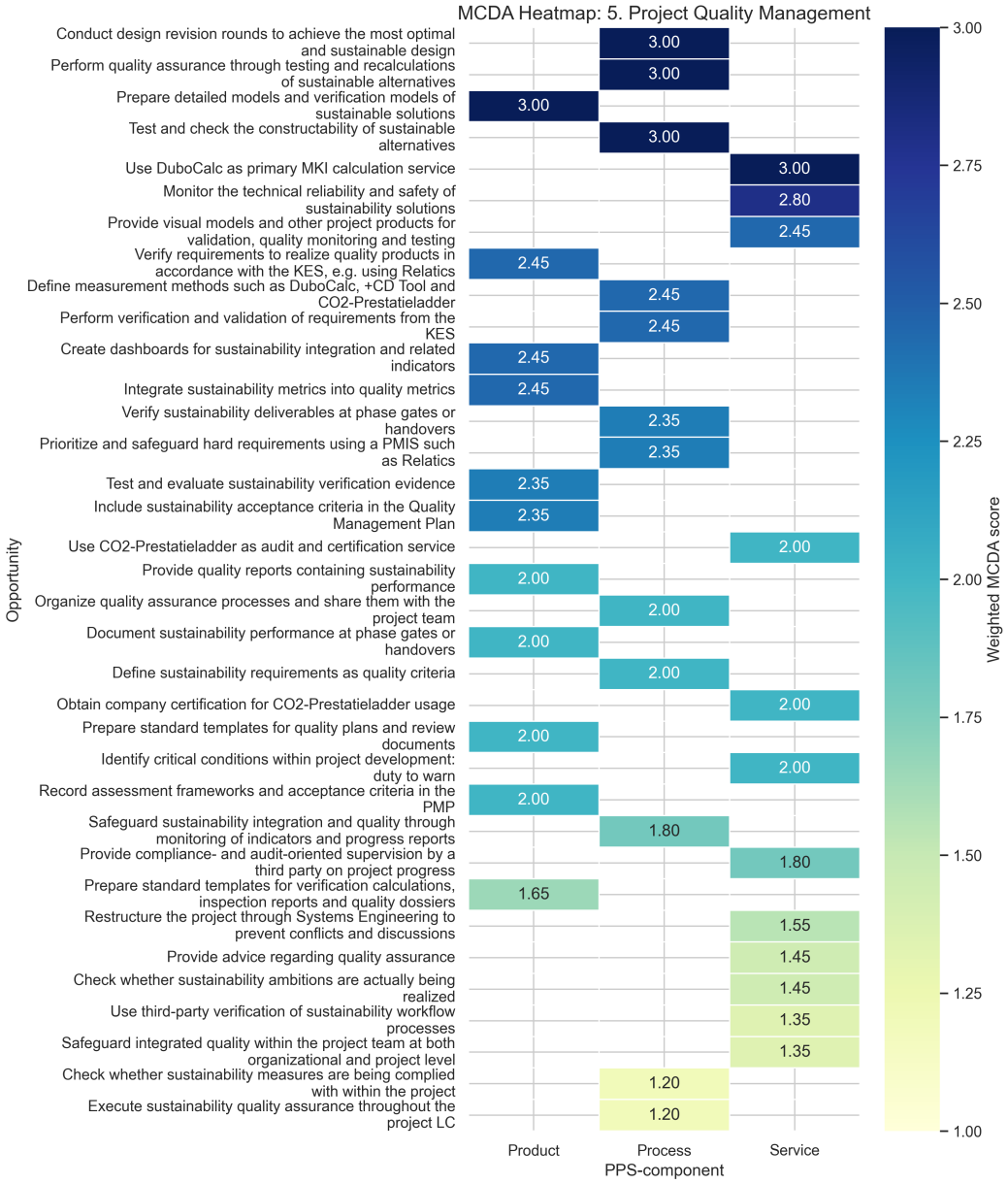


Figure D.5: Overview of the MCDA scoring results for sustainability integration opportunities within Project Quality Management across the PPS-components using Python (source: Author).

Top PPS-components

Again, the biggest potential of opportunities with a score equal to 3.0 are listed in Table D.14, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	SSI-based; (CE, BIM)	Test and check the constructability of sustainable alternatives	3.00
2	Process	SSI-based; (PA)	Conduct design revision rounds to achieve the most optimal and sustainable design	3.00
3	Process	SSI-based; (TM)	Perform quality assurance through testing and recalculations of sustainable alternatives	3.00
4	Product	SSI-based; (PM, BIM)	Prepare detailed models and verification models of sustainable solutions	3.00
5	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00

Table D.14: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Quality Management based on the MCDA analysis (source: Author).

Project Resource Management

The amount of identified PPS-component related opportunities are in total 23, as shown in Table D.4.

Scoring heatmap

All of these 23 components are scored and shown as a heatmap visualization in Figure D.6 showing the total score, presenting $V(a)$ per opportunity.

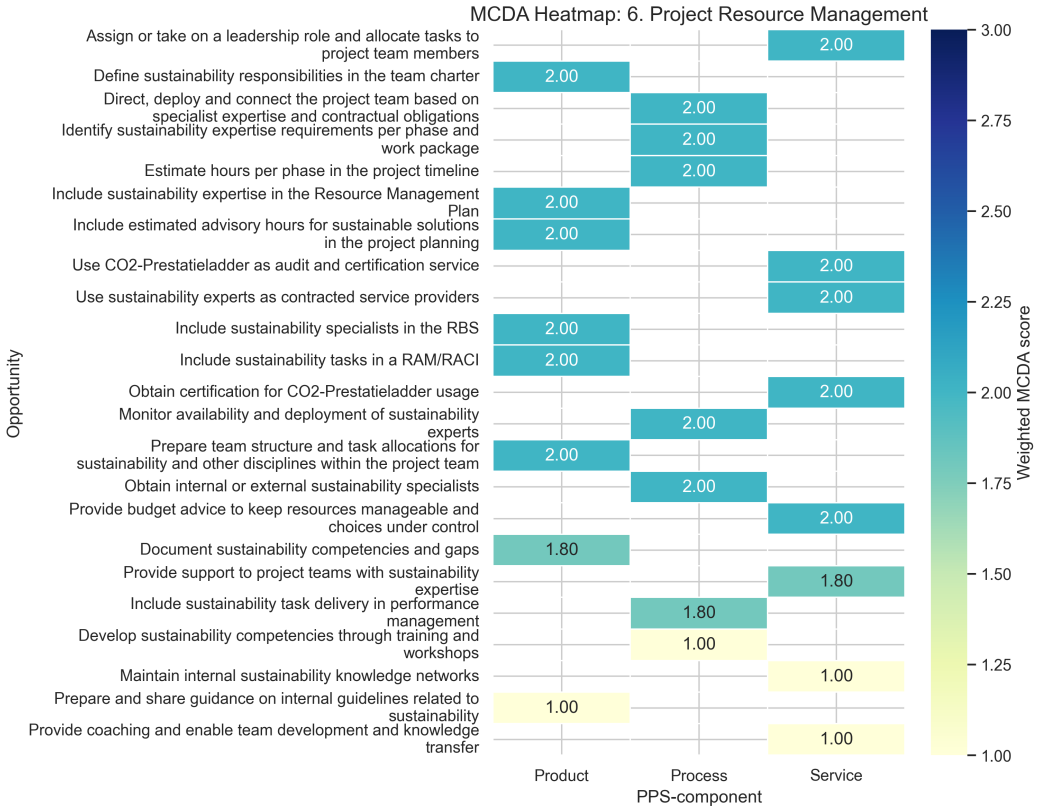


Figure D.6: Overview of the MCDA scoring results for sustainability integration opportunities within Project Resource Management across the PPS-components using Python (source: Author).

Top PPS-components

Unfortunately, within this PM-domain, there were no top opportunities that performed a score $V(a)$ of 3.0.

Project Communications Management

The amount of identified PPS-component related opportunities are in total 30, as shown in Table D.4.

Scoring heatmap

All of these 30 components are scored and shown as a heatmap visualization in Figure D.7 showing the total score, presenting $V(a)$ per opportunity.

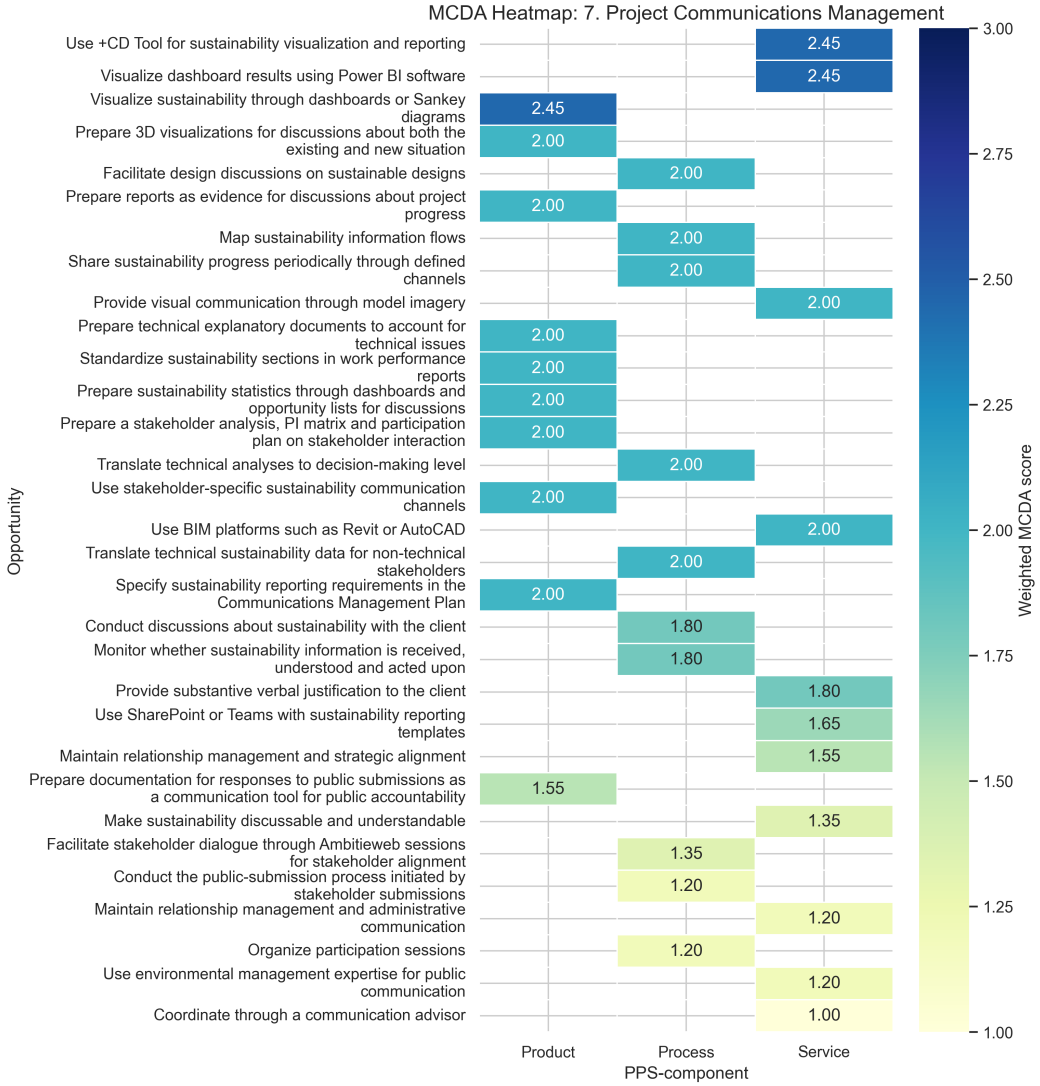


Figure D.7: Overview of the MCDA scoring results for sustainability integration opportunities within Project Communications Management across the PPS-components using Python (source: Author).

Top PPS-components

Unfortunately, within this PM-domain, there were not top opportunities that performed a score $V(a)$ of 3.0.

Project Risk Management

The amount of identified PPS-component related opportunities are in total 30, as shown in Table D.4.

Scoring heatmap

All of these 30 components are scored and shown as a heatmap visualization in Figure D.8 showing the total score, presenting $V(a)$ per opportunity.

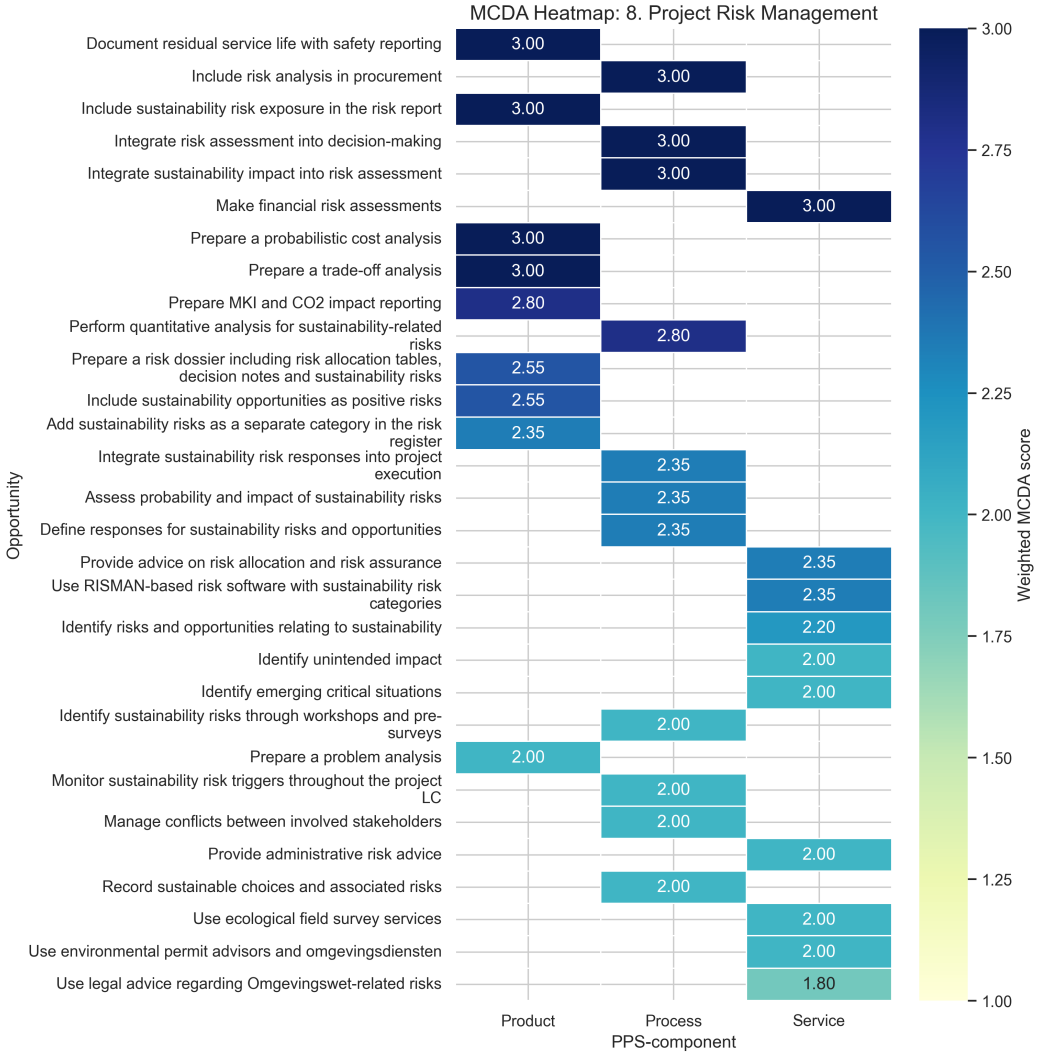


Figure D.8: Overview of the MCDA scoring results for sustainability integration opportunities within Project Risk Management across the PPS-components using Python (source: Author)

Top PPS-components

Again, opportunities with total scores of 3.0 are listed for further analysis in this research, see Table D.16, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	SSI-based; (CE, CM, MPB)	Include risk analysis in procurement	3.00
2	Process	SSI-based; (PL, TM)	Integrate risk assessment into decision-making	3.00
3	Process	SSI-based; (DA)	Integrate sustainability impact into risk assessment	3.00
4	Product	PMBoK-based	Include sustainability risk exposure in the risk report	3.00
5	Product	SSI-based; (PA)	Prepare a trade-off analysis	3.00
6	Product	SSI-based; (TM)	Document residual service life with safety reporting	3.00
7	Product	SSI-based; (CE)	Prepare a probabilistic cost analysis	3.00
9	Service	SSI-based; (CE)	Make financial risk assessments	3.00

Table D.16: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Risk Management based on the MCDA analysis (source: Author).

Project Procurement Management

The amount of identified PPS-component related opportunities are in total 28, as shown in Table D.4.

Scoring heatmap

All of these 28 components are scored and shown as a heatmap visualization in Figure D.9 showing the total score, presenting $V(a)$ per opportunity.

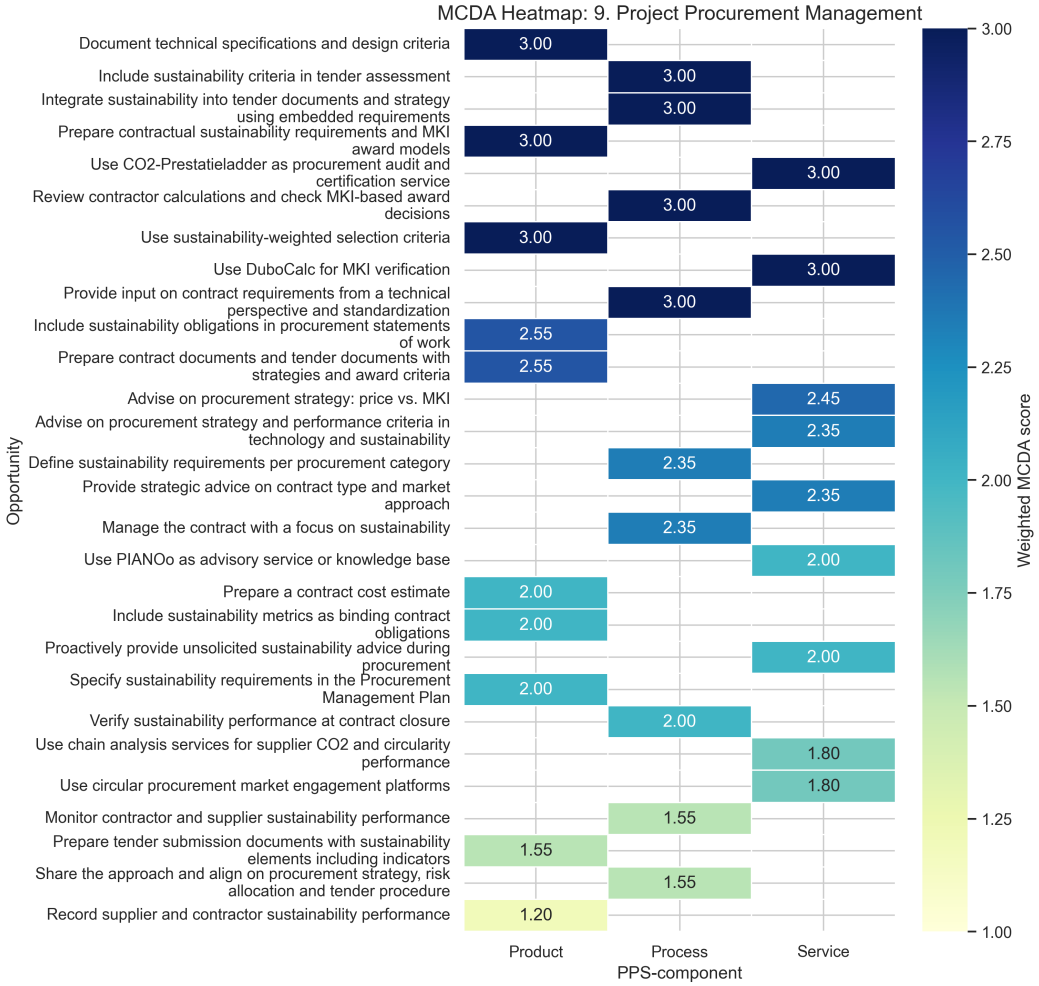


Figure D.9: Overview of the MCDA scoring results for sustainability integration opportunities within Project Procurement Management across the PPS-components using Python (source: Author)

Top PPS-components

Again, opportunities with total scores of 3.0 are listed in Table D.18, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Process	PMBoK-based	Include sustainability criteria in tender assessment	3.00
2	Process	SSI-based	Integrate sustainability into tender documents and strategy using embedded requirements	3.00
3	Process	SSI-based	Provide input on contract requirements from a technical perspective and standardization	3.00
4	Process	SSI-based	Review contractor calculations and check MKI-based award decisions	3.00
5	Product	PMBoK-based	Use sustainability-weighted selection criteria	3.00
6	Product	SSI-based	Prepare contractual sustainability requirements and MKI award models	3.00
7	Product	SSI-based	Document technical specifications and design criteria	3.00
8	Service	PMBoK-based	Use CO_2-Prestatieladder as procurement audit and certification service	3.00
9	Service	PMBoK-based	Use DuboCalc for MKI verification	3.00

Table D.18: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Procurement Management based on the MCDA analysis (source: Author).

Project Stakeholder Management

The amount of identified PPS-component related opportunities are in total 33, as shown in Table D.4.

Scoring heatmap

All of these 33 components are scored and shown as a heatmap visualization in Figure D.10 showing the total score, presenting $V(a)$ per opportunity.

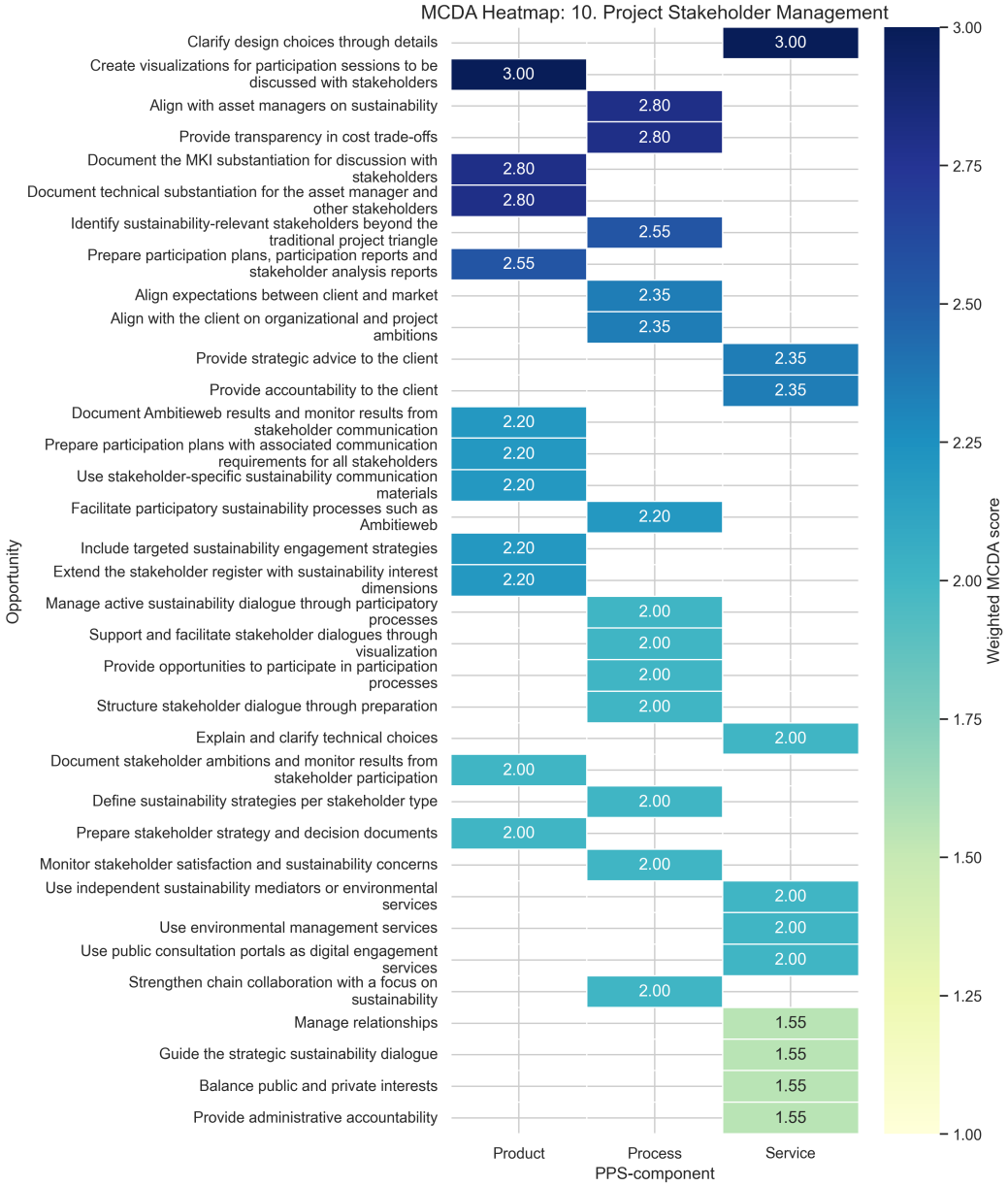


Figure D.10: Overview of the MCDA scoring results for sustainability integration opportunities within Project Stakeholder Management across the PPS-components using Python (source: Author)

Top PPS-components

Again, opportunities with total scores of 3.0 are listed in Table D.20, further analysis in this research.

Nr.	PPS-component	Origin	Opportunity	Score
1	Product	SSI-based	Create visualizations for participation sessions to be discussed with stakeholders	3.00
2	Service	SSI-based	Clarify design choices through details	3.00

Table D.20: Highest scoring sustainability integration opportunities, their origin and corresponding PPS-components within Project Stakeholder Management based on the MCDA analysis (source: Author).

Final ranking and conclusion

The results from this MCDA have been translated into a number of other relationships, including the distribution of $V(a)$ scores (1), PM-domain vs PPS-component score heatmap (2) and finally the average $V(a)$ score per PM-domain (3). This information provides an overview of the most essential PM-domain including the opportunities and associated PPS-component(s) for sustainability integration during the planning and design phase.

Distribution of $V(a)$ scores

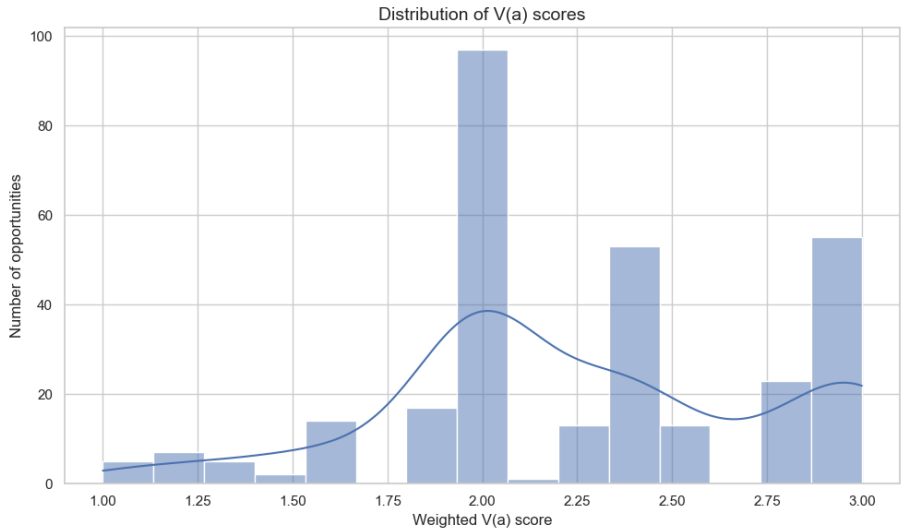


Figure D.11: Score distribution of $V(a)$ scores for all opportunities across the 10 PM-domains and corresponding PPS-components

As show in Figure D.11, it is clear that a lot of opportunities are clustered around **2.00**, whereas another two important groups are placed around **2.25 - 2.50** and **2.75 - 3.00**. The latter group is analyzed extensively, but before the first cluster around **2.00** indicates that many sustainability opportunities are relevant but are not completely measurable, decision-relevant or embedded currently within W+B. Matching with the statement that sustainability knowledge is often to access, insufficiently shared or hidden. Resulting in low visibility of both expertise and opportunities ([P3],[P4]). Meaning that many opportunities exist, but they have not yet been translated into standardized project management instruments. To standardize a developed method, it is essential to see what opportunities can assist in this, therefore the high scoring group (**2.75 - 3.00**) is important. As they are measurable, decision-relevant and are capable to be embedded in project workflows at W+B. Sustainability must be followed just as serious as planning and budget if it is to remain visible and steerable during projects ([P6],[P11]). These highest scoring opportunities are not directly the most visionary ideas, but are ideas that can be potentially converted into project control, design choices, dashboard, cost estimates, risk registers and requirements which support decision-making.

Average $V(a)$ per PM-domain and PPS-component

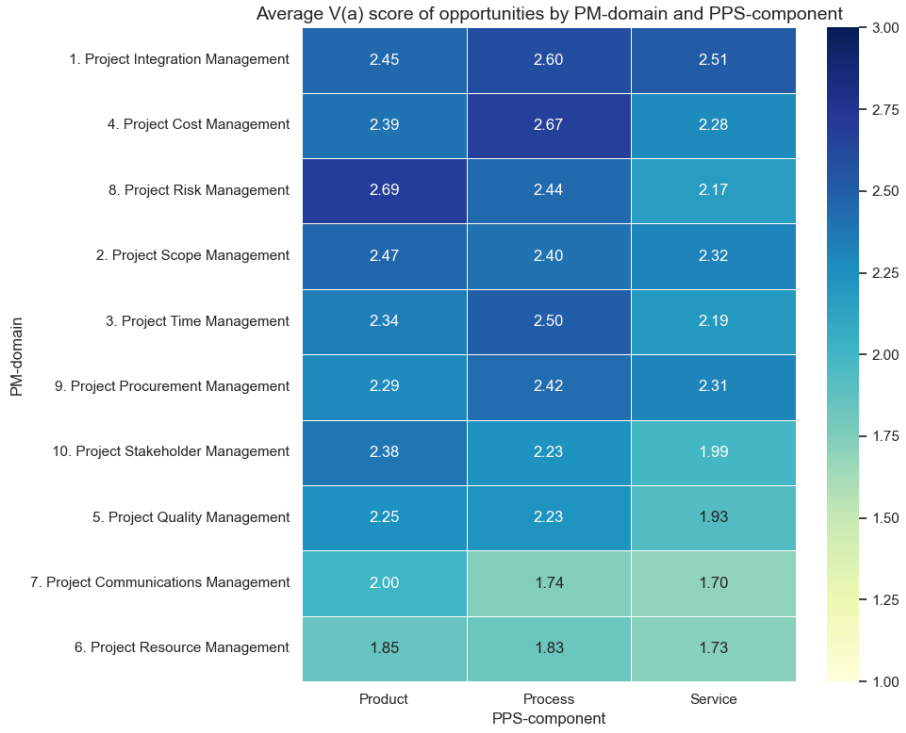


Figure D.12: The average $V(a)$ score per PM-domain and PPS-component

In order to get a better understanding of this distribution a more zoomed approached is handled, by setting up a heatmap that visualizes the average $V(a)$ score per PM-domain and PPS-component. As shown in Figure D.12, the top ranked PM-domains are visualized with each average score on each PPS-component. In this research, the top 5 PM-domains remain relevant as they are traditional project control and management domains that naturally contribute more to project development and result. **Project Integration Management** is **1st**, with a highest value in the Process-component at **2.60**. Meaning that the strongest integration potential lies in the way sustainability is anchored in project workflows, decision-making structures and coordination processes. As verified by a participant that sustainability should be anchored in existing management documents and control mechanisms ([P8],[P14]). For example, by including sustainability in the PMP as a dedicated section in larger projects ([P13]). Proving the interpretation that the Process-component is critical in Project Integration Management.

Additionally, the same component is the strongest for the **2nd** ranked **Project Cost Management** with a score of **2.67**. Representing the highest value in the heatmap, meaning that that main opportunities lies in the process of comparing alternatives, making trade-offs and integrating sustainability into cost decision-making. As sustainable alternatives gain traction, only when they become comparable within standard cost assessments ([P7]) and without integration into financial models, sustainability remains an additional consideration that is overridden when trade-offs are made ([P7]). The heatmap supports this as cost processes are crucial because they determine whether sustainability is treated as evidence or as a secondary preference.

The Product-component scores the highest for the **3rd** ranked **Project Risk Management** with **2.69**, having the highest score of the whole heatmap. Indicating that sustainability risk integration becomes impactful when it results in concrete outputs (e.g., risk reports or probabilistic cost analysis). Despite that it has been incorporated more and more within W+B as an additional sustainability risk category, it still remains weakly anchored in risk management overall ([P8],[P14]). Sustainable risk management requires formal products and documentation to become visible and actionable during project development, without these sustainability remains implicit and can disappear from project control.

The **4th** ranked **Project Scope Management**, contains a balanced score across all three PPS-components, showing the stability of the PM-domain. Scope definition is not limited to one aspect or component, as it needs requirements, practical processes and technical advisory input. This is reflected by the fact that actors tend to deliver only what is contractually required, nothing more nothing less. Meaning that when sustainability is explicitly included in the assignment, it quickly disappears and becomes secondary ([P5],[P10]). This domain is key for formalizing sustainability (e.g. including sustainability objectives, indicators and requirements) in the project scope, where sustainability becomes part of what the project must deliver rather than something optional.

Again, the Process-component, scores the highest within the **5th** **Project Time Management** with **2.50**, confirming that timing is critical for sustainability integration. Sustainability considerations are often introduced too late in the project lifecycle, particularly in financial evaluations. Early stage decisions (during FEDP) largely determine sustainability outcomes, yet cost-benefit analyses (e.g. MKBA) of sustainable options are frequently postponed until later phases, when flexibility is already reduced ([P17]) due to embedding of a technical solution in contracts, permit and stakeholder communication. This supports the need for sustainability milestones, early variant studies, scheduled MKI/LCA/LCC calculations and design review moments before stage gates (or accelerate stage gates by integrated automation).

Average overall $V(a)$ score per PM-domain

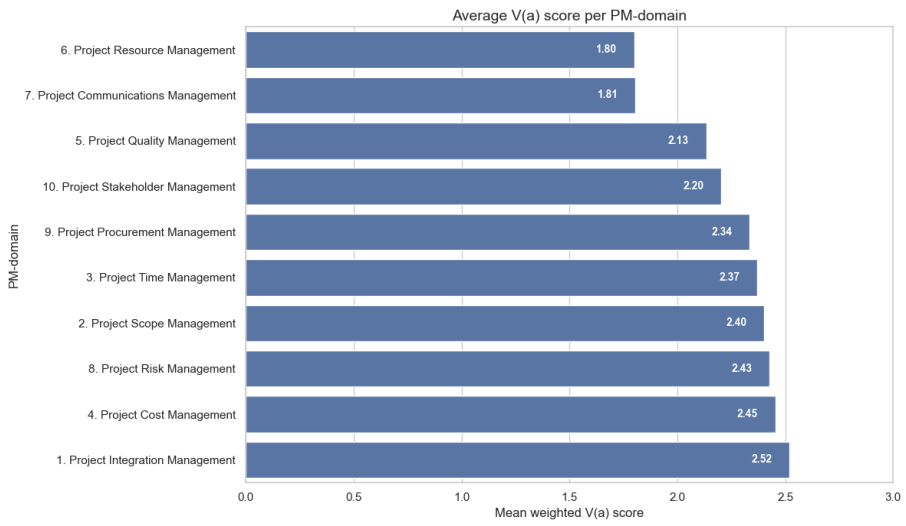


Figure D.13: The average overall $V(a)$ score per PM-domain

The ranking could already be identified by the visualization of the heatmap in Figure D.12. It is more interesting to know what the overall average $V(a)$ score is per PM-domain, in Figure D.13, it shows the most prominent PM-domains for sustainability integration where project decisions are coordinated, quantified, risk-assessed, scoped and planned. **1st** ranked **Project Integration Management** obtains the highest average overall score of **2.52**, proving that sustainability inclusion is integrative by nature and should not be treated as a separate domain or advisory activity, but instead as an integrated project control task. Participants from W+B experience that sustainability still remains fragmented across roles and project structures and even across multiple PM-domains, which diminishes integration rather than strengthening it ([P9]). Conclusively, sustainability integration depends on clear role allocation, explicit ownership and continuous coordination across project processes. By not maintaining these elements, sustainability ambitions are vulnerable to (ambition) erosion, causing fragmentation and eventually loses its attention and priority. This explains why Project Integration Management ranks highest, as it is a central challenge not only to identify sustainable solutions, but to coordinate them across the PM-domains. Aside from this, sustainability is not always seen as a hard project constrained, remaining secondary to other priorities unless it is explicitly incorporated in project goals, scope and responsibilities ([P1],[P11]). This is relevant to interpret this figure, as the corresponding high score of this domain suggests that sustainability needs to be anchored in documents. Without this integration layer, sustainability can and will remain dependent on individual initiative instead of becoming a structure part of project steering.

Project Cost Management ranks **2nd** with an average overall score of **2.45**, as reflection of the statement that one dimensional financial metrics are dominant in decisions making. Meaning that if decisions are based on direct costs only, then the more sustainable option are often eliminated. Proving that metric choices shape outcomes, because what is not monetized or measured remains invisible in decision-making ([P12]). This statement reflects, why the weighting factor is so high for the criteria of Measurability and Quantifiability' as it is essential for outcomes. Sustainability is influential if it is translated into comparable metrics (e.g. MKI, MCI, LCA or CO_2). The ranking of this domains shows that sustainability integration requires more than ambition only, it requires financial and technical language to compete with conventional solutions (and cost, time and scope arguments).

Project Risk Management ranks **3rd** with an average overall score of **2.43**, confirming that sustainability should be treated as an uncertainty and exposure issue (receiving sufficient attention). Sustainability is implicitly present in risk management, but barely treated as an explicit and structurally monitoring risk category on its own ([P8],][14]). The findings suggest that sustainability is not completely absent from projects, but is still insufficient institutionalized, whereas it depends too much on personal initiative and is not completely anchored in project management and control practices. This supports the result of this MCDA, whereas risk management has a big potential for sustainability integration, containing several and different types of sustainability risks. Highlighting the importance of not assessing sustainability as a performance ambitions, but also as a risk category with ownership, probability, impact and mitigating measures.

Project Scope Management ranked **4th** and **Project Time Management** ranked **5th**, with scores of **2.40** and **2.37**, complete the top 5. Their position is particularly important for the planning and design phase, in regards to the sustainability ambitions that are often not sufficiently specified SMART at the start of an infrastructure project ([P5]). This causes the ambitions to remain formulated at a high level and missing targets using specific metrics (e.g. MKI, MCI or CO_2). This indicates why the scope domain is critical, as sustainability must be translated into requirements within the KES, (design) boundaries and performance indicates before the design becomes permanent and fixed. Similarly, the time domain should be considered equally important, because sustainability is often introduced too late in the project LC, when design flexibility is reduced and rigidity remains (less impact on changes). This supports the need to include sustainability milestones, calculation moments, variant studies and review points before formal design stage gates (or accelerate stage gates by integrated automation).

Project Procurement Management has a middle level average overall score of **2.34** on the **6th** place below the top five and is just a bit behind the 5th place, meaning that it is still relevant for sustainability integration. Specifically during the procurement phase, where sustainability ambitions are translated into contracts, tender criteria, supplier requirements an award systems. Based on Figure D.12 the main opportunities lies in the Process-component (e.g. tender evaluation, contract conditions and market dialogue). However, it does not take place before the other top 5 domains, because the procurement often takes place after design choices have been made. Therefore, procurement is highly important for formalizing and enforcing sustainability requirements, but it is less suitable as the primary entry point for early design optimization.

Project Stakeholder Management at the **7th** place has an average overall $V(a)$ score of **2.20**, which has a meaningful but indirect role in sustainability integration within project management and project control (aside from the fact that at W+B the sustainability ambitions are identified during stakeholder Ambitieweb and Omgevingswijzer sessions). Again, within the Product-component Figure D.12 shows that stakeholder related sustainability integration is realized more concrete when the results are tangible outputs (e.g. stakeholder analysis, participation reports or decision justification). Gaining a 'goodwill' factors is due to good 'stakeholder management' which is important in realizing the sustainability objectives in infrastructure projects. However, stakeholder management and engagement alone does not directly imply sustainability integration or whether sustainable alternatives are selected. Stakeholders can influence priorities and acceptance depending on their power and interests (PI-matrix), regardless, some of them still needs to be translated into the project

context (e.g. scope requirements, design criteria en cost estimates) related to other domains.

Project Quality Management has an average overall $V(a)$ score of **2.13**, which ranks **8th** position. Figure D.12 indicates that this domain is mainly contributing through Product- and Process-components (e.g. quality criteria, verification procedures, design checks or review moments). The domain is relevant for sustainability integration as well, because products need to be delivered within agreed acceptance criteria and expectation of the client and other stakeholders and should be checked during project development. However, this domain is more evaluative rather than generative, so it checks whether requirements are met (on quality) rather than defining or proposing sustainable solutions or ideas. It can help ensure that sustainability indicators are consistently reviewed, validated and documented, but it should support rather than replace the earlier integration, design optimization and decision-making processes. Therefore it scores relatively low compared to the other domains.

Project Communications Management has a an average $V(a)$ overall score of **1.81** ranking **9th** and **Project Resource Management** has an average $V(a)$ overall score of **1.80** ranking **10th**. Based on Figure D.12 it is shown that their PPS-components do not perform well and reach the thresholds required to be considered a '*top opportunity*' cluster. The low ranking does not directly imply that resources and communication are irrelevant for sustainability integration, but within the defined boundary conditions of the MCDA they have less direct leverage on sustainability integration compared to the other PM-domains. Resource management domains mainly involves about the availability, allocation, coordination of people and knowledge capacity. They help in providing room to assist sustainability integration, but these domains do not automatically produce measurable sustainability outcomes. An example is that a sustainability advisor or allocating design capacity can support sustainability, but the real impact depends on whether it is translated into tangible project management or control deliverable and documents (e.g. KES, MKI or cost estimates). This explains why **Project Resource Management** scores lower on measurability (***MaQ***) and decision leverage (***DL***). As the findings from the SSIs indicate that sustainability depends on individual awareness, expertise and intrinsic motivation instead of being a part of standard role responsibilities and workflows ([12],[P18]). This highlights that if it only depends on motivated individual then this domains functions more as a supporting condition rather than as a strong direct decision mechanism. Additionally, sustainability knowledge tends to be difficult to access, insufficiently shared or hidden, resulting in low visibility of both expertise and opportunities ([P3],[P4]). Highlighting that not the challenge not only lies in people within this domain, but also the structural organization of knowledge, responsibilities and capacity.

Project Communication Management does lack '*top opportunities*' as well, because again this domain is mainly an enabling and supporting domain, which creates awareness alignment and stakeholder understanding. Furthermore, communication alone does not guarantee that sustainability will be anchored in the design, budget, timeline or scope. Within W+B the advisory role whereas signaling, raising awareness and structuring information are more contributory to sustainability rather than direct authority to integrate. The signaling acts more as a safeguard to sustainability consideration, reflecting a proactive behavior ([P7],[P12],[P14]). This shows why this domain scores relatively low, as it can support sustainability integration, but its effect is indirect unless it is connected to direct decision-making. Communication can help maintain alignment through Ambitieweb sessions, stakeholder dialogue, dashboards and decision justifications but it does not by itself determine whether a sustainable alternative is selected.

In conclusion, **Project Resource Management** and **Project Communications Management** should be seen as supporting domains rather than primary methodological domains for sustainability integration. They are and still remain necessary parallel with the order more essential domains to realize sustainability integration, but as the MCDA results proof, the main foundation on sustainability integration is built on the opportunities of the top 5 PM-domains:

1. Project Integration Management
2. Project Cost Management
3. Project Risk Management
4. Project Scope Management
5. Project Time Management

These domains offer stronger direct potential to make sustainability measurable, decision-relevant and embedded in the project control and management processes of an infrastructural project during the planning and design phase within W+B.

All top PPS-components

Based on the previous sections, an overall overview in Table D.21 presents a comprehensive overview of all highest-scoring sustainability integration opportunities ($V(a) = 3.00$) across the examined PM-domains.

Table D.21: Overview of the highest scoring sustainability integration opportunities across the examined PM-domains based on the MCDA analysis (source: Author).

PM-domain	PPS	Origin	Top opportunity	Score
Project Integration Management	Process	PMBoK-based	Formulate SMART sustainability objectives before PMP baseline setting	3.00
Project Integration Management	Process	PMBoK-based	Integrate sustainability milestones into the project timeline	3.00
Project Integration Management	Process	SSI-based; PA	Apply iterative design processes	3.00
Project Integration Management	Process	SSI-based; CE	Align design, costs and sustainability	3.00
Project Integration Management	Product	PMBoK-based	Integrate sustainability metrics, e.g. MKI, MCI or CO_2, in deliverables	3.00
Project Integration Management	Product	SSI-based; BIM	Deliver a 3D BIM model, clash-detection models and other visualizations	3.00
Project Integration Management	Product	SSI-based; DA, MPB	Prepare a sustainability roadmap including indicators and a sustainability dashboard	3.00
Project Integration Management	Product	SSI-based; PL	Prepare an integrated project strategy, e.g. IPM-model and decision-making documents	3.00
Project Integration Management	Product	SSI-based; TM	Prepare technical design documentation, e.g. on IFD	3.00
Project Integration Management	Product	SSI-based; CE	Prepare integrated cost reporting	3.00
Project Integration Management	Service	SSI-based; BIM	Integrate calculation models into realistic sustainable geometry	3.00
Project Integration Management	Service	SSI-based; PA	Shape design processes iteratively	3.00
Project Integration Management	Service	SSI-based; CE	Align design, costs and sustainability as an integrated advisory service	3.00
Project Scope Management	Process	SSI-based; TM	Assess residual capacity and alternatives	3.00
Project Scope Management	Product	PMBoK-based	Include TBL or QBL performance in requirements documentation, KES	3.00
Project Scope Management	Product	SSI-based; DA, MPB, OM	Prepare a KES document with sustainability objectives together with associated performance standards and sustainability requirements	3.00
Project Scope Management	Product	SSI-based; TM	Delineate technical scope including strengthening vs. replacement alternatives	3.00
Project Scope Management	Product	SSI-based; CE	Perform cost estimates for sustainability variants following variant study	3.00
Project Scope Management	Service	PMBoK-based	Use DuboCalc for MKI validation at product or project level	3.00
Project Scope Management	Service	SSI-based; TM	Advise on the optimal technically sustainable solution direction	3.00
Project Time Management	Process	PMBoK-based	Integrate sustainability milestones into critical path analysis	3.00
Project Time Management	Process	SSI-based; TM	Plan technically sustainable analyses per design phase	3.00
Project Time Management	Product	SSI-based; MPB	Produce deterministic sustainability planning	3.00
Project Cost Management	Process	SSI-based; MPB, CM, PA, PL, PM	Make trade-offs for each sustainable solution based on budget, financial monitoring, progress control and LCC	3.00
Project Cost Management	Process	SSI-based; DA	Integrate MKI into variant studies	3.00
Project Cost Management	Process	SSI-based; TM	Substantiate costs from a technical perspective	3.00
Project Cost Management	Process	SSI-based; CE	Prepare deterministic and probabilistic cost estimates for variants using Monte Carlo simulations	3.00
Project Cost Management	Product	SSI-based; TM, DA, CE	Perform MKI calculations, LCA analyses and LCC substantiations for each sustainable design	3.00
Project Cost Management	Product	SSI-based; TM	Conduct variant studies comparing strengthening vs. replacement options	3.00
Project Cost Management	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00
Project Cost Management	Service	SSI-based; TM	Provide advice on cost-effective technical choices	3.00
Project Quality Management	Process	SSI-based; CE, BIM	Test and check the constructability of sustainable alternatives	3.00
Project Quality Management	Process	SSI-based; PA	Conduct design revision rounds to achieve the most optimal and sustainable design	3.00
Project Quality Management	Process	SSI-based; TM	Perform quality assurance through testing and recalculations of sustainable alternatives	3.00
Project Quality Management	Product	SSI-based; PM, BIM	Prepare detailed models and verification models of sustainable solutions	3.00
Project Quality Management	Service	PMBoK-based	Use DuboCalc as primary MKI calculation service	3.00
Project Risk Management	Process	SSI-based; CE, CM, MPB	Include risk analysis in procurement	3.00
Project Risk Management	Process	SSI-based; PL, TM	Integrate risk assessment into decision-making	3.00
Project Risk Management	Process	SSI-based; DA	Integrate sustainability impact into risk assessment	3.00
Project Risk Management	Product	PMBoK-based	Include sustainability risk exposure in the risk report	3.00
Project Risk Management	Product	SSI-based; PA	Prepare a trade-off analysis	3.00
Project Risk Management	Product	SSI-based; TM	Document residual service life with safety reporting	3.00
Project Risk Management	Product	SSI-based; CE	Prepare a probabilistic cost analysis	3.00
Project Risk Management	Service	SSI-based; CE	Make financial risk assessments	3.00
Project Procurement Management	Process	PMBoK-based	Include sustainability criteria in tender assessment	3.00
Project Procurement Management	Process	SSI-based; DA, OM, PM	Integrate sustainability into tender documents and strategy using embedded requirements	3.00
Project Procurement Management	Process	SSI-based; TM	Provide input on contract requirements from a technical perspective and standardization	3.00
Project Procurement Management	Process	SSI-based; CE	Review contractor calculations and check MKI-based award decisions	3.00
Project Procurement Management	Product	PMBoK-based	Use sustainability-weighted selection criteria	3.00
Project Procurement Management	Product	SSI-based; OM, DA	Prepare contractual sustainability requirements and MKI award models	3.00
Project Procurement Management	Product	SSI-based; TM	Document technical specifications and design criteria	3.00
Project Procurement Management	Service	PMBoK-based	Use CO_2-Prestatieladder as procurement audit and certification service	3.00
Project Procurement Management	Service	PMBoK-based	Use DuboCalc for MKI verification	3.00
Project Stakeholder Management	Product	SSI-based; BIM	Create visualizations for participation sessions to be discussed with stakeholders	3.00
Project Stakeholder Management	Service	SSI-based; BIM	Clarify design choices through details	3.00

References for Appendices

Journal articles

Buyle, M., Braet, J., & Audenaert, A. (2013). Life cycle assessment in the construction sector: A review. *Renewable and Sustainable Energy Reviews*, *26*, 379–388. https://doi.org/10.1016/j.rser.2013.05.001

Clevenger, C. M., Ozbek, M. E., & Simpson, S. (2013). Review of sustainability rating systems used for infrastructure projects. *49th ASC annual international conference proceedings*, 10–13.

Coenen, T. B. J., Visscher, K., & Volker, L. (2023). A systemic perspective on transition barriers to a circular infrastructure sector. *Construction Management and Economics*, *41*(1), 22–43. https://doi.org/10.1080/01446193.2022.2151024

Gluch, P., & Baumann, H. (2004). The life cycle costing (lcc) approach: A conceptual discussion of its usefulness for environmental decision-making. *Building and Environment*, *39*(5), 571–580. https://doi.org/10.1016/j.buildenv.2003.10.008

Honic, M., Kovacic, I., & Rechberger, H. (2019). Improving the recycling potential of buildings through material flow analysis (mfa) in the early design stage. *Journal of Cleaner Production*, *232*, 1–10. https://doi.org/10.1016/j.jclepro.2019.05.329

Jacobs, M., & Stott, M. (1992). Sustainable development and the local economy. *Local Economy*, *7*(3), 261–272. https://doi.org/10.1080/02690949208726152

Pereira, A., Serra da Fonseca, M., & Fernandes, P. (2019). Come in, who is it? the predisposition of the social economy toward the circular economy. *4th Regional Helix | Porto, 2019- Book of Abstracts*, 287–295.

Pots, J. M. (2018). The stimulation of circular economy in the dutch construction industry : How procurement processes can realize a transition arena that is required in order to stimulate the transition to a circular economy. https://api.semanticscholar.org/CorpusID:169606951

Prins, M. M., Mohammadi, S., & Slob, N. (2015). Radical circular economy. https://api.semanticscholar.org/CorpusID:113016070

van der Voet, E., van Oorschot, J., Verhagen, T., van Oers, L., van Straalen, V., Tunn, V., Kersten, K., & Delahaye, R. (2025). The urban mine of the netherlands: The material basis for a circular economy. *Journal of Industrial Ecology*, *29*(3), 967–981. https://doi.org/10.1111/jiec.70030

Veen, C. (2023). Reducing ambition erosion to achieve strategic sustainability ambitions a research on the realisation of strategic sustainability ambitions in the exploration phase.

Woodward, D. G. (1997). Life cycle costing — theory, information acquisition and application. *International Journal of Project Management*, *15*(6), 335–344. https://doi.org/10.1016/S0263-7863(96)00089-0

Books

World Commission on Environment and Development. (1987). *Our Common Future: Report of the World Commission on Environment and Development*. Oxford University Press. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Theses

Wong, W. K. Y. (2024). *Sustainability in construction management: How can sustainability be effectively incorporated into risk management and measured in projects?* [Honours Program Master Thesis]. Delft University of Technology.

Reports and standards

Central Commission for the Navigation of the Rhine. (2024). *Annual report 2025 – observation du marché* (tech. rep.). Central Commission for the Navigation of the Rhine. https://www.ccr-zkr.org/files/documents/om/om25_II_en.pdf

de Silva, M. (2016). *The use of ceequal in complex projects* (tech. rep. No. Micro□report). Crossrail Ltd / Learning Legacy. https://learninglegacy.crossrail.co.uk/documents/ceequal-in-complex-projects/

Fuller, S. (2016). *Life-cycle cost analysis (lcca)* (tech. rep.). National Institute of Building Sciences. Washington, D.C. https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca

ISO 14040: Environmental management – Life cycle assessment – Principles and framework. (2006). International Organization for Standardization.

Kingdom of the Netherlands. (2022). *Voluntary national review on the sustainable development goals* (tech. rep.). United Nations. https://hlpf.un.org/sites/default/files/vnrs/2022/VNR%202022%20Netherlands%20Report.pdf

Ministerie van Infrastructuur en Waterstaat. (2023, February). *Nationaal programma circulaire economie 2023–2030* (Beleidsnota / Policy Report). Rijksoverheid. https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/beleidsnotas/2023/02/03/nationaal-programma-circulaire-economie-2023-2030

Netherlands Enterprise Agency (RVO). (2022, April). *Nl dutch solutions for a hydrogen economy v* (Policy report / brochure) (Rijksdienst voor Ondernemend Nederland (RVO) publication). Netherlands Enterprise Agency. https://www.rvo.nl/files/file/2022-05/NL-Dutch-solutions-for-a-hydrogen-economy-V-April-2022-DIGI.pdf

Network, S. D. S. (2012). *A framework for sustainable development* (tech. rep.). Sustainable Development Solutions Network. http://www.jstor.org/stable/resrep16082

PIANOo & Rijksoverheid. (2021, January). *Opdrachtgeven met ambitie, inkopen met impact: Nationaal plan maatschappelijk verantwoord inkopen 2021–2025* (tech. rep.). PIANOo / Rijksoverheid. https://www.pianoo.nl/sites/default/files/media/documents/2021-02/plan_mvi_opdrachtgeven_met_ambitie_inkopen_met_impact_2021-2025-jan2021.pdf

Royal College of Pathologists and Crossrail Learning Legacy. (2018). *Ceequal case study* (tech. rep.). Royal College of Pathologists / Crossrail Learning Legacy. https://learninglegacy.crossrail.co.uk/documents/ceequal-in-complex-projects/

Sustainable Development Solutions Network (SDSN). (2025b). *Sustainable development report 2025: Netherlands country profile*. United Nations Sustainable Development Solutions Network (SDSN). https://dashboards.sdgindex.org/profiles/netherlands/

Wilkins, S., & Schuster, S. (2025). *Application of the envision sustainability rating system to enhance the upper truckee river restoration strategy* (tech. rep.). CDM Smith Inc. https://tahoe.ca.gov/wp-content/uploads/sites/257/2014/06/files/2013_VO/UTR_/Envision_Analysis_of_UTR_Restoration_Strategy_-_CDM_Smith.pdf

Websites and online sources

Ambitieweb. (2024, January). Duurzaam gww. https://www.duurzaamgww.nl/documenten/58-ambitieweb

Bedggood, J. (2025). Sustainable infrastructure and the is rating scheme by isca. https://www.anthesisgroup.com/au/insights/is-rating-scheme-by-isca/

BlueScope Steel Limited. (2025). Infrastructure sustainability (is) rating scheme. https://steel.com.au/resources/articles/infrastructure-sustainability-rating-scheme

Brainport Eindhoven. (2026). Discover brainport eindhoven. https://brainporteindhoven.com/int/discover-brainport-eindhoven

Building Research Establishment. (1990). How breeam works. https://breeam.com/about/how-breeam-works

CEEQUAL Ltd. (2018, May). An introduction to ceequal. https://www.ceequal.com

Construction Law Made Easy. (2025). Chapter 22 – is rating system. https://constructionlawmadeeasy.com/construction-law/chapter-22/is-rating-system/

CROW Kennisplatform. (2026). Programma schoon en emissieloos bouwen in de aanbesteding. https://www.crow.nl/Onderwerpen/aanbesteden-contracteren/aanbesteden/programma-schoon-en-emissieloos-bouwen-in-de-aanbesteding/

CROW / Kennisplatform Aanpak Duurzaam GWW. (2025). Aanpak duurzaam gww: Een praktische werkwijze om duurzaamheid in gww projecten een plaats te geven. https://www.duurzaamgww.nl/aan-de-slag/aanpak-duurzaam-gww

Delta Programme. (2024). Publications of the delta programme. %7Bhttps://english.deltaprogramma.nl/delta-programme/publications-of-the-delta-programme%7D

Dutch Green Building Council (DGBC). (2025). Breeam□nl (english) – building research establishment environmental assessment method. https://www.breeam.nl/english-9

Duurzaam GWW. (2026). Over kci – duurzaam gww. https://www.duurzaamgww.nl/over-kci

Duurzaam GWW CROW. (2016, December). Aanpak duurzaam gww. https://www.duurzaamgww.nl/documenten/67-aanpak-duurzaam-gww

Government of the Netherlands. (2023). National circular economy programme 2023–2030. https://www.government.nl/documents/reports/2023/09/27/national-circular-economy-programme-2023-2030

Government of the Netherlands. (2025). Circular dutch economy by 2050. https://www.government.nl/topics/circular-economy/circular-dutch-economy-by-2050

Infrastructure Sustainability Council (ISC). (2021). Is v2.1 design and as□-built rating. https://www.iscouncil.org/is-v2-1/

Infrastructure Sustainability Council (ISC). (2025). Is planning rating: Informed infrastructure decisions. https://www.iscouncil.org/is-planning-tool/

Infrastructure Sustainability Council of Australia. (2025). Is rating scheme. https://sustainable-infrastructure-tools.org/tools/is-rating-scheme/

Institute for Sustainable Infrastructure. (2024). Envision Packet Final. https://sustainableinfrastructure.org

Institute of Sustainability and Environmental Professionals (ISEP). (2025). Ceequal and eia – mutually beneficial. https://www.isepglobal.org/articles/ceequal-and-eia-mutually-beneficial

ISCA. (2016). Advancing sustainability in infrastructure planning, procurement, delivery and operation. https://www.eianz.org/document/item/3422

ISI. (2023). Use envision. https://sustainableinfrastructure.org/envision/use-envision/

ISPT. (2026). Themes – ispt. https://ispt.eu/themes/

MVI Criteriatool. (2025). Mvi criteriatool – selecteer en download ruim 900 criteria voor maatschappelijk verantwoord inkopen. https://www.mvicriteria.nl/nl

NEN. (2025). Second generation eurocodes. *NEN*. %7Bhttps://www.nen.nl/en/bouw/constructieve-veiligheid/eurocodes/tweede-generatie-eurocodes%7D

Noordzeeloket. (2026). Windenergie op zee. %7Bhttps://noordzeeloket.nl/functies-gebruik/energietransitie-zee/windenergie-zee/%7D

Omgevingswijzer. (2023, February). Duurzaam gww. https://www.duurzaamgww.nl/documenten/55-omgevingswijzer

PIANOo / Expertisecentrum Aanbesteden. (2026). Nationaal plan maatschappelijk verantwoord inkopen 2021–2025. https://www.pianoo.nl/nl/themas/maatschappelijk-verantwoord-inkopen/beleid-en-uitvoering/nationaal-plan-maatschappelijk

Port of Rotterdam Authority. (2025, December). Port vision 2050 summary. https://www.portofrotterdam.com/sites/default/files/2025-12/port-vision-2050-summary.pdf

Port of Rotterdam Authority. (2026, January). 2050 port vision officially launched. https://www.portofrotterdam.com/en/news-and-press-releases/2050-port-vision-officially-launched

Programma Schoon en Emissieloos Bouwen. (2024, November). Routekaart seb: Schoon en emissieloos bouwen. https://www.opwegnaarseb.nl/documenten/2024/11/04/routekaart-seb

Rijksdienst voor Ondernemend Nederland. (2025). Circulariteit: 4 strategieën & de R-ladder. https://www.rvo.nl/onderwerpen/circulaire-economie/r-ladder

Rijksinstituut voor Volksgezondheid en Milieu (RIVM). (2026). Schone lucht akkoord en gezondheidswinst. https://www.rivm.nl/lucht/effecten-luchtkwaliteit-op-gezondheid/schone-lucht-akkoord-gezondheidswinst

Rijksoverheid. (2007). Meerjarenprogramma infrastructuur, ruimte en transport (mirt). https://www.rijksoverheid.nl/onderwerpen/ruimtelijke-ordening-en-gebiedsontwikkeling/meerjarenprogramma-infrastructuur-ruimte-en-transport-mirt

Rijksoverheid / Ministerie van Economische Zaken en Klimaat. (2019, June). Klimaatakkoord. https://www.rijksoverheid.nl/documenten/rapporten/2019/06/28/klimaatakkoord

Rijksoverheid / Ministerie van Infrastructuur en Waterstaat & Ministerie van Volkshuisvesting en Ruimtelijke Ordening. (2025, June). Bijlage 10: Beleidsevaluatie klimaatneutrale en circulaire rijksinfrastructuurprojecten (kci). https://www.rijksoverheid.nl/documenten/rapporten/2025/06/13/bijlage-10-beleidsevaluatie-klimaatneutrale-en-circulaire-infrastructuur

Rijksoverheid / Ministerie van Landbouw, Natuur en Voedselkwaliteit. (2022, December). Programma stikstofreductie en natuurverbetering 2022–2035. https://www.rijksoverheid.nl/documenten/kamerstukken/2022/12/19/programma-stikstofreductie-en-natuurverbetering-2022-2035

Rijksoverheid & Partijen. (2023, November). Convenant schoon en emissieloos bouwen. https://open.overheid.nl/documenten/dpc-6803f920cde0721f5385b8152a73e8e192efd3cb/pdf

Rijkswaterstaat. (2023). Richtlijnen Ontwerp Kunstwerken. https://rok.rwskennisbron.nl/index.php/Richtlijnen_Ontwerp_Kunstwerken

Rijkswaterstaat. (2025, March). Kompas RWS is geactualiseerd! https://www.rijkswaterstaat.nl/nieuws/archief/2025/03/kompas-rws-is-geactualiseerd

Rijkswaterstaat. (2026a). Co□-prestatieladder als inkoopinstrument. https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/duurzaam-inkopen/co2-prestatieladder

Rijkswaterstaat. (2026b). Deltawerken. %7Bhttps://www.rijkswaterstaat.nl/water/waterbeheer/bescherming-tegen-het-water/waterkeringen/deltawerken%7D

Rijkswaterstaat. (2026c). Economisch meest voordelige inschrijving / beste prijs-kwaliteit verhouding (bpkv). https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/aanbesteden/economische-meest-voordelige-inschrijving

Rijkswaterstaat. (2026d). Integraal projectmanagement. %7Bhttps://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/werkwijzen/werkwijze-in-gww/werken-in-projecten/integraal-projectmanagement%7D

Rijkswaterstaat DuboCalc. (2025). Dubocalc; duurzaam bouwen calculator. https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/duurzaam-inkopen/dubocalc

RWE. (2026). North2 – hydrogen project development. %7Bhttps://www.rwe.com/en/research-and-development/hydrogen-projects/north2/%7D

Schone Lucht Akkoord. (2026). Schone lucht akkoord. https://schoneluchtakkoord.nl/

SE 2050 Secretariat. (2025). The civil engineering environmental quality assessment and award scheme for infrastructure (uk ireland). https://se2050.org/the-civil-engineering-environmental-quality-assessment-and-award-scheme-for-infrastructure-assessment-uk-ireland/

Stichting Klimaatvriendelijk Aanbesteden & Ondernemen. (2025a, September). Aanbesteden met gunningscriterium co□-prestatieladder 4.0 in vier stappen. https://www.co2-prestatieladder.nl/blog/aanbesteden-met-gunningscriterium-co2-prestatieladder-4-0-in-vier-stappen/

Stichting Klimaatvriendelijk Aanbesteden & Ondernemen. (2025b, Maart). Wat is de co□-prestatieladder? https://www.co2-prestatieladder.nl/wat-is-de-co2-prestatieladder/

Stichting Nationale Milieudatabase. (2020, February). Voor Rijkswaterstaat is duurzaam inkopen geen vrijblijvende zaak, 2030 is morgen. https://milieudatabase.nl/nl/actueel/nieuws/voor-rijkswaterstaat-is-duurzaam-inkopen-geen-vrijblijvende-zaak-2030-is-morgen/

Sustainable Development Solutions Network (SDSN). (2025a). Netherlands — country profile | sustainable development report 2025. https://dashboards.sdgindex.org/profiles/netherlands/

TenneT. (2023). Target grid. %7Bhttps://www.tennet.eu/target-grid-0%7D

Witteveen+Bos N.V. (2026). +circular design tool – digital solutions. https://www.witteveenbos.com/digital-solutions/circular-design-tool