Environmental Sustainable Project Portfolio Management

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Master Thesis

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Management summary

Although environmental sustainability is a big topic today, in most organizations it is not yet an explicit part of project portfolio management (PPM). It is important however that projects are in line with the business strategy and that strategic priorities are reflected in PPM (Cooper, Edgett & Kleinschmidt, 1997), which underlines the significance of taking sustainability into account in PPM. The initiator of this research, Bicore Services B.V., identified the mismatch between sustainability goals and PPM and wanted to act on this. The goal of this study was to find out how organizations can make sustainability part of their PPM. The following research question was answered:

How can organizations consider the sustainability of innovation projects when making portfolio decisions in the ideation phase?

This study followed the design science research methodology of Van Aken and Romme (2009). Sustainable PPM has been examined in a systematic literature review and practical insights were gathered by interviewing 10 high-tech organizations. This led to design propositions, which formed the basis for the solution design. This study resulted in a set of guidelines and recommendations to make sustainability part of PPM decision-making. This is elaborated on below.

Sustainable PPM

Projects play an important role in realizing sustainability in organizations (Silvius, Kampinga, Paiagua, & Mooi, 2017). This can be done with PPM, which is about resource allocation in organizations, making decisions about which projects should be selected, continued, and which projects should receive priority (Cooper et al., 1997), and also about delivering projects within time and budget (Fragola, 2010). With their projects, organizations aim to achieve their overall goals while taking into account the constraints (Fragola, 2010). Since most organizations do have sustainability objectives in their organizational strategy, sustainability must be part of their PPM. Furthermore, theory and practice underlined the importance of taking sustainability into account in the innovation process as soon as possible, from the ideation phase and onwards. This is because in this stage companies need to generate a sufficient number and variety of high-quality ideas to obtain a well-balanced portfolio of potentially successful innovation projects, but companies must strictly select and prioritize promising ideas and concepts because resource constraints do not allow for the pursuit of every idea (Kock, Heising, & Gemünden, 2015).

Guidelines for making project portfolio more sustainable

This study resulted in guidelines for integrating sustainability assessment in the decision support system (DSS), setting environmental targets and making commitments, and making more sustainable

portfolio decisions. Figure I shows the guidelines. The guidelines are explained below and recommendations for executing these steps are provided.

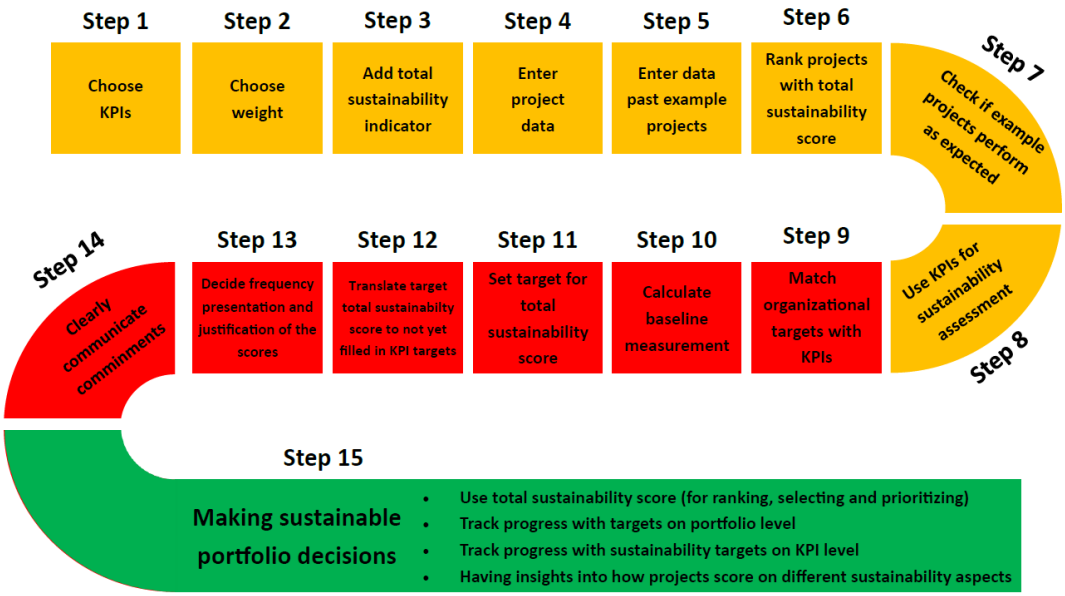

Figure I: Guidelines for sustainable PPM

Integrating sustainability in PPM

First, organizations must integrate sustainable assessment in their DSS for PPM, to make sustainability an integral part of their PPM. By integrating sustainable KPIs next to other KPIs, such as financial and risk KPIs, sustainability is explicitly made part of the multi-criteria decision-making, and in turn part of the project's success. This study provided a list of potentially useful environmental KPIs, shown in Table I. It is suggested that organizations use the KPIs relevant to them. The KPIs must reflect the impact organizations can have on the environment with their projects, customization is therefore necessary. Organizations can select KPIs from the provided list and add other relevant environmental KPIs.

Table I: Proposed environmental KPIs

Climate change mitigation	**Pollution prevention and control**	**Protection and restoration of biodiversity and ecosystems**
1. Energy consumption in manufacturing in MJ per unit 2. Energy consumption in use in MJ per unit 3. Global warming in Kg CO_2 per unit	9. Life-cycle greenhouse gas (GHG) emissions in weight 10. NO_x air emissions in weight 11. SO_x air emissions in weight 12. PM10 and PM2,5 in weight	15. Acidification in Kg SO_x and NO_x 16. Impacts on biodiversity (low/medium/high)

Transition to a circular economy	**Sustainable use and protection of water and marine resources**	**Climate change adaptation**
4. Cumulative energy demand in MJ per unit 5. Total number and volume of significant spills (calculated per unit) 6. Product life in days/months/years 7. Percentage of materials used that can be recycled (in %) 8. Life-cycle raw material consumption (excluding water and renewable or recycled materials) in Kg	13. Water used in the production process per unit in m^3 14. Project life-cycle water requirement in m^3	17. The contribution of the project to climate change adaptation (low/medium/high)

After KPI selection, weights can be attached, which is step 2. Organizations may have more influence on certain environmental aspects, which can be reflected in the attached weight towards the total sustainability score, which is represented by step 3. In step 4 organizations enter their project data. Steps 5, 6, and 7 are used to validate whether the attached weights are well adjusted. If not, the weight attachment should be revised and steps 5 to 7 should be repeated. This part concludes with step 8, stating that the sustainability assessment can now be used. Table II shows recommendations for executing the steps.

Table II: Integrating sustainability assessment

Step	**Recommendation**
1 Choose KPIs	- Select the KPIs on which the organization has an influence. Choose KPIs from a broad perspective of sustainability. - A list with proposed KPIs is provided to trigger looking beyond what already is in place. - The KPIs are selected for the portfolio, and every project within the portfolio will be scored on the same KPIs. - If no sustainability expertise is available within the organization to support the selection of environmental KPIs, it would be best to get external advice on this.
2 Choose weight to link to KPI	- The weight should express the relevance of the KPIs for the organization. Attach more weight to KPIs for the environmental aspects with which the organization can have a bigger influence on the environment and less weight to those the organization has minimal impact on. For example, if a lot of water is used, attach more weight to water usage and if energy usage is minimal, attach less weight to that. - If no sustainability expertise is available within the organization to support the relevance assessment, it would be best to get external advice on this.
3 Add total sustainability score	- All selected KPIs and the attached weight will lead to the total sustainability score.
4 Enter project data	- Enter the project data about environmental sustainability.
5 Enter data past example projects	- Make sure to enter project data of at least one NOT sustainable project, one medium sustainable project, and one very sustainable project. Adding more projects in these three categories will make the validation more reliable.
6 Rank projects using the total sustainability score	- This is executed by the DSS.
7 Check if example projects perform as expected	- If example projects perform as expected, delete the past projects from the set. - If example projects do not perform as expected, the attached weights need to be adjusted.

8 Use KPIs for sustainability assessment	-	Use the KPIs for sustainability assessment of innovation projects and the project portfolio.

Setting targets and making commitments

When sustainability assessment is integrated into the DSS, it is important to set targets and make formal commitments. The performance on the KPIs can be followed, to see if the targets are met. By setting targets on the portfolio level, it is possible to compensate less sustainable projects with more sustainable projects, and by setting portfolio targets for each KPI, none of the environmental aspects will be overlooked and compensated for each time. Steps 9 to 12 are about setting targets, based on already existing organizational targets, the potential influence on the environment the organization has, and baseline measurement. Step 13 is about deciding on the frequency and way of presenting and justifying the sustainable results. Step 14 embodies the importance of communicating the commitments made. Table III shows the steps and recommendations for executing these steps. To reach the targets, support from higher management is required. In the long-term, it is advisable to repeat steps 1 to 14, to set new targets when the previous set targets are met, and to use new sustainability insights that become available due to the increasing knowledge on sustainability.

Table III: Setting targets and making commitments

Step	Recommendation
9 Match (already present) organizational targets with selected KPIs	- If there are already organizational targets that match the selected KPIs from step 1, fill in these targets for the KPIs.
10 Calculate baseline measurement	- This is executed by the DSS.
11 Set target for total sustainability score	- Look at the baseline measurement and set an ambitious but achievable target for a defined period.
12 Translate target for total sustainability score back to targets for the single KPIs	- Look at the target for the total sustainability score and translate this target back to targets for the single KPIs. - Set ambitious but achievable targets for a defined period.
13 Decide on frequency, presentation, and justification of the sustainability scores	- Decide how received results are presented and to whom. - Decide the frequency for presenting the results. - Decide who is responsible for justifying the (not) achieved results. - Link this to formal moments in the organization.
14 Communicate the commitments	- Communicate the commitments to stakeholders, especially to the employees, other players in the supply chain, clients, and shareholders. - Link this to formal moments within the organization.

Making sustainable decisions

When the sustainability assessment is integrated and the targets are set, the tools can be used for decision-making, which is step 15. In Table IV recommendations are presented on how sustainability can be taken into account when making project portfolio decisions.

Table IV: Recommendations for sustainable decision-making

15 Making sustainable decisions **Recommendations**
By using the total sustainability score: organizations can rank projects on their sustainability. They can use the total sustainability score next to other criteria for project selection, e.g. using the total sustainability score, project costs, project risk, etc. to select and prioritize projects**.**
By using the sustainability targets on the portfolio level: organizations can track their progress and keep an eye on if they will meet their targets or if other choices are needed, such as attracting and selecting more sustainable projects.
By using portfolio targets on the KPI level: organizations are challenged to not only focus on 'easy wins' but also to make progress on more challenging KPIs.
By having the insight into how each project scores on different aspects: organizations are challenged to look for sustainable alternatives for projects, for example, the material choice.
By having all the data and the ability to show the meaning of the data: organizations can show the progress on sustainability targets and see which need additional attention to meet the targets. This not only challenges the managers in charge of selecting and prioritizing projects, but also the designers and other people involved in the innovation process.

Conclusion

The 15-step guide and recommendations provide organizations the tools to integrate sustainability into their DSS for PPM, set sustainable targets and make commitments, and advice on how to use these tools for making more sustainable decisions. Using the guide and recommendations will lead to a more sustainable project portfolio. In the long-term, it is advisable to repeat steps 1 to 14, to update the targets and commitments, and use the increasing knowledge on sustainability.

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1. Introduction

The main goal of this study is to find out how sustainability could be integrated into project portfolio management (PPM) decision-making. PPM is about resource allocation in organizations, making decisions about which projects should be selected, continued, and which projects should receive priority (Cooper, Edgett, & Kleinschmidt, 1997), and it is about delivering projects within time and budget (Fragola, 2010). With their projects, organizations aim to achieve their overall goals while taking into account the internal and external constraints (Fragola. 2010). It is important that projects are in line with the business strategy and that strategic priorities are reflected in PPM (Cooper et al., 1997). Therefore, for organizations that have strategic sustainability goals, sustainability must be part of project portfolio decision-making. This study offers organizations guidelines for integrating sustainability in their PPM and provides recommendations on how sustainability can be considered in portfolio decision-making.

This study focuses on environmental sustainability, which recently became even more appealing for organizations due to the introduction of the European Green Deal. The goal of the Green Deal is that the EU becomes climate neutral in 2050. To reach this goal, the EU Taxonomy Regulation was introduced. The EU Taxonomy Regulation establishes six environmental objectives being: (1) climate change mitigation, (2) climate change adaptation, (3) the sustainable use and protection of water and marine resources, (4) the transition to a circular economy, (5) pollution prevention and control and (6) the protection and restoration of biodiversity and ecosystems. These objectives cover a big range of environmental aspects and are therefore a good reference point for this study.

A sustainable organization is an organization that translates the green objectives of the EU Taxonomy Regulation into its business operations. This is in line with the definition of an environmentally sustainable company by Dyllick and Hockers (2002). They state that an environmentally sustainable company is characterized as a company that: (1) only uses natural resources that are consumed at a rate below the natural reproduction or a rate below the development of substitutes, (2) does not cause emissions that accumulate in the environment at a rate beyond the capacity of the natural system to absorb and assimilate and, (3) it does not engage in activities that degrade ecosystem services.

1.1 Context

Considering sustainability in business operations can be done in multiple ways. One way is to consider sustainability in PPM. Bicore is a company that is looking for a way to do so. Bicore is located in

Eindhoven and is specialized in PPM. Bicore develops software to support organizations with optimizing portfolio decisions. The software tool they offer to their clients is called Flightmap. With Flightmap they provide their clients support with portfolio composition, insight analyses, monitoring progress, business intelligence, and process control. In line with the societal movement towards a climate conscience, clients of Bicore are becoming more interested in considering green objectives in their project portfolio decisions. Bicore would like to support its clients with enhancing these environmental objectives by implementing green objectives in Flightmap, based on academic insights on which and how sustainability objectives could be integrated. Bicore wants the sustainability assessment tool to be useful for most of its clients. Their clients mainly belong to three industries; being SMEs, high-tech companies, and housing corporations, where the high-tech companies form the biggest share of their clients. Therefore, the focus of this study is on introducing a sustainability assessment tool for high-tech companies.

1.2 Research objective and research questions

Organizations want to include sustainability objectives when managing their project portfolio. There is a need for a tool to help consider the sustainability of their innovation projects. The goal of this study is to design a solution for the sustainability assessment of innovation projects when making portfolio decisions in the ideation phase. Insights from existing literature and practice are used to create this tool. To guide this research, the main research question is introduced as follows:

How can organizations consider the sustainability of innovation projects when making portfolio decisions in the ideation phase?

To answer the research question, multiple sub-questions should be answered. These sub-questions are divided into three categories, the theoretical research questions addressed by the literature review (LRQ), the empirical research questions (ERQ), and an additional question that should be answered when testing the solution design (TestQ). The sub-questions are presented in Table 1.

Table 1: Overview sub-questions

	Question	Addressed in:
LRQ1	What is an environmentally sustainable innovation project and what is an environmentally sustainable project portfolio?	Chapter 2
LRQ2	How to evaluate the environmental sustainability of an innovation project?	Chapter 2
LRQ3	How can indicators to assess the environmental sustainability of innovation projects be integrated into decision support systems (DSS) for PPM decision-making?	Chapter 2
ERQ1	How do companies decide on which projects to continue while managing their project portfolio?	Chapter 3
ERQ2	How do environmental concerns influence PPM decision-making?	Chapter 3

ERQ3	To what extent are the objectives of the EU Taxonomy Regulation embedded in the companies' strategy and more specifically in the PPM?	Chapter 3
ERQ4	What are the biggest barriers to the incorporation of environmental aspects in project development decision-making and how could these barriers be broken down?	Chapter 3
ERQ5	Is there a need for additional tools to enhance sustainable portfolio management and what are the requirements for these additional tools?	Chapter 3
TestQ	What is the influence of including criteria for environmental sustainability on the a) sustainability of the portfolio, b) time and resource planning of an innovation project and the project portfolio?	Chapter 6

1.3 Theoretical background

This section covers the theoretical background on sustainable portfolio management and portfolio management in the ideation phase.

1.3.1 Sustainable portfolio management

Innovation is one of the key drivers of economic growth for a company. There is an increasing interest in organizations to pay attention to sustainability when innovating, for example, to address the long-term challenges the world is facing, including climate change, population aging, desertification, water scarcity, pollution, and critical raw materials scarcities (Montalvo et al., 2006; Boons, Montalvo, Quist, & Wagner, 2013). Sustainable innovation could be defined as creating new products and processes that provide customer value while using fewer resources and resulting in reduced environmental impacts (Johansson & Magnusson, 1998). Projects play an important role in realizing sustainability in organizations and project managers are accordingly in a position to contribute to sustainable management practices (Silvius, Kampinga, Paiagua, & Mooi, 2017).

A way to manage innovation projects and the corresponding decision-making is with portfolio management. According to Cooper et al. (1997), portfolio management is about resource allocation in the organization, including answering the questions of which new projects should be funded and which projects should receive top priority and be accelerated to the market. Cooper et al. (1997) defined portfolio management as "a dynamic decision process, whereby a business's list of active new product (and R&D) projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be accelerated, killed or de-prioritized; and resources are allocated and reallocated to the active projects." (p. 16).

Portfolio management helps to ensure that created projects are in line with the strategic goals of the organization. According to Cooper et al. (1997), the misfit between the portfolio of projects and the business's strategy is a key problem in portfolio management and project selection. Too many projects are not in line with the business strategy and the strategic priorities are not reflected in the cost distribution between the projects (Cooper et al., 2017). Sustainability can be one of those strategic goals of an organization. According to Brockhaus, Petersen, and Knemeyer (2019), there is

often an underlying disconnect between strategy and new product development (NPD) that explains the lack of momentum when making more sustainable products mainstream. When portfolio management addresses environmental sustainability, it should be done in an integrated way (Jugend et al., 2017a). Brook and Pagnanelli (2014) indicate a need to assess certain aspects of the product portfolio management decision-making process, including that: (1) projects should be aligned with the sustainability agenda of the organization, (2) projects should strengthen the brand position of the organization concerning sustainability, (3) projects should contribute to achieving the zero emission target and/or increasing fuel efficiency, (4) projects should have the potential to strengthen the technical capabilities of the company with regard to sustainability and the projects should be (5) profitable, (6) have market potential, and (7) should tap into customer demand.

Another important aspect of portfolio management is time and resource planning. According to Fragola (2010), the main objective of PPM is to establish the optimal mix and sequencing of current and proposed projects to achieve the organization's overall goals while taking into account the constraints. The goal of portfolio project management is to deliver projects within time and budget, not just manage projects from a schedule perspective (Fragola, 2010). The definitions maintained by Cooper et al. (1997) and Fragola (2010) differ by emphasizing different purposes of portfolio management (respectively focusing on resource allocation in line with the organizational strategic goals and focusing on delivering projects within time and budget). Combining both definitions will help focus this study not only on aligning the organization’s project portfolio with its strategic sustainability goals but also on how this influences the time and resource management of a certain project and the project portfolio.

1.3.2 Portfolio management in the ideation phase

The innovation process can be divided into three parts: the front end of innovation (FEI), the development phase, and the commercialization phase (Koen, Bertels, & Kleinschmidt, 2014). According to Koen et al. (2014), the FEI is a critical component of the innovation process because the choices that are made in the FEI will determine which innovation projects will be continued and therefore can be considered in the development and commercialization phases. The FEI-decision-making is important for the sustainability of a new product because (1) it is best to choose a target market in the FEI that allows for or even asks for a product that is environmentally sustainable throughout its life-cycle, (2) to maximize sustainability a wise decision in terms of the technology choice is required in the FEI and (3) an anticipatory decision needs to be made in the FEI concerning a new product’s sustainability with regard to the product form (Eling, 2020).

According to Heising (2012), “the front end is an umbrella term for everything that occurs between the proverbial blank sheet of paper up to the project proposal, that is, the scope change of

running projects" (p. 584). In this study, the FEI is referred to as the ideation phase. The ideation phase contains three smaller stages being (1) identifying opportunities and generating ideas, (2) evaluating and selecting these ideas, and (3) condensing, clustering, and bundling these ideas into proposals for new projects or changes in the scope of existing projects (Heising, 2012). The ideation phase concludes with a project proposal or a proposal for a change of scope of a running project. Ideation portfolio management is a way to manage this ideation phase and is about making decisions about which ideas should be further developed into concepts (Heising, 2012). The task of ideation portfolio management is to support PPM with a flow of project proposals that generate high value and that support the implementation of developed strategic goals (Heising, 2012). Kock, Heising, and Gemünden (2015) emphasize the importance of the ideation stage because in this stage companies need to generate a sufficient number and variety of high-quality ideas to obtain a well-balanced portfolio of potentially successful innovation projects, but companies must strictly select and prioritize promising ideas and concepts because resource constraints do not allow for the pursuit of every idea.

It is most efficient to take sustainability into account in the ideation phase because by doing so the sustainability of projects is evaluated before the projects are further developed. Hakkarainen and Talonen (2014) also state that "infertile ideas and subsequent projects must be screened out as early as possible. This will save money, time, and effort, as well as reduce waste. Rescued resources can be re-focused and allocated to more promising initiatives" (p. 65). Therefore, it is resource-efficient to consider sustainability in the ideation phase, because when the project proposal is accepted, a considerable amount of resources is committed and these resources will be wasted when stopping the project due to not taking into account strategic goals earlier on.

1.4 Research methodology

The design science research (DSR) methodology is taken as the approach. Van Aken and Romme (2009) define DSR) as "research based on the approach of the design sciences, that is, research that develops valid general knowledge to solve field problems" (p.7). DSR has three characteristics: (1) research questions are driven by field problems, (2) it emphasizes solution-oriented knowledge, linking interventions or systems to outcomes, as the key to solving field problems, and (3) the justification of research products is largely based on pragmatic validity (Van Aken & Romme, 2009). This study is driven by a field problem, has an emphasis on solution-oriented knowledge to solve the field problem and pragmatic validity is the key to justifying the solution. The three characteristics of DSR as proposed by Van Aken and Romme (2009) therefore have a good fit with this study and DSR is consequently used as the basis for the research design of this study.

To be more specific, the DSR-cycle from Van Aken and Romme (2009), shown in Figure 1, is taken as the reference point for the research design. The DSR-cycle of Van Aken and Romme (2009) is not only based on DSR, it also addresses evidence-based management (EBM). EBM helps to integrate formal and explicit knowledge and offers a way for theory-informed field problem-solving (Van Aken & Romme, 2009). Since the provided case of Bicore aims for a theory-based solution, this research design fits.

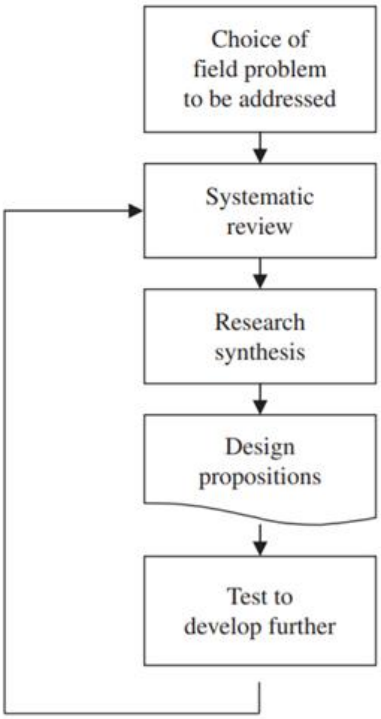

Figure 1: The design science research cycle (Van Aken & Romme, 2009)

Every step of the research design model asks for a different method. According to Van Aken and Romme (2009), DSR can use all methods for data gathering and analysis, but in practice research strategies tend to be case-based, collaborative, and interventionist. For the first step of the research cycle, to choose the field problem to address, practical insights from Bicore are gathered. The second step is to conduct a systematic review, this is done with a systematic literature review (SLR) to investigate useful objectives in the existing literature and an empirical review by conducting interviews with high-tech companies to get insights into the needs and requirements from practice. In the third step, research synthesis, insights from literature and practice are combined.

The fourth step is to develop design propositions. Denyer, Tranfield and Van Aken (2008) proposed a design proposition that could help in designing a solution to apply relevant theory in practice. Their design proposition follows the CIMO-logic, which means that there is a Context with a problem, for which the design proposition suggests a certain type of Intervention, to get through specified generative Mechanisms to the intended Outcome(s). This CIMO-logic is helpful to design the solution to support organizations in considering the sustainability of projects when making portfolio decisions in the ideation phase. The fifth step is to test the specific design in the specific setting. Design propositions should be tested on pragmatic validity (Aken & Romme, 2009). This is done with interviews with high-tech companies, supported by visualizations of the solution.

1.5 Document set-up

This master thesis report offers organizations insight into how sustainability can be considered in PPM. This chapter covers the context, theoretical background, research methodology, and research questions of this study. Chapter 2 elaborates on the SLR and the theoretical results are presented. Chapter 3 elaborates on how the empirical research is conducted and the results of the empirical research are discussed. This is followed by chapter 4 in which the theoretical and empirical design

propositions are combined and these are used in chapter 5 to design the solution. Chapter 6 discusses the validation of the solution design. Finally, chapter 7 provides the conclusion and discussion of this research.

2. Literature review

The first three sub-questions are answered with the use of an SLR. First, it is explained how the research items are selected. Second, the selected research items are used to answer the sub-questions. The theoretical findings are also used to base theoretical design propositions upon.

2.1 Method

An SLR is conducted to find the existing knowledge on the topic. According to Hiebl (2021), the desired attributes of systematic reviews are that they should be (a) structured, (b) transparent, and (c) comprehensive. The sample selection process in systematic reviews contains three steps: first the identification step, the second step is screening and the third step is the disclosure of the review sample. This chapter elaborates on the choices made in each step and the results of the SLR.

2.1.1 Identification

The first step is the identification which "encompasses the search for research items that are potentially relevant to the predefined research question(s)" (Hiebl, 2021, p.5). The predefined research questions that this SLR is focused on are sub-questions a), b) and c):

a) *What is an environmentally sustainable innovation project, and what is an environmentally sustainable project portfolio?*
b) *How to evaluate the environmental sustainability of an innovation project?*
c) *How should indicators to assess the environmental sustainability of innovation projects be integrated into the decision support system (DSS) for the PPM decision-making process?*

Hiebl (2021) distinguishes four types of approaches for the identification of relevant research items, (a) the journal-driven approach, (b) the database-driven approach, (c) the seminal-workdriven approach, and (d) combined approaches. For this SLR the database-driven approach is taken, which entails that the search for items is done with the use of one or multiple electronic databases and with the help of predefined keywords (Hiebl, 2021). The advantages of using the database-driven approach according to Hiebl (2021) are that it makes the identification phase structured, a wide range of research items are included and it will help discover research that is new to the researcher.

Keywords that address the topics of the sub-questions are defined, to find literature that helps answer the sub-questions. To cover a wide range of potentially relevant research, corresponding synonyms of the keywords are included when searching through the electronic databases. In Table 2 an overview is provided with search terms and corresponding synonyms that are used for this SLR. The synonyms for 'sustainable' address the broad concept of sustainability. More synonyms can be

thought of when addressing subjects within this broad concept, such as circularity, zero emission, zero waste, or climate change mitigation, but these are not included in the search to keep the focus on the broad concept in which all the objectives of the EU Taxonomy Regulation are included.

Besides defining the keywords, which in turn lead to search strings, it is also important to select databases. According to Hiebl (2021), a rough benchmark for the number of databases that should be used is three. Therefore, in this SLR three databases are selected which are (1) Proquest, (2) Scopus, and (3) Web of Science. Research items should cover relevant research items irrespective of their publication date and therefore the time period is not disclosed. Not disclosing a time period is according to Hiebl (2021) "particularly suitable for topics where there has not been a review published before and where the resulting number of research items is still manageable" (p. 11), which is expected to be the case for this study.

Table 2: Overview of keywords and synonyms

Index	Keyword	Synonym
1	Sustainable	Green, environmental-friendly, eco-friendly
2	Innovation	Introduction, breakthrough
3	Evaluate	Assess, indicate
4	Portfolio management	

2.1.2 Screening

The second step is to screen the potential relevant research items. Since the database-review approach is taken, the identification can lead to thousands of potentially relevant research items. A time-saving strategy is to first skim only through the titles of the research items, to find content fit before analyzing the abstracts and keywords of the items (Hiebl, 2021). During the screening, a few articles are labeled as irrelevant based on their title. For the remaining articles, the abstract and keywords were used for the relevance assessment. For a structured and transparent evaluation of the fit between the research subject and the research items, the A/B/C logic as proposed by Pittaway et al. (2004) is used, in which all research items are classified as particular relevant (A), potentially relevant (B), and a little or not relevant (C). Also, inclusion and exclusion criteria are used to help assess the relevance of the research items. In Table 3 an overview of these inclusion and exclusion criteria is provided. These will also help the SLR to be structured, transparent, and comprehensive and will help to focus on the research items that can help answer the predefined research questions.

To ensure the quality of the research items, only peer-reviewed research items are included. This means that grey literature is not part of this SLR, because it is hard to assess the quality of these research items.

Table 3: Inclusion and exclusion criteria

Criteria	Reason
Inclusion criteria	
The research item is published in English	The literature should be understandable for a big part of the population, for the SLR to be reproducible and transparent.
The research item is available online	The literature should be accessible to a big part of the population, for the SLR to be reproducible and transparent.
The research item is peer-reviewed	Quality standards for the literature should be met.
The research item addresses the topics of environmental sustainability; innovation projects; portfolio management	The literature should help answer the research (sub) questions.
Exclusion criteria	
The research item will not help answer the research (sub) questions	The literature should help answer the research question.
The research item is about ESG but is solely about financial investments	The literature should help answer the research question.
The research items are about green or sustainable building	The literature should help answer the research question.

2.1.3 Disclosure of the research sample

The predefined search strategy leads to the following results, as presented in Table 4.

Table 4: Overview of research strategy and results

Digital library	Proquest	Scopus	Web of Science
Search query	ab((sustainability OR sustainable OR green OR eco-friendly OR environmental-friendly)) AND ("portfolio management") AND ab((innovation OR innovative)) AND NOT ab(building)	TITLE-ABS-KEY ((sustainable OR green OR eco-friendly OR environmental-friendly) AND (innovation) AND "portfolio management" AND NOT (building OR stock))	(sustainable OR green OR eco-friendly OR environmental-friendly OR sustainability OR ecological) (All Fields) AND (innovation OR innovative) (All Fields) AND "portfolio management" (All Fields)
Search in	Peer-reviewed	TITLE-ABS-KEY	All fields
Language filter	English	English	English
Results	89	32	76
Unique results	163		

2.1.4 List of articles and their assessed relevance

The complete list of research items that results from the research strategy is presented in Appendix A. With the search strings in the three different digital libraries, there are 163 unique research items found. After assessment for the relevance, (A) 27 are classified as particularly relevant, (B) 23 as potentially relevant, and (C) 103 as little or not relevant. The relevance score for each article can be found in Appendix A.

With the use of the search strategy for the identification, the screening, the inclusion and exclusion criteria, and the relevance assessment, research items are selected. The selected research

items are the research items that are classified as particularly relevant (Relevance Score A). The selected articles can be found in appendix B.

2.2 Results

The selected research items are used for answering the research questions. The results are divided into three sections. First, the definitions of environmental sustainable innovation projects and sustainable project portfolios are discussed. Second, there is elaborated on how the environmental sustainability of projects can be assessed, including topics such as checklists, scoring and ranking, environmental indicators, and diagrams and matrices. Third, it is discussed how environmental indicators can be integrated into the DSS. The most important insights are translated into empirical design propositions and are summarized in the conclusion of this chapter.

2.2.1 Environmental sustainable innovation project and project portfolio

To answer the first sub-questions, an environmental sustainable innovation project should be defined. Not all of the selected articles focus solely on the environmental aspect of sustainability. Some of the articles focus on the triple bottom line of sustainability. The triple bottom line of sustainability addresses the 3P's of sustainability referring to people (i.e. social values), planet (i.e. environmental or green values), and profit (i.e. economic values) (Vandaele and Decouttere, 2013; Daneshpour and Takala, 2017; Armenia, Dangelico, Nonino, & Pompei, 2019; Garcez, Junior, & Farah, 2016; Paillé & Halilem, 2019). The triple bottom line of sustainability helps to explain the broader concept of sustainability, however, the focus of this study is on environmental sustainability i.e. the P for planet. A commonly used definition for sustainability, that is mentioned in a considerable part of the selected articles, is the definition of sustainable development from the Brundtland report where it is defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (1987, p. 37).

Besides using different definitions for sustainability, different terms are used to address the topic of environmental sustainability in project development, such as eco-design, sustainable product design, life-cycle approach, and green product development. According to Topleva and Prokopov (2020), "the eco-design is a preventative approach to manage environmental aspects" (p. 1464). Brones, Zancul, and Carvalho (2020) refer to the definition of Goffin (2012) where "eco-design requires the alignment and insertion of formal environmental commitments in innovation processes throughout the stages and gates for decision-making". Letens (2015) refers to the '12 Facts of Ecological Design' (IDSA, 1992) which include "(1) make it durable, (2) make it easy to be repaired, (3) design it so it can be remanufactured, (4) design it so it can be reused, (5) use recycled materials (6)

use commonly recyclable materials, (7) make it simple to separate the recyclable components of a product from the non-recyclable components (8) make products more energy/resource efficient, (9) eliminate the toxic/problematic components of a product or make them easy to replace or remove before disposal, (10) use product design to educate on the environment, (11) work toward designing source reduction-inducing products (i.e., products that eliminate the need for subsequent waste), and (12) adjust product design to reduce packaging" (p. 55).

From the different terms and definitions used in the selected articles, characteristics for sustainable innovation projects can be retrieved. For example, Jugend et al. (2017b) use the definition for green product development (GPD) as provided by Albino, Balice, and Dangelico (2009) where GPD is defined as "the development of a product designed to minimize its environmental impact during its entire lifecycle" (p. 1182). This definition is similar to the definition of the life-cycle approach, which according to Helling (2015) "helps to ensure that environmental burdens are not unintentionally transferred from one life-cycle stage to another during process improvement, and thus helps to prevent unintended environmental consequences (p. 1773). Dangelico and Pujari (2010) choose to take the view of Ottman, Stafford, and Hartman (2006) as their reference point, stating that ''although no consumer product has a zero impact on the environment, in business the terms 'green product' or 'environmental product' are used commonly to describe those that strive to protect or enhance the natural environment by conserving energy and/or resources and reducing or eliminating the use of toxic agents, pollution, and waste.'' (p. 471). So, the environmental impact of a project should be minimized, unintended environmental consequences should be prevented and the project should strive to protect or enhance the natural environment.

With this explanation of what environmental sustainability in project development entails, a translation to the level of innovation projects should be made. Kaboyashi, Kato, Maezawa, and Sano (2011) distinguish between two categories of innovation: (1) process innovation, which is about improving efficiency or optimizing cost and in sustainable product design it is related to eco-improvement, and (2) value innovation, which is about creating new-value added or new functions and in sustainable product design corresponds to eco-innovation. Both categories of innovation are important when evaluating the sustainability of innovation projects because both contribute to a more sustainable portfolio differently, whether it is by improving the sustainability of an existing project or product or by introducing a new project or product that is sustainable from the start. A way to enhance the sustainability of innovation projects is with sustainable portfolio management. According to Villamil and Hallstedt (2018) "Sustainability product portfolio is about sustainability considerations into product portfolio development. A company portfolio is a set of programs and projects and it is related completely to the business goals and the strategy of the organization. That means that

companies introducing sustainability into their portfolio guarantee to have more sustainable products, services, processes or technologies." (p. 154). A sustainable project portfolio could therefore be defined as a set of programs and projects of which a significant part can be labeled as sustainable innovation projects and the set of programs and projects is related to the sustainability goals and strategy of the organization.

To summarize the findings related to the first sub-question, an overview of the characteristics of a sustainable innovation project is presented in Table 5.

Table 5: Characteristics of a sustainable innovation project

	Characteristics of a sustainable innovation project	References
1	Designed to minimize its environmental impact during its entire lifecycle	Jugend et al. (2017b); Albino et al. (2009)
2	Unintended environmental consequences are prevented	Helling (2015)
3	Strives to protect or enhance the environment by conserving energy and/or resources and reducing or eliminating the use of toxic agents, pollution, and waste	Dangelico and Pjuari (2010); Ottman et al. (2016)
4	Based on formal environmental commitments for decision-making in the innovation processes	Brones et al. (2020); Goffin (2012)

Remarkably, most of the selected articles focus on NPD, instead of the broader concept of project development. Therefore, the characteristics are translated from the perspective of NPD to innovation projects.

What is an environmentally sustainable innovation project?
A sustainable innovation project is designed to minimize its environmental impact during its entire lifecycle (1), prevents unintended environmental consequences (2), strives to protect or enhance the environment (3) and is based on formal environmental commitments for decision-making in the innovation process (4).

What is an environmentally sustainable project portfolio?
A sustainable project portfolio is a set of programs and projects that is related to the sustainability goals and strategy of the organization (1) and a significant part of the projects can be labeled as sustainable innovation projects (2).

This leads to the first theoretical design proposition: *In a high-tech organization that applies PPM (C), formal environmental commitments for decision-making are made (I), such that the innovation projects are designed to minimize their environmental impact during their entire life cycle; unintended environmental consequences are prevented; there is strived to protect or enhance the environment (M) and as a result, the project portfolio is labeled environmentally sustainable (O).*

Text box 1: Answer to literature research question 1 and theoretical design proposition 1

2.2.2 Assessing environmental sustainability

In the selected articles multiple methods and assessment tools for sustainability are addressed. The tools and methods in the development of green products must be easy to use, to increase the

possibility of companies overcoming limitations and barriers to their application, and for optimizing the time and resources available for selecting and applying them (Ammenberg & Sundin, 2005; Pinheiro et al., 2018). The methods and tools used in the selected articles can be divided into two categories. The first category contains checklists, scoring, and, ranking. These methods and tools, such as the eco-design checklist and the ecological footprint, can help to verify if environmental objectives are considered and support the selection and prioritization of projects by using predefined evaluation criteria (Pinheiro et al., 2018). The second category includes diagrams and matrices, such as the MET-Matrix, which can help to provide insight into the product life cycle and show possible improvements related to the environmental performance of the project (Pinheiro et al., 2018). An overview of the most mentioned methods and tools can be found in Table 6.

Table 6: Overview of methods and tools for evaluating project sustainability

Methods & tools	Application	Examples	References
Checklists, scoring, and ranking	1) Verify if environmental objectives are considered. 2) Support selection and prioritization projects by using predefined evaluation criteria	Eco-design checklist; sustainability criteria for choosing and allocating resources among projects; ecological footprint; multi-criteria decision-making; analytic hierarchy process (AHP), Data envelopment analysis (DEA)	Pinheiro et al. (2018); Kobayashi et al. (2011); Jugend et al. (2017b); Jugend et al. (2017a); Danesphour and Takala (2017); Lee et al. (2021); Garcez et al. (2016b); Brones et al. (2020); Ellis et al. (2021); de la Cruz López et al. (2021)
Diagrams and Matrices	1) Provide insight into the product life cycle 2) Provide insight into possible improvements related to the environmental performance of the projects	MET-Matrix; life-cycle flow diagram	Pinheiro et al. (2018); Topleva and Prokopov (2020); Jugend et al. (2017a)

2.2.2.1 Checklists, scoring, and ranking

Most of the methods and tools mentioned belong to the category of checklists, scoring, and ranking. Good indicators are crucial for this category of sustainability assessment. First, some methods and tools are discussed. Second, useful indicators are discussed concerning the objectives of the EU Taxonomy Regulation, since this is the reference point of this study.

Life-Cycle Assessment (LCA) is one of the most used tools for guiding the selection of the elements that will be part of the portfolio according to Villamil and Hallstedt (2018). The LCA techniques are mentioned in a considerable share of the selected articles (de la Cruz López et al, 2021; Villamil & Hallstedt, 2018; Peralta, Alcalá & Soltero, 2021; Kobayashi, Kato, Maezawa and Sano, 2011).

There are different ways in which LCA can be used, Peralta et al. (2021) came up with a combination of LCA and cradle-to-cradle (C2C) techniques and their method can be referred to as the LCA+C2C endpoint weighting method. Instead of C2C, Ellis, Colin-Jones, Solvay, and Washer (2021) used cradle-to-gate life-cycle assessment. It is therefore important to make explicit which part of the project life needs to be assessed. Combing methods is also possible, for example, at DOW they encourage their project teams to a life-cycle perspective by embedding in the Dow Chemical Sustainability Footprint Tool ©, which is a simple life-cycle flow diagram for the team to complete (Helling, 2015). However, according to Kobayashi et al. (2011) "full LCA is difficult to apply because of the lack of detailed product life cycle information at the R&D stage". Another difficulty to overcome is that LCA is mainly based on the assessment of a new product instead of a new project, and since project development encompasses more aspects than NPD, a broader approach is needed.

Multiple articles address multi-criteria decision-making (MCDM) methods for indicator integration (Daneshpour & Takala, 2017; Lee, Lui & Tsang, 2021; de la Cruz López et al., 2021; Brook & Pagnanelli, 2014). According to Lee et al. (2021), MCDM methods play an essential role in prioritizing the emerging product features on the market and in ranking various NPD projects. The best worst method (BWM) and technique for order of preference by similarity to ideal solution (TOPSIS) are good examples. BWM is especially helpful when comparing project features is complex and TOPSIS can help focus on the trade-offs among the various criteria to obtain an ideal solution (Lee, et al., 2021). The AHP (Analytic Hierarchy Process) is also an MCDM method that is mentioned in multiple articles (de la Cruz López et al., Brook & Pagnanelli, 2014; Lee et al., 2021) and it can help structure complex decision-making. A big advantage of MCDM is that sustainability indicators can easily be integrated as one of the criteria to base decision-making on. Companies focus their decision-making on multiple criteria such as profit and project risk. By integrating sustainability as an additional criterion, sustainability is considered and the project can still be assessed from a holistic view.

Including sustainability may sound easy, however, some sustainability objectives are hard to quantify and the relative importance of sustainability objectives differ for each project. This makes different types of projects hard to compare. For example, comparing a project for a new type of car tire with a project for a new type of car engine is hard because they are both related to different aspects of sustainability. Garcez et al. (2016b) came up with a solution for this, they proposed a list of environmental indicators and then score each project according to these indicators on a scale from 1 (very low) to 5 (very high), as well as how important that indicator is for the project on a 5-point scale from very low to very high and a relative score. By doing so, the relative important indicators for each project weigh more towards the sustainability score than relative unimportant indicators for the specific project.

Another way to assess the environmental impact is with the use of the eco-design checklist (Jugend et al., 2017a; Jugend, et al., 2017b; Kobayashi et al., 2011). The eco-design checklist can support the analysis of the impact of the project on the environment. Besides, it will make sure that the sustainability of a project is considered. The checklist of Kobayashi et al. (2011) with examples of evaluation items for all research and development (R&D) themes shows an interesting insight into what should be included in the assessment. They used four evaluation categories: (1) energy-saving and low carbonization, (2) resource-saving, (3) resource circulation, and (4) low harmful material. Within each category two or three evaluation items are included. Their checklist should be filled in by comparing with the competitor's technology. This is unfortunately not something that can always be easily executed because not every project is a substitute for a competitor's project nor is every detail about the competitor's project available. Besides, it will be hard to use this for selecting and prioritizing the projects in an organization's innovation portfolio because other projects might not be comparable. Nevertheless, such a checklist can help to place the project of the company in context.

2.2.2.2 Environmental indicators

For checklists, scoring, and ranking tools to be useful, they should be based upon good indicators. According to Daneshpour and Takala (2017), useful indicators to measure sustainability are quantitative indicators that can represent the main elements of sustainability, such as material flow analysis (MFA) and the ecological footprint. Ellis et al. (2021) also choose to quantify environmental footprints and Brones, Zancul, and Carvalho (2020) also include the carbon footprint of a product in their environmental calculator. DOW introduced its tool to assess the sustainable footprint of its projects. Of the six sustainability dimensions covered in the Dow Chemical Sustainability Footprint Tool ©, three are about environmental aspects: (1) life-cycle greenhouse gas (GHG) emissions, (2) life-cycle water requirements, and (3) life-cycle raw material consumption (excluding water and renewable or recycled materials). Using indicators for assessing sustainability during the management of R&D is therefore nothing new, however, the indicators must fit with the strategic goals of the company as well as the sector it operates in. For example, even though for DOW the Sustainable Chemistry Index is useful to identify improvement opportunities, drive innovation, and measure progress, this index will not fit companies within other sectors than chemistry.

Within the selected articles, different indicators are proposed with different levels of being specific. For example, Garcez et al. (2016b) propose a list of 12 environmental indicators including: "(1) materials used by weight or volume, (2) direct energy consumption by primary energy source, (3) indirect energy consumption by a primary source, (4) total water withdrawal by source, (5) location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas, (6) total direct and indirect greenhouse gas emissions by

weight, (7) other relevant indirect greenhouse gas emissions by weight, (8) emissions of ozone-depleting substances by weight, (9) NOx, SOx, and other significant air emissions by type and weight, (10) total water discharge by quality and destination, (11) total weight of waste by type and disposal method, and (12) total number and volume of significant spills" (p. 29). This is an elaborate list because for example there is a distinction between the indirect and direct energy consumption of the primary source and between waste and significant spills. Other studies focused on less but broader indicators, such as cumulative energy demand (Peralta et al., 2021) and impacts on biodiversity (Jugend et al., 2017). Good communication about what each indicator entail is therefore important.

Most of the methods and tools presented in Table 6 rely on sustainability indicators that reflect the sustainable impact of the project. During the SLR multiple indicators came across. Since the solution should be based on the environmental objectives of the EU Taxonomy, an overview of useful indicators to match these objectives is presented in Table 7. When looking at Table 7, it becomes clear that even though a lot of useful indicators are presented in previous articles, none of the indicators belong to the category of climate change adaptation. Indicators for the sixth objective "protection and restoration of biodiversity and ecosystems" also seem insufficient in covering the objective. It also strikes that all indicators focus on preventing environmental harm and not on preparing or improving the environmental quality. However, the objectives of the EU Taxonomy go beyond preventing environmental harm and looking for additional indicators to fill this gap is therefore necessary.

Table 7: Sustainability indicators related to the EU Taxonomy

Objective EU Taxonomy Regulation	**Useful indicators**
1. Climate change mitigation	● Energy consumption in manufacturing (Koboyashi et al., 2011; de la Cruz et al., 2021; Jugend et al., 2017) ● Energy consumption in use (Koboyashi et al., 2011; de la Cruz et al., 2021; Jugend et al., 2017) ● Global warming in Kg CO_2 (Brook & Pagnanelli, 2014; Peralta et al. 2021; de la Cruz et al., 2021) ● Ozone depletion in Kg CFC-11 (Peralta et al., 2021)
2. Climate change adaptation	-
3. Sustainable use and protection of water and marine resources	● Total water withdrawal by source (Garcez et al., 2016b) ● Total water discharge by quality and destination (Garcez et al., 2016b) ● Fresh water and marine aquatic eco-toxicity in Kg 1.4-DB (Peralta et al., 2021) ● Eutrophication in Kg PO4 (Peralta et al., 2021) ● Water use/depletion (Peralta et al., 2021; Jugend et al., 2017) ● Life-cycle water requirements (Helling, 2015)

4. Transition to a circular economy	● Cumulative energy demand in MJ (Peralta et al., 2021) ● Life-cycle raw material consumption (excluding water and renewable or recycled materials) (Helling, 2015) ● Waste by type and disposal method (Garcez et al., 2016b; Jugend et al., 2017) ● Total number and volume of significant spills (Garcez et al., 2016b) ● Indicator for material saving (TMR) (Kobayashi et al., 2011) ● Product life (Kobayashi et al., 2011) ● Materials to be used (Jugend et al., 2017)
5. Pollution prevention and control	● Human toxicity in Kg 1.4-DB (Peralta et al., 2021) ● Particulate matter formation in Kg PM10 (Peralta et al., 2021) ● Photochemical oxidation potential (SMOG) in Kg C2H4 (Peralta et al., 2021) ● Life-cycle greenhouse gas (GHG) emissions (Helling, 2015; Garcez et al. 2016b) ● NOx, SOx, and other significant air emissions by type and weight (Garcez et al., 2016b) ● Toxic potential indicator (TPI) (Kobayashi et al., 2011)
6. Protection and restoration of biodiversity and ecosystems	● Acidification in Kg SO2 (Peralta et al., 2021) ● Terrestrial eco-toxicity in Kg 1.4-DB (Peralta et al., 2021) ● Impacts on biodiversity (Jugend et al., 2017)

2.2.2.3 Diagrams and matrices

Different diagrams and matrices can be used to give insight into the project life cycle and to shed light on possible environmental improvements. The MET-Matrix is frequently mentioned in the selected research items to help create insight into the environmental sustainability of a product during its entire life cycle. The MET-matrix can help visualize the environmental impact of a project, with Materials, Energy, and Toxicity on the y-axis and Production, Use, and Disposal on the X-axis is also mentioned by for example Topleva and Prokopov (2020) and Jugend et al. (2017a). Even though it provides insight into what the environmental impact of the project is in terms of the materials and energy used and the toxicity it is associated with, during the multiple phases of the life cycle, it does not help to quantify the environmental impacts.

Since the goal of this study is to come up with a solution to assess the sustainability of innovation projects to fit in an existing DSS, it could be concluded that tools providing qualitative information such as diagrams and matrixes can be helpful to get insight into the sustainability of a project but will not be the easiest solution to integrate into the project portfolio DSS. As Brones and Carvalho (2015) put it “the integration of eco-design in project management, complementing more global portfolio guidelines, calls for new approaches such as project success factors and “trade-off” solutions between the various dimensions (quality, cost, time, and environmental sustainability), the

multifunctional teamwork, covering the perspectives of the life cycle of products and the various stakeholders of the value chain". It is therefore important to make the sustainability assessment part of the broader approach towards PPM and the trade-offs that need to be made, for quantifiable tools such as scoring and ranking will be most easy to integrate.

How to evaluate the environmental sustainability of an innovation project?

There are multiple tools that could be used to evaluate the sustainability of innovation projects, however not all tools are easy to integrate into the broader approach of PPM, for example, because they are not based on quantitative information. It is therefore most practical to use checklists, scoring, and ranking tools. It is important that these tools are based on solid environmental indicators that reflect the sustainable impact of the projects.

This leads to the second theoretical design proposition: *In a high-tech organization that applies PPM (C), checklist, scoring, and ranking tools for sustainability are integrated in the decision support tools; based on solid environmental indicators that organizations have impact on (I), such that sustainability is one of the aspects considered in PPM (M) and as a result the project portfolio is environmentally sustainable (O).*

Text box 2: Answer to literature research question 2 and design proposition 2

2.2.3 Integrating indicators in the DSS

The previous section elaborates on multiple tools that could be used to assess environmental sustainability. Potential indicators are presented, but the question about how this sustainability assessment could be integrated into an existing DSS remains.

Project management software is a way to help companies to manage their projects to control the time, costs, and scope, and this software forms an important foundation for project management and offers possibilities from the sustainable project management perspective (Daneshpour & Takala, 2017). However, according to Daneshpour and Takala (2017) "there is a close relationship between software and standards of project management while these standards, themselves, have failed to respond to the need of sustainability management properly" (p. 18). It is therefore important to first set standards for sustainability and then integrate these standards into the DSS.

So, a DSS offers possibilities to take into account sustainability in portfolio management, and in the previous section, it was concluded that MCDM is a suitable method to include sustainability in the decision-making process. This leads to the question of how additional criteria can be integrated into the DSS. Villamil and Hallstedt (2018) refer to Hallstedt and Isaksson (2017), stating that "sustainable product development has a "strategic sustainability perspective" based on life-cycle

thinking and is implemented in the early stages of the innovation process." (p. 147/148). According to Brones et al. (2015) integrating environmental requirements at the meso-level is aimed at the product development process and portfolio management. On this level, Brones et al. (2015) propose "alignment and insertion of formal environmental requirements in the product development process throughout the key stages and gates for decision-making, from the early and particularly decisive stages (Goffin, 2012)" and "integration of eco-design in portfolio management, including decision/trade-offs criteria associated with the environmental dimension; quantitative environmental life cycle indicators (Pigosso, Rozenfeld, & McAloone, 2013)" (p. 54). Jugend et al. (2017b) analyzed the integration of environmental sustainability issues and NPD and found in previous studies (from Collado-Ruiz and Ostad-Ahmad-Ghorabi (2013) and Sihvonen and Partanen (2016) amongst others) that "the product portfolio decision selection phase represents an opportunity to improve the environmental impact of the product since it is at this moment that more possibilities for choosing the project characteristics can arise and be chosen, and these will influence the entire product life cycle" (p. 432). So, the sustainability criteria should be implemented to guide decision-making in the early stages of the project development process and are particularly relevant at the decisive stages.

How should indicators to assess the environmental sustainability of innovation projects be integrated in the DSS for the PPM decision-making process?

The indicators for sustainability should be implemented in the DSS to support the MCDM-method. This to improve the decision-making in the early stages of the innovation process and the sustainability criteria should be considered when making decisions in the FEI.

This leads to the third theoretical design proposition: *In a high-tech organization that applies project portfolio management (C), the indicators for sustainability should be implemented in the DSS to support the MCDM-method (I), such that sustainability is considered when making decisions in the FEI (M) and as a result the project portfolio is environmental sustainable (O).*

Text box 3: Answer to literature research question 3 and design proposition 3

2.3 Conclusion

Different definitions and terms for sustainability are used in previous research. A big share of the previous research focuses on NPD, while sustainable innovation is broader than NPD. Previous insights are therefore translated to the level of innovation projects. To assess the sustainability of these projects, different methods and tools can be used but most methods are based on a broad range of sustainability indicators. Where the EU Taxonomy focuses on preventing harming the environment, as well as enhancing the environment, and adapting to the new climate, almost all selected research

items solely focus on doing no or less harm to the environment. The indicators presented in the selected articles do not cover all environmental objectives of the EU Taxonomy.

Since an important characteristic of PPM is holistically approaching the portfolio, sustainability should be integrated and considered in decision-making, as well as other aspects such as costs, risks, profit, and return on investment. This makes the MCDM-method fit the approach, to include sustainability as one of the criteria to base decisions on. Integrating the environmental indicators into DSS to support the MCDM-method should be done in the early stages of the innovation process, so it can support the decision-making in the FEI.

Based on these theoretical findings, theoretical design propositions were formulated. An overview of these theoretical design propositions can be found in Table 8.

Table 8: Theoretical design propositions

	Theoretical design proposition
1	In a high-tech organization that applies PPM (C), formal environmental commitments for decision-making are made (I), such that the innovation projects are designed to minimize their environmental impact during their entire life cycle; unintended environmental consequences are prevented; there is strived to protect or enhance the environment (M) and as a result, the project portfolio is labeled environmentally sustainable (O).
2	In a high-tech organization that applies PPM (C), checklist, scoring, and ranking tools for sustainability are integrated into the decision support tools; based on solid environmental indicators that organizations have an impact on (I), such that sustainability is one of the aspects considered in PPM (M) and as a result, the project portfolio is environmentally sustainable (O).
3	In a high-tech organization that applies PPM (C), the indicators for sustainability should be implemented in the DSS to support the MCDM-method (I), such that sustainability is considered when making decisions in the FEI (M) and as a result, the project portfolio is environmentally sustainable (O).

3. Empirical research

The goal of the empirical research is to gather insights from practice about how sustainability is considered in PPM and how this could be improved. Besides, the interviews can help validate the results from the SLR. It is also important to get more insights into how the environmental objectives of the EU Taxonomy can be used from a portfolio perspective and to what extent the objectives are already included in project portfolio decision-making. These interviews help to shed more light on how environmental sustainability can influence PPM and how the role of sustainability can be strengthened in practice, for example with the use of a DSS. It is also important to gather information about at what moment in the innovation process sustainability should be considered. To get a better feeling of what companies need for improving sustainability enhancement in their decision-making, the biggest barriers are discussed and the needs for additional tools are identified. The information that is gathered is used to base empirical design propositions upon. Besides, the empirical research questions, as mentioned in Table 1, are answered.

3.1 Empirical method

Due to the practical character of this study, it is important to gather insights from practice about how sustainability is taken into account in portfolio management and how this could be improved. To gather these insights, 10 interviews are held to gather in-depth information. The organizations are carefully selected. To make sure the interviews present a broad group of high-tech companies, the contact procedure includes contacting clients of Bicore as well as high-tech companies outside of their network. Before contacting the companies, a list of potentially interesting organizations is drawn up. This list contains a wide range of high-tech companies with an important part of their R&D in the Netherlands. Before contacting the organization the list is discussed with the supervisor at Bicore and Bicore offered help with sending an introduction e-mail to the organizations on the list that they have connections with. In total 15 organizations are contacted with the request if they are willing to be interviewed. Of the contacted organizations, four are clients of Bicore and all four accepted to be interviewed, six organizations are contacted with the use of the connections of Bicore, of whom three organizations accepted the request for an interview, and five organizations are contacted through Linked-In of whom three accepted to be interviewed.

The result of the contact procedure is a selection of 10 organizations to interview. The R&D departments of the selected organization mainly focus on creating high-tech solutions. The selected organizations fulfill the selection criteria, i.e. they use an innovation process with multiple stages and show a certain level of maturity in managing their project portfolio. Two interviewed organizations

can be distinguished from the others, organization H because it is an independent research institute and therefore is more focused on developing techniques for others and less focused on making a profit. Organization J also differs from the others in the aspect that their core business is not in the technology sector but is in the agriculture and food sector, however, they develop techniques for biorefinery and are therefore also interesting to include. Besides, they already show a very mature level of integrating sustainability aspects in their PPM, which makes them even more interesting to include.

All respondents are familiar with PPM within their organization, for example as a product manager, strategy manager, or innovation manager. More information about the selected organizations and the function title of the respondents can be found in Table 9. The name of the organization and respondents are left out due to confidentiality. Appendix D presents more information about the interview results of each interview with illustrative quotes.

Table 9: Overview of organizations and respondents

Organization & Respondent	Description Organization	Function title respondent
A	A group within a big international company that is specialized in medical equipment. The group is an innovation service provider and works on innovative problems for the parent organization and third parties.	Senior position (mainly working in the field of portfolio management and governance)
B	International company that develops and produces semiconductors	Strategy Manager for Technology & Operations
C	International company that develops and produces in the area of photography, optics, medical electronics, biotechnology, and chemicals.	Director Open Innovation
D	International company specialized in transport systems for intern logistics	Manager Innovation & Sustainability
E	International company specialized in navigation systems, mainly B2B	Advanced Engineering Lead
F	A group within a large international company that operates in the field of electronics. The group is specialized in the development and production of equipment for the military industry	Product Lead
G	An international company that develops and produces analytic lab instruments	Product Marketing Lead
H	An independent technical research institute	Strategy Lead
I	A group within a larger international company in the industrial sector, the group is specialized in designing and producing mechatronic systems and system supply, in the B2B-market	Innovation Technology Manager
J	Dutch company specialized in biorefinery of plant-based raw materials	Project Lead

An interview guide is drawn up to develop and help coordinate the interviews. The interview guide contains 18 predefined interview questions, divided into five categories. During the interviews, there was room to dig deeper and elaborate more on certain answers and topics. This helped create a bigger

understanding of the processes in place within the organization. The questions can be found in Table 10 and the interview guide can be found in Appendix C.

Before the start of each interview, more information on the respondent and their function title is gathered with the use of Linked-In and Google as well as more information about the company and its sustainability activities and goals from their company website and Google. This information is used to ask follow-up questions during the interview.

At the beginning of the interview, respondents are asked to give informed consent to use the interviews as input for the research. It is specified that the interview data will be anonymized. Consent is also asked for recording the interview, so the information can be extracted correctly. The recordings are deleted after transcripts of the interviews are written, which is also pointed out to the respondents. Nine out of ten interviews are held in Dutch and translated afterward and one interview is held in English. Due to COVID-19, the interviews are held in a digital meeting with the use of Microsoft Teams.

When the recording is started, a small introduction is given about the subject of the study, with an emphasis on the green aspect of sustainability. Next, the respondent is asked to introduce themselves and tell about their function within the organization. After this introduction, questions 1 to 5 are asked, where 1 to 3 belong to the section of PPM and questions 4 and 5 to the section of environmental concerns. After the respondent answers these questions, the respondent is shown the six environmental objectives of the EU Taxonomy Regulations on a PowerPoint slide with the use of screen sharing. These objectives are on the screen when questions 6 to 10 are asked, all part of the EU Taxonomy section. When these questions are answered, screen sharing is stopped and the objectives are no longer visible to the respondent. Questions 11 to 18 are asked without the use of imaging. By showing the environmental objectives of the EU Taxonomy, the answers of the respondents could be biased from that moment on. It is therefore important to ask for the environmental concerns and how environmental criteria are included in project portfolio decision-making before showing these objectives. So, the section about environmental concerns has some overlap with the section on environmental decision-making, but while asking about their environmental concerns, no direction of the environmental objectives of the EU Taxonomy is given.

Table 10: Interview questions

Category	Question	Reason	Reference
Project management	Q1: In the project development process, how does the company select the projects to be developed? Q2: Which stages comprise the process of project development in the company?	To check the level of maturity of the portfolio management	Pinheiro et al. (2018)
	Q3: Does the company use decision support software for making portfolio decisions? If so, what does this software comprehends? If not, are there other tools used?	To check the level of maturity of the portfolio management	
Environmental concerns	Q4: Does the company have environmental concerns in the project development process? How are these identified? Q5: Does the company consider environmental criteria when making decisions about which new projects it selects? How does this process work?	To check the level of maturity in issues related to environmental practices	Pinheiro et al. (2018)
EU Taxonomy	Q6: To what extent does the company take (all) the objectives of the EU Taxonomy into account and how? Q7: Can you rank the six objectives of the EU Taxonomy, from the objective the company pays the most attention to – to the objective that receives the least attention? Q8: To what extent does your company strive to a) prevent harming the environment? b) improve the environment? c) adapt to climate change?	In the SLR it came across that not all objectives of the EU Taxonomy receive the same attention and some are understudied in relation to portfolio management. It is important to know if this is also the case in practice	*EU Taxonomy Regulations*
	Q9: What role do the EU Taxonomy objectives have in the current project development process of your company? Q10: Do you think the role of the EU Taxonomy objectives should be enlarged in the project development process of your company? If so, how do you think this could be done?	These questions are important to gather insight on how the EU Taxonomy objectives can be related to the project development process.	*EU Taxonomy Regulations*
Environmental decision-making	Q11: Does the company adopt specific environmental methods to support decision-making on which projects to develop? Please elaborate.	In the SLR multiple methods and tools came across, but MCDM seems to have the best fit. This question is open to not guiding the answer, but the goal is to validate if MCDM is also popular in practice.	Pinheiro et al. (2018)

	Q12: (this question is only relevant if the company uses decision support software or other decision support tools for making portfolio decisions) How is sustainability embedded in the decision support software (or in other decision support tools)?	This question can help to identify design requirements and possible directions for the solution design	-
	Q13: What are the main barriers or needs in the incorporation of environmental aspects in the project development process? Please elaborate	It is important to get insight into the barriers and needs for the incorporation of environmental aspects so these can be used as design requirements when designing the solution	Pinheiro et al. (2018)
	Q14: In your opinion, how can environmental aspects influence decision-making on which projects to develop?	When working towards an MCDM-method, it is important to gather insight into what weight should be given to sustainability, related to other criteria such as profit and project costs	Pinheiro et al. (2018)
	Q15: In your opinion, in which stage(s) of the project development process is it important to consider sustainability? Why?	It is important to, from a practical point of view, understand what the most logical/optimal time is to consider sustainability	-
Additional tools	Q16: Is there a need for additional tools to consider sustainability in your PPM? And what kind of tools would you prefer? Q17: On which aspects of sustainability should these tools focus? Q18: If you had access to these tools that you prefer, to what extent would you let them influence the decision-making?	Gather information on the needs from practice to help build the design propositions as well as to get more insights on if (and to what extent) they would use additional tools for managing their portfolio	-

The data is analyzed with the use of template analysis. Template analysis is a form of thematic analysis that balances a high degree of the structure while analyzing and coding textual data and the flexibility to adapt to certain needs of the study (Brooks, McCluskey, Turley, & King, 2015). Brooks et al. (2015) propose the following steps that were followed: (1) Firstly it is important to get familiar with the text that needed to be analyzed, so all interview transcripts are read fully. (2) Secondly, a preliminary coding is carried out, meaning important sentences are highlighted that contribute to the understanding of the topic and processes in place. (3) After, the themes are organized in meaningful clusters and attention is paid to the relations among the clusters. (4) Next, an initial coding template is defined. (5) This is followed up by using the template to apply to the interview data and make some small iterations to better fit all the data. (6) The last step is to finalize the template and apply it to the full data set. The template approach offers the tools for an across case analysis (Brooks et al., 2015), which is preferable in this study since the solution to be designed should be a 'one size fits all' type of solution and should therefore be applicable in different organizations with different standards and procedures in place. The approach also supports comparing different organizations along the way and showing the different maturity levels in sustainable portfolio management from early on. The final coding scheme with the code descriptions is presented in Table 11, including illustrative quotes from the interviews.

Finally, the empirical findings are translated into empirical design propositions. The design propositions as proposed by Denyer, Tranfield, and Van Aken (2008) are used to support designing a relevant solution to apply in practice. Therefore, the CIMO-logic is followed, which means that there is a Context with a problem, for which the design proposition suggests a certain type of Intervention, to get through specified generative Mechanisms to the intended Outcome(s).

Table 11: Coding scheme

Category	Code	Description	Illustrative quote
Project management	Method	The method that is used to select the projects to be developed	*"Specific teams decide what should be one the development roadmaps for the coming 2 years. Every two years budget rounds take place to decide on which funds are allocated to which projects" (Respondent D)*
	Structure	The structure of the project development process	*"Stage-gate model with 9 stage gates" (Respondent D)*
	Tools	Tools to support the decision-making about which projects to select and further develop	*"Software tool to execute portfolio analyses, comparable to Flightmap" (Respondent A)*
Environmental concerns	Concerns	The environmental concerns of the company	*"The climate is important for our organization" (Respondent H)*
	Identifications	How the environmental concerns are identified in the project development process	*"It is implicitly part of our roadmaps" (Respondent E)*
	Criteria	The environmental criteria that the company uses	*"We have some procedures to check the environmental impact with some kind of decision tree" (Respondent C)*
	Usage	How the environmental criteria are used in project portfolio decision-making	*"Now it is more a plus if it is green. … I can imagine in 5 years it will be more explicit." (Respondent B)*
EU Taxonomy	Mitigation	To what extent does the company take into account the goal of climate change mitigation	*"By efficiently organizing our production processes, using as much sustainable energy as we can and align our products to it"(Respondent C)*
	Adaption	To what extent does the company take into account the goal of climate change adaptation	*"Not really relevant for our company, it is more about mitigating" (Respondent G)*
	Water	To what extent does the company take into account the goal of the sustainable use and protection of water and marine resources	*"Yes, this is important for us. We have projects aim to reduce our water consumption, water usage." (Respondent J)*
	Circular	To what extent does the company take into account the goal of the transition to a circular economy	*"Extremely important for us. Embraced it as our new business model" (Respondent A)*
	Pollution	To what extent does the company take into account the goal of pollution prevention and control	*"It is obligatory within our company, it is obligated by our control group" (Respondent I)*
	Biodiversity	To what extent does the company take into account the goal of the protection and restoration of biodiversity and ecosystems	*"I am not aware what we do when we manage projects. Our offices yes" (Respondent D)*
	Goals	The order of goals receiving the most attention from the company	*"1 - 4 - 2 - 5 - 6 – 3" (Respondent H)*

	Preventing	The extent the company strives to prevent environmental damage	*"We do prevent harm and we try to basically improve by implementing new techniques, to be more efficient and use less resources" (Respondent J)*
	Restoring	The extent the company strives to restore and improve the environment	*"The only thing now is planting trees, but that is more about compensating. … You first need to take your business operations to 0, and then you can start doing extra. If you are now in the negative it is hard to something extra, because everything is then compensation anyways" (Respondent D)*
	Current	The current role of the EU Taxonomy objectives in the project development process	*"Goals are limitedly taken into account. Legal and customer related requirements weigh heavily. You can see it is now becoming more important due to goals on a company level. We are still at the beginning" (Respondent F)*
	Future	The role the EU Taxonomy objectives should in the future have in the project development process	*"Yes, by making it more explicit instead of implicit giving it low profile" (Respondent B)*
Environmental decision-making	Environmental tools	The tools the company uses to consider sustainability	*"Not standard, but are familiar with LCA. Important to not get lost in the details" (Respondent G)*
	Environmental DS	The way sustainability is embedded in the used decision support tools	*"Not embedded in the tools. The data is available and discussed during our meetings, but it is not on our current portfolio management tools. The data is updated every phase, but that is done offline" (Respondent J)*
	Barriers	The main barriers to the incorporation of environmental aspects in project development decision-making	*"The multidimensionality. You need to take care of 100.000 things and this is one of them. There are a lot of trade-offs" (Respondent B)*
	Needs	The needs to overcome the barriers to the incorporation of environmental aspects in project development decision-making	*"You want to be able to steer the consideration, shift the balance. … It helps if you can make it simple, but you also want to engage the people, it is not all about profit, it is about more" (Respondent B)*
	Influencing	The way decision-making on which projects to select and develop should be influenced by sustainability	*"Now it is a wish, but it should be a must" (Respondent D)*
	Stage	In which stage of the project development process sustainability should be considered	*"Especially in the beginning, but sometimes it can also be helpful during the innovation process" (Respondent H)*
Additional tools	Additional	The need for additional tools	*"Not solely for sustainability. Everything should be combined in one tool" (Respondent I)*
	Focus	The aspects of sustainability additional tools should be focused	*"To cluster it on where we can have the most impact on, energy is obvious, mobility as well, smartness. … It is a weighted judgement on what we can have an impact, with the technology that we make" (Respondent B)*
	Willingness	The willingness to let new tools influence the decision-making in the project development process	*"I do not think it will influence the decisions, but it will influence the visibility of the impact of the projects" (Respondent J)*

3.2 Results

This section elaborates on the findings of the empirical research. Commonalities between the interview answers are discussed and differences in sustainable maturity and needs for support are distinguished. The results are divided into five sections, in line with the five categories of the coding scheme.

3.2.1 PPM

The previous chapter elaborates on the definitions of PPM as presented in the literature. How PPM is carried out in practice is important to know, to understand how sustainability can be integrated into the holistic approach. In other words, to approach the project portfolio as a whole, including all the portfolio aspects of which sustainability is one.

The most common approach according to the respondents is that higher management decides on the strategy for the company. This strategy is top-down reflected in the different factories, offices, departments, and project teams. This approach is mentioned by 60% of the respondents, however, this does not mean it is not the approach taken in the other 40% of the organization, but the respondents highlight other aspects of how projects are selected. The pace at which strategy is adjusted differs amongst organizations, for example, organization B has strategic cycles of one year and in organization A the organizational unit sets the strategy for three to five years. Based on this strategy, roadmaps are made, explaining what the company will be working on for the coming period. In most organizations higher management or strategic teams are in charge when making these roadmaps, this is highlighted by 50% of the organizations. However, this does not mean that in the other 50% another approach is taken, the respondents choose to highlight other aspects in their answers. The frequency of these roadmap meetings differs per organization. For example, organization A decides every year what will be done in the next year, organization B goes through a strategic cycle every year to decide the focus areas and from which areas they want to pull away from and organization D makes roadmaps every two years.

In 90% of the organizations, the structure of the project development process is comparable, following a Stage-Gate® process [see endnote][1]. Only organization E expresses to work with an agile model, meaning they only plan three months in advance. Companies following the Stage-Gate® model divide the innovation process into different phases, ranging from organization A using four stages to organization D using nine stages. Organization A clearly distinguishes between two types of processes. First the process for projects that are part of the predefined roadmap of the company and second the

[1] Stage-Gate® is a registered trademark of Stage-Gate Inc.

projects that are new to the company and are not on the roadmap, for example, because it fits the company strategy and shows a market potential or because a client specifically asks for it. Both processes follow a Stage-Gate® model, but the stages and gates differ. In addition, organization H is using the Stage-Gate® model for project combinations instead of individual projects. Organization H also adds that it is not always a linear process because sometimes a path is redirected and the combination of projects goes back to a previous stage.

Organizations A, D, and F emphasize delivering the service to their equipment, which also sheds light on the importance of the sustainability aspect of their products. Organization D finds it important that service is taken into account at the beginning of the innovation process because you want to think about the service model when all sorts of things can still be decided, to make the service easier. As respondent D puts it "you want to take into account maintenance from the beginning, you need to make sure things are replaceable and reparable on-site with easy tools, such that everyone can do it, then we do not have to take the equipment back to the factory". Organizations A and F also highlight how the disposal phase can support the sustainability objectives. For example, organization A is committed to taking all equipment back to recycle it from 2025 onwards and company F tries to harvest from old equipment to use used parts as spare parts for still working equipment.

Companies maintain different criteria at the gates for projects to receive a go or no go to enter the next phase. These criteria are mainly based on the higher strategy of the company and whether there is a fit with the roadmaps. Managing a project portfolio is also about dividing resources over projects, therefore choices need to be made because resources are not infinite. Organization D has budget rounds in place, twice a year, to divide resources over specific projects. Questions like 'where do we want to be in X months/years and what do we need to get there' are frequently asked. There is a relationship between resources that a company is willing to allocate and the fit of the project to the strategy of the company, or sometimes more specifically, the importance of the project within a roadmap.

According to respondent C, in practice it is not about ranking projects, because projects are all following their own timeline and do not appear at the gates at the same time. "It is organic how the projects come out of the front-end of innovation, out of that process, out of the cloud of ideas. Most of the time they all come after each other, sometimes you have two projects at the same time. It is not deciding on which project you chose to continue, every time it is a unique consideration for each project if you are going to continue it or stop it". It is interesting to add that this organization practices open innovation, which could explain why, in relation to other organizations like organization D, it is less about ranking and more about setting requirements that the ideas from 'the cloud of ideas' should meet to be continued.

The organizations all show maturity in managing their project portfolio. Nevertheless, there is no one way to go. Of the interviewed organizations 40% use Flightmap for portfolio analysis, 20% use a different software tool for portfolio analysis and 40% rely on Excel and PowerPoint with multiple criteria and checklists.

How do companies decide on which projects to continue while managing their project portfolio?
60% of the organizations emphasize the role of the strategy set by higher management that is top-down implemented and how it influences PPM. Half of the respondents create roadmaps with activities they are planning to work on for the coming period, but they also want to remain flexible for new business opportunities. Of the interviewed organizations 90% uses a Stage-Gate® model to manage their innovation process. The criteria used at the gates reflect the strategy. 60% of the organizations use software tools to support their PPM, while 40% rely on Excel sheets and PowerPoints with multiple criteria and checklists.

Text box 4: Answer to empirical research question 1

3.2.2 Environmental concerns

All respondents express that they do have environmental concerns. Multiple organizations, 40%, express that their attention to environmental objectives is currently increasing and this is in line with the increasing attention of society towards the environment and climate change. In 80% of organizations, the environmental concerns are identified in their strategic agenda or by making commitments. For example, respondent A says that they "make robust commitments that are substantiated in the value chain" and they are committed to the 1.5-degree, and organization D is committed to the climate pledge.

Organizations find it important that hard targets are set, to make sure the company and employees act on them. Organizations respond to these targets by including sustainable objectives in their roadmaps or having incentives in place to stimulate sustainable projects. For example, organization J has roadmaps specifically for CO_2-reduction, nitrogen deposition, water usage, and energy usage, to monitor if they are on track to meet their targets. Organization G also has a roadmap for its net-zero target. Organization B has an incentive in place to stimulate sustainable projects, this is done by making it cheaper to lend money for a project that could be labeled 'green'. 80% of the organizations have translated organization-wide sustainability objectives into quantifiable targets. However, for PPM decision-making, 50% of the organizations expressed that sustainability is not explicitly considered. Like respondent D answered the question if there are environmental criteria in place to take into account when making project portfolio decisions "at this moment it is not fixed, it is formulated as a wish: it would be nice if ...". Only in 40% of the organization sustainability is explicitly

part of the decision-making and in 10% it is not part of the decision-making unless the client asks for it. This means that even though organizations have sustainability criteria in place, they are not considered in project portfolio decision-making. 30% of the organizations expressed that it "is not yet" explicitly incorporated or fixed, but finished the sentence with the wish that in the coming years it should be more explicitly part of the decision-making process in PPM.

Some companies have procedures to shed light on sustainability when managing a project and some companies have a checkbox that can be checked if the project is "green". 60% of the organizations already have some criteria in place to assess the sustainability of the innovation projects, 10% addressed they are currently working on developing criteria to take sustainability into account in project portfolio decision-making, and 10% said to only take it into account if the client specifically asks for it and 20% has no criteria to assess the sustainability of projects.

How do environmental concerns influence PPM decision-making?

Environmental concerns currently have limited influence on the decision-making in PPM, only in 40% of the organizations sustainability is explicitly considered in decision-making. Even though in an additional 50% of the organizations sustainability is implicitly part of PPM, it is more a wish than a requirement, because there are no targets related to the criteria or there is not much weight attached to the environmental impact of the project portfolio. Since 80% of the organization have sustainability targets on company level, and 30% of the organizations expressed the wish to go from implicitly considering sustainability to explicitly considering sustainability in PPM, it is a matter of time before sustainability is more explicitly part of PPM.

This leads to the first empirical design proposition 1*: In a high-tech organization that applies PPM (C), PPM should explicitly include sustainability (I), such that it is clearly part of the decisions made (M) and as a result, the project portfolio is more sustainable (O).*

Text box 5: Answer to empirical research question 2 and empirical design proposition 1

3.2.3 EU Taxonomy Regulations

The environmental objectives of the EU Taxonomy Regulations show a big range of environmental topics that organizations can embed in their PPM. In the literature review, it became clear that not all objectives receive the same attention in sustainable portfolio management literature and some objectives could even be labeled as understudied. This can also be seen in practice. It can however be concluded that in every organization climate change mitigation is on the agenda, as well as pollution prevention and control and a transition to a circular economy. Sustainable use and protection of water and marine resources is only an objective in 50% of the organizations, for 40% of the organizations it

is not relevant or they have a limited impact and 10% is not sure. Climate change adaptation receives attention in 40% of the organizations and is labeled as not important or irrelevant in 60% of the organizations. Protection and restoration of biodiversity and ecosystems seem to receive the least attention when looking at the responses, only 30% of the organizations think it is relevant to them, 20% is not sure and 50% label this objective as not important, not relevant or outside their circle of influence. Most mentioned reasons for objectives not being on the company agenda are that the company has only a small or no impact on the objective or the objective is not relevant in the market the company operates in. The results of which objective was important for each organization can be found in Table 12.

Table 12: Importance of environmental objectives

Organization → Environmental objective↓	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Climate change mitigation										
Climate change adaptation										
Sustainable use and protection of water and marine resources										
Transition to a circular economy										
Pollution prevention and control										
Protection and restoration of biodiversity and ecosystems										

Inscription:

Relevant objective
Not or limited relevant objective/none or limited impact on
Not sure

Organizations are eager to elaborate on how the objectives are part of their operations and own production process, even though most questions are focused on the innovation process and the sustainability of the projects and the portfolio. The difference between those activities is that on the first category of activities the organization has a direct sustainability impact e.g. their production processes, factories, and offices, and the second category of activities they have an indirect sustainability impact on e.g. sustainability impact with their products because they help their customers to be more sustainable. While in the category of activities, with which the organization directly has an impact on the environment, sustainability is already embedded to a big extent, for example, the net-zero goal of the factories of organization F or the commitment to zero-waste till

landfill of organization A. There is still much to accomplish with the projects with which the organizations can have an indirect impact on the environment, including the products they sell to their customers. For example, organization B invests in making its components more energy-efficient, so the end-users use less energy. There are multiple possible explanations why climate change mitigation, pollution prevention and control, and a transition to a circular economy are on the agenda of every organization but are not in every organization part of PPM. For example, the emissions and water usage in a period are easier to measure, because there are a lot of techniques available to organizations. Another example is the pressure from the government, for example in the permits they can grant for factories and subsidiaries to stimulate more sustainable operations. To include sustainability in PPM, there are more barriers as well as the complexity to quantify the broad concept of sustainability makes it harder to measure the impact. Even though not all the environmental objectives are yet incorporated in PPM to the extent that they influence portfolio decision-making, 70% of the interviewed organizations express that the role of the sustainability objectives in PPM should, according to the respondent, be increased in the future.

To what extent are the objectives of the EU Taxonomy Regulations embedded in the companies' strategy and more specific in the project portfolio management?

Answer: Most sustainability goals are part of the organizational strategy. Climate change mitigation, pollution prevention and control, and the transition to a circular economy are on the agenda of each organization, while sustainability use and protections of water and marine resources, climate change adaptation and protection and restoration of biodiversity and ecosystems are not being seen as very important or relevant to all organizations. The difference in importance can be explained through the level of impact a company (thinks) can have on the objective and the level of awareness of how an organization could contribute to the objective. Organizations have embedded a part of the objectives at their factories, in their production and operation processes, but their role in PPM is rather vague. Currently, companies are looking for ways to embed sustainability objectives, such as the objectives of the EU Taxonomy Regulation, in their PPM. 70% of the respondents view that in the future the role of the environmental objectives should be strengthened in PPM.

Text box 6: Answer to empirical research question 3

3.2.4 Environmental decision-making

Now it is established that the role of the environmental objectives of the EU Taxonomy Regulation should be strengthened in PPM, it is important to get a better understanding of how sustainability is currently embedded in PPM, to find out what the starting point is.

Organizations take sustainability into account in different ways. For example, organizations A, D, and J use a sustainability (impact) score for projects, organization B has a checkbox for if the project is green, and organization C uses checklists to assess the sustainability of the project. Organizations E and I only introduce sustainability assessments of projects when the client actively asks for it. For both, it is hard to underpin the impact of the sustainability assessment on the project portfolio decision-making. This could be explained by answers like organization E saying "it is not standardly included" or organization F saying that they do have a sustainability assessment tool "but we do not use it that much". Organization D adds to this that it is scored on how it contributes to the idea of the sustainability goals and "it is about gut feeling, no hard proof". In organization G it is also not standard to use environmental assessment tools nor is sustainability part of the decision support tools. In organizations A, C, and J sustainability is however a standard part of the considerations made. Nevertheless, it can be concluded that in 70% of the organizations sustainability is not yet an explicit part of the trade-offs that are made when deciding on which projects should be further developed and which not.

Knowing the starting point and knowing where companies want to go, it is important to identify the main barriers that prevent the organizations from having integrated sustainability considerations in their PPM to a bigger extent. The detected barriers can be clustered into three categories: (1) barriers related to a lack of knowledge, (2) barriers depending on the business environment, and (3) the barriers related to the company culture. In Table 13 an overview is presented of the mentioned barriers that stand in the way of integrating sustainability to a bigger extent PPM.

First of all, organizations A, B, D, F, and H expressed some barriers related to the lack of knowledge to include sustainability. To be more specific, more knowledge is necessary for identifying possible green alternatives according to organization D and according to organization A, it can be hard to quantify sustainability. It is however not only about scoring sustainability, but it is also about taking it into account next to all other important criteria such as costs and project risk. Organizations A, B, D, and H expressed that the multidimensionality of PPM makes it hard to add sustainability, for example, because new balances should be determined to make sustainability an explicit part of the trade-offs. As respondent B states, "there are 100,000 things that you need to take care of, and this is one of them. There are all sorts of trade-offs".

The second cluster of barriers could be labeled as being dependent on the actors in the business environment. For example, organizations B and I pointed out that they depend on what their suppliers offer them. Respondent B explained this problem by telling that they rely on one supplier for some advanced components and are therefore dependent on how sustainable they deliver their component, as respondent B puts it “we cannot say ‘you are not environmentally friendly, we will go to your competitor’, because there is no competitor”.

For some components, there are not yet sustainable alternatives, so there is no choice to make, which is a barrier for organizations C and I. Another problem encountered is that sometimes sustainable products are more costly. Companies need to charge these extra costs to their customers, which means the prices of their products rise. Not all customers are willing to pay more and can go off to the competitor. As organization F expresses “you can have a very energy-efficient product, but if no one buys it, then it is of no use”. Besides the willingness of customers to pay for the additional costs, it is also about the willingness of the customer to use the more eco-friendly additions, for example, respondent F states “we can add smart features such that there are different eco-modes, but if everyone always wants to be in full-power sports mode, we will not make a difference”.

Another barrier is that laws and regulations sometimes block new technical possibilities or create a situation of unfair competition by giving some big players exceptions. As respondent C puts it “there already are more technical possibilities, but often they are blocked by laws and regulations or by exceptions made for companies in consortia”. Respondent I also adds to this that top-down requirements from the government, such as laws and regulations can help create a one-level playing field. Respondent I explained this as follows “you can see your dependence on the competitors. If I can make the product green but the costs increase by 5 Euros, then I am not sure what my client will do. If the market is a one-level playing field, then it will not be hard. Then those 5 Euros difference is for everybody the same”.

The third identified cluster is about the culture of the company. Organization E and I underline that sustainability is not their core business, which is inherent to expressing to feel no drive to make it part of their business operations. Organizations B and H do want it to be part of their business operations, but their employees and more specifically the developers should be more aware of how they could contribute. This is something organization D is already working on by giving presentations to employees on how everyone can contribute. This shows there is a cultural change necessary amongst employees, to be more aware of the environmental impact itself can have by thinking and doing green. Another addressed barrier in this cluster is costs, if a company wants to embrace sustainability, it should allocate resources to it. It is hard to integrate sustainability when beforehand it is known that it may not lead to additional costs.

Table 13: Main barriers

Category	Barrier	Mentioned by organization:
Knowledge	Lack of knowledge about green alternatives	D
	Still finding out how to make products green	A, D
	Lack of knowledge about how sustainability can be integrated	D
	Multidimensionality makes PPM complicated and complex	A, B, D, H
	Lack of knowledge about how to quantify sustainability	A
	Lack of insight into trade-offs (costs vs added-value)	F
Business environment	No sustainable alternatives for some components or materials	C, I
	Dependence on supplier	B, I
	Costs	C, F
	Law and regulation (block new technical possibilities and there is no one level playing-field, export restrictions)	C, G
	Dependence on other partners	E
Company culture	Lack of motivation to make it part of business operations (employees and management)	G
	Internal alignment on how to deal with projects, processes, and decision-making	J
	Hard to guide all designers to make sustainable decisions	B
	Employees are not yet aware of how they can/should contribute	H
	Willingness to allocate money	G

From the literature review, it became clear that it is most beneficial to start considering sustainability in the FEI. This is confirmed by the interviewed organizations. 80% of the organizations believe that sustainability should be considered as soon as possible and 'from the very beginning'. In addition, 70% find it important to consider sustainability in every stage. Like respondent J says, "from that moment on we should keep just updating the data, more data becomes available, and then the case becomes stronger". In addition respondent A mentions that taking it into account from the beginning can even be an impulse for what goes into the innovation funnel "it will get more quantitative, more extensive, and more detailed, but you need to take it into account from the first day. It could even be an impulse for the projects that go into the innovation funnel".

What are the biggest barriers to the incorporation of environmental aspects in project development decision-making and how could these barriers be broken down?

The most mentioned barrier is the multidimensionality of PPM, which causes companies to struggle with how to integrate sustainability. This barrier could be broken down with creating the knowledge on how to integrate sustainability in addition to other, already existing, important criteria such as costs and project risk. This barrier belongs to the category of knowledge barriers, which also includes barriers like the difficulty to quantify sustainability and the process of figuring out how to make projects green. The second category of barriers is about the dependence on the business environment, for example, the reliance on one supplier for a specific component and the lack of green alternatives. Unfortunately, it is not within the scope of this study to solve this problem. This because a solution for integrating sustainability will not solve the problem of lack of choice due to other actors in the business environment. The third category of barriers is about company culture. Most barriers addressed regarding company culture are not part of the scope, because the goal of this study is to provide a solution to integrate sustainability in PPM and not change a company culture. Nevertheless, providing insights into how sustainability can be included in the project development process, can lead to more understanding and, in turn, willingness to include it. This could support the motivation to allocate budget and motivate employees. Sustainability should be considered as soon as possible in PPM according to 80% of the organizations. 70% of the organizations find it important that sustainability is considered in every stage of the innovation process.

This leads to empirical design proposition 2: *In a high-tech organization that applies PPM (C), sustainability of projects should be considered as soon as possible (I), such that sustainability is part of the decision-making from the early phases of the innovation process on (M) and as a result the project portfolio is environmental sustainable (O).*

Text box 7: Answer to empirical research question 4 and empirical design proposition 2

3.2.5 Additional tools

Most respondents have a need for additional tools to enhance sustainability in their PPM. Of the 10 interviewed organizations, organizations A and H are currently developing some sort of additional tool to enhance sustainability in project management. Organizations B, D, F, G, I, and J, so 60% of the organizations, have a need for an additional tool or an addition to their tool. In organizations C and E there are no additional needs, of which organization C already has a mature tool in place to take sustainability into account in PPM.

It could therefore be concluded that organizations can benefit from an additional tool to assess sustainability. The next step is to further elaborate on what this tool should focus on, to fit their needs. The needs could be clustered into 5 groups. The first group of needs is about making sustainability part of the holistic approach. This means that sustainability criteria should be considered in PPM, next to the other relevant criteria, because sustainability is one of the criteria that should be taken into account in decision-making. All important criteria for project portfolio decision-making should be combined in one tool, to provide insights into the trade-offs. This will shed light on sustainability in relation to costs, price, and usability. It is important to show the choices that can be made and what the alternatives are. **This leads to empirical design proposition 3:** In a high-tech organization that applies PPM (C), portfolio management supporting tools should include all relevant criteria for decision-making, under which sustainability (I), such that sustainability is part of the holistic approach (M) and as a result, sustainability is part of the trade-offs that are made (O).

The second group of needs is that it should be a real-time, living document. This means that it should not be a list that after a certain decision is made gets lost in a folder, but it needs to be part of the portfolio analyses. It should be possible to alter the information along the way because during the innovation process the project gets more detailed and not be dropped after a checkbox is checked in a certain stage. **This leads to empirical design proposition 4:** In a high-tech organization that applies PPM (C), portfolio management supporting tools should include the relevant sustainability criteria and frequently update the information (I), such that the latest available data is taken into account (M), and as a result, sustainability is part of the real-time portfolio analyses (O).

The third group of needs addresses the importance to make sustainability transparent and explicit. The tool should make transparent what an organization invests in sustainable initiatives and what it contributes. It should make the choices and the consideration of sustainability explicit. It is important to not only keep sustainability in mind and use 'your gut feeling' for selecting projects but also to substantiate the choices made. This also means that it should be clear what weight is attached to sustainability criteria, to be transparent about what importance the organization links to sustainability, and also in relation to other criteria such as costs and project risk. **This leads to empirical design proposition 5:** In a high-tech organization that applies PPM (C), portfolio management supporting tools should provide insights into all criteria and their attached weight (I), such that it becomes clear how much sustainability profits and how much this costs (M), and as a result, tradeoffs are made transparently and can be substantiated (O).

The fourth category of needs addresses that the tool should focus on the sustainability aspects that an organization can have an impact on. For example, for some organizations water usage is an important criterion because during their production process a lot of water is needed but for other

organizations there is not much water used and therefore not much to gain by considering water usage as a criterion in decision-making. This need could be covered by including criteria of the sustainability aspects which are relevant for the specific organization i.e. the aspect of sustainability on which the organization can have a relatively big influence. **This leads to empirical design proposition 6:** In a high-tech organization that applies PPM (C), portfolio management supporting tools should focus on sustainability aspects that the organization can have an impact on (I), such that these aspects are taken into account when making decisions (M), and as a result, the organization efficiently improves project portfolio sustainability (O).

The last group of needs addresses that the additional tool should not be too complex and not too detailed. The tool must be easy to understand and apply, and therefore it should not be too complex or too detailed. If people can understand how trade-offs are made, they are more willing to stick with it. As organization G puts it "if the choices are also supported by intuition, the use of the tool is reinforced". **This leads to empirical design proposition 7:** In a high-tech organization that applies PPM (C), portfolio management supporting tools should focus on the bigger picture of sustainability and not on too many details (I), such that the tool is not too complex and easy to understand (M), and as a result, there is a willingness to use the tool (O).

An overview of the needs for an additional tool and with which empirical design propositions they are tackled can be found in Table 14.

Table 14: Additional needs

Category	Need	Mentioned by organization:	Tackled with empirical design proposition:
Holistic approach	Sustainability should be captured in your portfolio management approach	A, D	1, 3
	Some criteria should be added to the portfolio analysis to take into account sustainability	G, I, D, G	1, 3
	A checklist to get the conversation started (and make it part of the considerations)	H	-
	Incorporating the sustainability KPI is into our PPM tool	J	3
	Support ranking ideas, projects, and proposals	G	3, 5
Real-time, living document	Show real-time what the sustainability is (adjustable when more information becomes available)	D	3, 4
	No static but a living document	I	4
	Administrative tool, because now the document disappears in the digital folder of the person in charge	C	4
Transparent and explicit	Support to make considerations more explicit	B	1, 5
	Support to make it transparent what you invest	B	5
	Make trade-offs transparent	D, G	1, 5
	Support sustainability assessment	F	1, 3
	Toolbox/practices that support insight into what choices can be made, and what the alternatives	F	3, 5

	are		
Focus on impact	An additional tool should focus on the environmental aspects that we have an impact on	B, I	6
	Classifications (a bigger product will always use more resources than a smaller product), and different standards for product categories	F	-
Not too complex	The model should not be too complex	G	6, 7

All organizations that have the need for additional tools to consider sustainability in PPM (B, D, F, G, I, and J) as well as the organizations that are currently developing a tool (A and H), are willing to let this new tool, and thus sustainability, influence the decision-making.

Is there a need for additional tools to enhance sustainable portfolio management and what are the requirements for these additional tool?

There is a need for additional tools to consider sustainability in PPM. This tool should integrate sustainability in the holistic approach, present the real-time situation, be transparent and make sustainability explicit, focus on the environmental aspects a company has impact on and should not be too complex or too detailed. If this new tool is created, 80% of the organizations are willing to let this influence portfolio decision-making.

This leads to empirical design propositions 3 to 7 which are presented in the text in bold.

Text box 8: Answer to empirical research question 5 and reference to empirical design propositions 3 to 7

3.3 Conclusion

Most organizations use a Stage-Gate® model to manage their innovation process. Higher management formulates an organizational strategy that is top-down reflected in business operations and PPM. The strategy is used to base the criteria for decision-making at the gates upon. All interviewed organizations show maturity in managing their project portfolio but there is no 'one way to go'. Of the interviewed organizations, 60% uses software tools for portfolio analysis and 40% relies on Excel and PowerPoints with multiple criteria and checklists.

Environmental concerns currently have limited influence on the decision-making in PPM, only 40% of the organizations explicitly consider sustainability in decision-making. Nevertheless, 80% of the organization have sustainability targets at the company level, and 30% of the organizations have the wish to go from implicitly considering sustainability to explicitly considering sustainability in PPM.

Organizations are asked which objectives of the EU Taxonomy Regulation are important to them. Climate change mitigation, pollution prevention and control, and a transition to a circular economy are on the agenda of each company, while sustainability use and protection of water and

marine resources, climate change adaptation and protection and restoration of biodiversity and ecosystems are not very important or relevant to all organizations. Nevertheless, 70% of the organizations agree that the role of the environmental objectives in PPM should be strengthened in the future.

There are detected barriers that are currently in the way of strengthening the role of sustainability in portfolio decision-making. Most barriers are related to (lack of) knowledge, the business environment an organization is acting in, and the company culture. To break down these barriers, it is important to create and promote knowledge of how sustainability can be integrated, the multidimensionality of PPM, and how to quantify sustainability to also give insights into the trade-offs made including sustainability. The interviews confirm that sustainability should be considered as soon as possible in PPM (according to 80% of the organizations). In addition, 70% of the organizations consider sustainability to be important in every stage of the project development process.

The interviews show that there is a need for additional tools to consider sustainability. All organizations that have the need for additional tools to consider sustainability in PPM (60% of the organizations) as well as the organizations that were currently developing a tool (20% of the organizations), show willingness to use this new tool.

Based on these findings empirical design propositions are formulated. An overview of these empirical design propositions can be found in Table 15.

Table 15: Empirical design propositions

	Empirical design proposition
1	In a high-tech organization that applies PPM (C), PPM tools should explicitly include sustainability (I), such that it is clearly part of the decisions made (M) and as a result, the project portfolio is more sustainable (O).
2	In a high-tech organization that applies PPM (C), sustainability of projects should be considered as soon as possible (I), such that sustainability is part of the decision-making from the early phases of the innovation process on (M) and as a result, the project portfolio is environmentally sustainable (O).
3	In a high-tech organization that applies PPM (C), portfolio management supporting tools should include all relevant criteria for decision-making, under which sustainability (I), such that sustainability is part of the holistic approach (M) and as a result sustainability is part of the trade-offs that are made (O).
4	In a high-tech organization that applies PPM (C), portfolio management supporting tools should include the relevant sustainability criteria and frequently update the information (I), such that the latest available data is taken into account (M), and as a result sustainability is part of the real-time portfolio analyses (O).
5	In a high-tech organization that applies PPM (C), portfolio management supporting tools should provide insights into all criteria and their attached weight (I), such that it becomes clear how much sustainability profits and how much this costs (M), and as a result trade-offs are made transparently and can be substantiated (O).
6	In a high-tech organization that applies PPM (C), portfolio management supporting tools should focus on sustainability aspects that the organization can have an impact on (I), such that these aspects are taken into account when making decisions (M), and as a result the organization efficiently improves project portfolio sustainability (O).
7	In a high-tech organization that applies PPM (C), portfolio management supporting tools should focus on the bigger picture of sustainability and not on too many details (I), such that the tool is not too complex and easy to understand (M), and as a result there is a willingness to use the tool (O).

4. Design propositions and requirements

In this chapter, the theoretical and empirical design propositions are combined, to come to a generic set of design propositions. Each theoretical and empirical design proposition is highlighted in the first section. After this generic set of design propositions is formulated, design requirements are proposed, including functional requirements, user requirements, boundary conditions, and design restrictions.

4.1 Combining design propositions

The first theoretical design proposition (TDP1) contains the definition of what environmental sustainable projects are and what is needed to create an environmentally sustainable project portfolio. The intervention of this design proposition is about making formal environmental commitments for decisions making. This theoretical design proposition can be combined with the second empirical design proposition (EDP2), which focuses on making environmental sustainability explicitly part of the decision-making, by including sustainability in PPM tools. Combining TDP1 and EDP2 leads to the first design proposition. This design proposition will support the solution to be less sensitive to greenwashing because formal commitments are made, a clear definition of sustainability that is supported by the literature review is taken as the basis and sustainability will explicitly be part of decision-making.

	Design proposition	Based on
1	In a high-tech organization that applies PPM (C), PPM tools should explicitly include sustainability and formal environmental commitments need to be made (I), such that the innovation projects are designed to minimize their environmental impact during their entire life cycle; unintended environmental consequences are prevented; there is strived to protect or enhance the environment (M) and as a result, the project portfolio is labeled environmentally sustainable (O).	TDP1 (sub-chapter 2.2.1), EDP2 (sub-chapter 3.3.2)

The second theoretical design proposition (TDP2) is about integrating checklist, scoring, and ranking tools for sustainability into the decision support tools, based on solid environmental indicators that organizations have an impact on. This can be combined with the third and sixth empirical design propositions (EDP3 and EDP6, respectively). The intervention of EDP3 is about integrating sustainability to make it part of the holistic approach. By including sustainability into the decision support tools, such as ranking, scoring, and checklists, sustainability is made part of the portfolio analyses. This supports considering sustainability next to the other criteria that are important for decision-making, such as costs and project risks. By doing so, sustainability is part of the trade-offs that are made. Next to EDP3, EDP6 can also be combined in this design proposition. The intervention of TDP2 also emphasizes solid environmental indicators that an organization has an impact on. This is comparable to the intervention of EDP6, stating that portfolio management supporting tools should

focus on the aspects that the organization has an impact on, such that the most relevant aspects are taken into account when making project portfolio decisions. Therefore, TDP2, EDP3, and EDP6 are combined in design proposition 2.

	Design proposition	Based on
2	In a high-tech organization that applies PPM (C), checklist, scoring, and ranking tools for sustainability are integrated into the DSS; based on solid environmental indicators that organizations have an impact on (I), such that sustainability is part of the project portfolio analyses and decision-making (M) and as a result, the project portfolio is environmentally sustainable (O).	TDP2 (sub-chapter 2.2.2), EDP3 (sub-chapter 3.3.5), and EDP6 (sub-chapter 3.3.5)

The third theoretical design proposition (TDP3) focuses on implementing sustainability indicators in the DSS to support the MCDM-method, such that sustainability is considered when making decisions in the FEI. This partly overlaps with the second design proposition, because introducing scoring, ranking, and checklist tools for sustainability in the DSS will help to make sustainability part of the MCDM-method. However, in this theoretical design proposition, the timing is crucial because it underlines the importance of taking it into account in the FEI. This theoretical design proposition can therefore be combined with the second empirical design proposition (EDP2). From the interviews, it became clear that sustainability should be taken into account as soon as possible, which therefore supports that it should be taken into account in the FEI. The design proposition is however broadened, so that sustainability is not only taken into account in the FEI, which is the focus of TDP3, but from the FEI and on through the rest of the innovation process.

	Design proposition	Based on
3	In a high-tech organization that applies PPM (C), sustainability of projects should be considered from the FEI on (I), such that sustainability is part of the decision-making from the early phases of the innovation process on (M) and as a result, the project portfolio is environmentally sustainable (O).	TDP3 (sub-chapter 2.2.3), EDP2 (sub-chapter 3.3.4)

Now that these combinations are made. Three empirical design propositions remain (EDP4, EDP5, and EDP7). The intervention of EDP4 highlights that supporting tools should include the relevant sustainability criteria and frequently update the information, such that the latest available data is taken into account and sustainability is part of the real-time portfolio analyses. This intervention could be split into two parts, which are 'include the relevant sustainability criteria' and 'frequently update the information'. The first part is covered in the new generic design proposition 2, which addresses that environmental indicators should focus on the aspects that an organization has an impact on. The second part of EDP2 is about frequently updating the information. However, since it is customary to update the information when using a decision support tool like Flightmap, there is no need to cover this in a generic design proposition. It can easily be covered by taking it into account as a design requirement. These requirements are discussed in the next section.

The intervention of the fifth empirical design proposition (EDP5) focuses on providing insights into all criteria and their attached weight, such that it becomes clear how much sustainability benefits

and how much this costs, to make trade-offs more transparent and to be able to substantiate the trade-offs. This is not yet covered in another generic design principle. Making it transparent and supporting not only the decision-making but also substantiating the decision, will answer the needs of multiple interviewed organizations. Therefore, this is covered by design proposition 4.

	Design proposition	
4	In a high-tech organization that applies PPM (C), portfolio management supporting tools should provide insights into all criteria and their attached weight (I), such that it becomes clear how much sustainability profits and how much this costs (M), and as a result, trade-offs are made transparently and can be substantiated (O).	EDP5 (sub-chapter 3.3.5)

The last design proposition from the previous chapter is EDP7. The intervention of EDP7 addresses that the PPM support tools should focus on the bigger picture and not on too many details, such that the tool is not too complex and easy to understand and work with by the users. This is important to ensure willingness to use the tool. This intervention embodies more than just making sure to be user-friendly, and therefore EDP7 leads to generic design proposition 5. This design proposition highlights the importance of introducing sustainability in PPM in a compact way. In the SLR it became clear that there are lots of environmental aspects and possible criteria, it is however important to choose those indicators that together create a clear picture but not be too detailed. This design proposition will challenge the solution on the usability of the tool.

	Design proposition	
5	In a high-tech organization that applies PPM (C), portfolio management supporting tools should focus on the bigger picture of sustainability and not on too many details (I), such that the tool is not too complex and easy to understand (M), and as a result, there is a willingness to use the tool (O).	EDP7 (sub-chapter 3.3.5)

4.2 Design requirements

The solution design must be in line with the needs of practice, it must be feasible and generalizable. Van Aken, Berends, and van der Bij (2012) proposed four types of design requirements which are (1) functional requirements, (2) user requirements, (3) boundary conditions, and (4) design requirements. Even though some of these design requirements may seem obvious, according to Van Aken et al. (2012) they can be overlooked in the heat of project execution. A list of design requirements can also serve as a checklist to check if all the requirements of the client's system are met (Van Aken et al., 2012). An overview of the design requirements is presented in Table 16.

Table 16: Design requirements

Type of design requirement	Design requirements	Retrieved from
Functional requirement	The business problem should be solved by implementing the design solution	Van Aken et al. (2017)
	The solution design should support environmental sustainability,	*Bicore*

	as approached by the EU Taxonomy, to be part of PPM	
	The solution design should increase the environmental sustainability of the project portfolio	*Bicore*
	The benefits of the solution design should exceed the costs	Van Aken et al. (2017)
User requirements	Flightmap should remain user-friendly	Van Aken et al. (2017)
	Current users of Flightmap should understand the additions and adjustments caused by the solution design	Van Aken et al. (2017)
	The design should be unambiguous	-
	There should be possibilities for organization-specific prioritization related to environmental criteria	*Bicore*
	The design should support frequently updating the information	*EDP2*
Boundary conditions	The design should fit in the software of Flightmap	*Bicore*
	The design should fit within the present business policies of Bicore	Van Aken et al. (2017)
Design restrictions	The design should cause as little change to Flightmap as possible	Van Aken et al. (2017)
	The design should be implemented within the allocated time	Van Aken et al. (2017)
	The design should fit within the allocated budget	Van Aken et al. (2017)

4.3 Conclusion

In this chapter, the theoretical design propositions from chapter 2 and the empirical design propositions from chapter 3 are combined into five generic design propositions. There are no contradictions between the theoretical and empirical findings but they add to each other. Every theoretical design proposition is combined with at least one empirical design proposition. The five generic design propositions are the basis for the solution design. In addition to the design propositions, the design requirements are presented. These requirements will make sure that the solution fits the needs of organizations, the needs of Bicore, and that the solution is feasible and generalizable.

5. Solution design

This chapter describes the solution design. The solution should support sustainability considerations in PPM. To be more specific, it should support the clients of Bicore by integrating sustainability in the portfolio analyses tool Flightmap. In this chapter, first, a recommendation is provided on what sustainability assessment should be integrated into Flightmap. Second, it is explained how this could best be integrated into Flightmap. Third, suggestions are given about setting targets and making formal environmental commitments. Fourth, it is discussed how the environmental addition in Flightmap can be used in decision-making. For the solution design, the design propositions from chapter 4 are in the lead, as well as the design requirements.

5.1 Design of the sustainability assessment

Flightmap makes portfolio analyses based on data entered by the organizations that use it. Organizations can choose which KPIs should be part of the portfolio analyses and based on the performance, measured with the KPIs, the projects can be ranked and an overview of the whole portfolio can be retrieved. Integrating multiple environmental KPIs is a way in which sustainability can be included in the portfolio analyses and trade-offs that are made. This is in line with the second design proposition, stating that checklists, scoring, and ranking tools for sustainability assessment need to be integrated into the DSS, based on solid environmental indicators that organizations have an impact on, such that sustainability is part of the project portfolio analyses and the trade-offs and decisions that are made.

Introducing environmental KPIs in the project portfolio analyses is an important first step in the solution design. It is however important to base these KPIs on solid environmental indicators an organization has an impact on (design proposition 2) as well as the idea that these KPIs should focus on the bigger picture of sustainability and not on too many details (design proposition 5). From the interviews, it became clear that not every environmental aspect is important for each organization. Bicore offers organizations customized portfolio analyses with Flightmap. It is therefore possible to adapt the environmental KPIs on the impact of the specific organization, which is also in line with the user requirement ‘there should be possibilities for organization-specific prioritization related to environmental criteria’.

It is an important aspect of the solution to first choose KPIs an organization can have an impact on, before setting targets. It is expected that this will trigger organizations to approach sustainability from a broader perspective, otherwise, organizations can get a tunnel vision on the environmental goals that already are in place within the organization, instead of thinking about if and how they could

influence all the environmental objectives as proposed by the EU Taxonomy Regulation. This is also in line with the functional requirement stating that 'the solution design should support environmental sustainability, as approached by the EU Taxonomy, to be part of PPM'.

This solution design proposes a set of KPIs that can be integrated. These KPIs are mainly retrieved from the SLR. However, some KPIs from the SLR showed overlap and are therefore combined. Some other KPIs from the SLR are too detailed or embody a very small environmental aspect, therefore, they are not included to not contradict generic design proposition 5 about not being too detailed, and to meet the user-requirement of remaining user-friendly.

Organizations can decide for themselves which KPIs are relevant for them and which are not relevant to include in their project portfolio analyses. It is however important that all projects are scored on the same aspects. Otherwise, it will be hard to rank projects. It is therefore important that organizations use one set of KPIs for the portfolio and all the projects within that portfolio, and not make project-specific choices for which KPIs to include.

From the interviews, it also became clear that multiple organizations already have sustainability assessments for their projects in place, but this information is not always used for project portfolio decision-making. A part of the information that is needed for the environmental KPIs is therefore already available in-house, but sometimes it need to be calculated on a different scale, e.g. now they show the environmental performance for each batch, per production unit, or for the entire project. Some information may not yet be available, this will cause additional work for the organization, to find out the specific information related to the KPIs in place.

As mentioned before, by first selecting which KPIs to include from a list that covers all six objectives of the EU Taxonomy Regulation, organizations are challenged to look beyond the environmental objectives that already are embedded in their organizational strategy and operations. The idea is that a broad list, covering a big range of objectives, will trigger organizations to consider sustainability from a broader perspective than for example solely focusing on air pollution, water usage, and climate change mitigation.

5.1.1 Environmental KPIs

From the interviews, it became clear that the most important environmental objectives for organizations are (1) climate change mitigation, (2) transition to a circular economy, and (3) pollution prevention and control. The environmental objectives for sustainable use and protection of water and marine resources and restoration of biodiversity and ecosystems, and climate change adaptation were not relevant to each organization, which makes an on-off button for the KPIs related to those environmental objectives useful. From the SLR, a list of useful indicators is gathered. Some of these useful indicators are however very detailed and show overlap with each other. During the interviews,

organizations also shared indicators they use, for example, the indicator of 'percentage of materials used that can be recycled', which helps measure the transition to a circular economy. In Table 17 a list of environmental KPIs proposed to be integrated into Flightmap is presented. It is suggested that an organization uses the KPIs relevant to them and adds KPIs for sustainability aspects they do have an impact on but are not on the list. Organizations do not need to include all 17 KPIs and customization is necessary. Nevertheless, using one or two is not enough. It is important to match the KPIs with the sustainable goals of an organization, but also to be open to additional environmental objectives to come to a broader approach towards sustainability. For example, if an organization writes down in their strategy that they are currently in the transition to a circular economy, it is important to include KPIs that show the progress. If the organization barely uses water for the production of a product, or the product-life water requirement is negligible, it is no problem to not include a KPI for sustainable use and protection of water and marine resources. Besides using a part of the 17 proposed KPIs, organizations are free to add other environmental indicators. The proposed KPIs are merely a suggestion, to provide a bigger understanding of what sustainability entails.

The 17 KPIs provide an overall view of the environmental performance of an organization since the list includes or covers the indicators presented in the literature review as well as having the focus on what organizations find most important. The KPIs are divided over the six environmental objectives of the EU Taxonomy Regulations because this is the reference point of this study.

Table 17: Proposed environmental KPIs

Environmental objective	Environmental KPI for innovation projects	Description	Source
Climate change mitigation	1. Energy consumption in manufacturing in MJ per unit	This KPI can help provide insight into the energy usage during the production process.	Retrieved from Koboyashi et al., 2011; de la Cruz et al., 2021; Jugend et al., 2017).
	2. Energy consumption in use in MJ per unit	This KPI can help provide insight into the energy used when the product is in use.	Retrieved from Koboyashi et al. (2011); de la Cruz et al. (2021); Jugend et al. (2017).
	3. Global warming in Kg CO_2 per unit	Global warming is an important part of climate change. CO_2 emission has a direct impact on global warming.	Retrieved from Brook and Pagnanelli (2014); Peralta et al. (2021); de la Cruz et al. (2021)
Transition to a circular economy	4. Cumulative energy demand in MJ per unit	In a circular economy organizations are less (or not) dependent on resources.	Retrieved from Peralta et al. (2021)
	5. Total number and volume of significant	This KPI can help to contribute to a zero-waste policy.	Retrieved from Garcez et al. (2016b).

	spills (calculated per unit)		
	6. Product life in days/months/years	Extending the product life is important for sustainability. This means that consumers need to buy fewer new products because the products they buy last longer. In turn, fewer materials are needed and fewer materials need to be disposed of over a time period, also less production and the corresponding resources are needed.	Retrieved from Kobayashi et al. (2011).
	7. Percentage of materials used that can be recycled (in %)	In a circular economy, waste is minimized, and after the product life ends materials are reused. This KPI provides insights into the extent to which the materials can be recycled.	Indicator used by organization H.
	8. Life-cycle raw material consumption (excluding water and renewable or recycled materials) in Kg	In a circular economy the use of raw materials is minimized.	Retrieved from Helling (2015).
Pollution prevention and control	9. Life-cycle greenhouse gas (GHG) emissions in weight	Greenhouse gas receives a lot of attention in relation to air pollution and global warming. This is key for most environmental policies of organizations.	Retrieved from Helling (2015) and Garcez et al. (2016b).
	10. NO_x air emissions in weight	Nitrogen oxides are pollutants that contribute to the formation of smog and acid rain.	Retrieved from Garcez et al. (2016b).
	11. SO_x air emissions in weight	Sulfur oxides are pollutants that contribute to the formation of acid rain and particulate pollution.	Retrieved from Garcez et al. (2016b).
	12. PM10 and PM2,5 in weight	Particulate matter is part of the standards describing air quality. For example, the air quality standards for PM10 and PM2,5 from the World Health Organization (WHO), the limit and target values from the EU, and PM10 and PM2,5 are in the Netherlands also part of the law and regulations ('Wet Natuurbeheer').	Indicator for PM10 retrieved from Peralta et al. (2021); World Health Organization (WHO); 'Wet Natuurbeheer'
Sustainable use and protection of water and marine resources	13. Water used in the production process per unit in m^3	Organizations can directly influence water usage in the production process. Therefore this is an important KPI for sustainable use of water.	-
	14. Project life-cycle water requirement in m^3	Important KPI to get insight into the water used for each unit during the entire life-cycle (during manufacturing, when in use, and for disposal).	Retrieved from Helling (2015)
Protection and restoration of biodiversity and ecosystems	15. Acidification in Kg SO_x and NO_x	Acidification has a strong impact on the biodiversity and the ecosystems in place.	SO_2 retrieved from Peralta et al. (2021), NO_2 retrieved from

			WHO advise and EU limit NO_2
	16. Impacts on biodiversity (low/medium/high)	This objective is not on top of the agenda of most organizations. For organizations, it can be vague on how to contribute to it. It would be best for organizations to score how projects contribute themselves, by doing so, they will consider the impact on biodiversity a project has.	-
Climate change adaptation	17. The contribution of the project to climate change adaptation (low/medium/high)	In the literature no useful indicator was found. Besides, this objective did not receive much attention from organizations. Since climate change adaptation is still very vague to most organizations and includes a lot of different ways to embrace it, it would be best for organizations to score the contribution of the project themselves.	-

5.2 Integrating the additional sustainability assessment

Now that a list of KPIs is formulated to support the sustainability assessment of projects, it is important to integrate the environmental KPIs in the correct place in Flightmap. Flightmap has multiple functions. Functions for project portfolio overview and functions to focus on viewing the performance of single projects within the portfolio. When looking at the project portfolio and the corresponding project list, a list of projects, KPIs, and the scores for each project are presented. It is possible to rank these projects based on each KPI. It is also possible to combine the KPIs into one total score, to create the possibility to rank the projects using multiple criteria at once. For example, in the demo version of Flightmap 12, asset management goals are combined, such as 'lifetime extension' and 'material cost reduction', in one score called 'Contribution to Asset Management Goals' as shown in Figure 2. The same can be done to create a total sustainability score. By doing so, projects can be ranked on a single environmental KPI and also on the total sustainability score of the project. A bad score for air pollution can for example be balanced by low energy and water usage.

Organizations should be able to choose which weight to attach to each KPI. By attaching weight, organizations can choose KPIs to weigh more heavily towards the total sustainability score, for example, because they think they have more impact on that environmental aspects. Organizations can also make KPIs weigh less heavily towards the total sustainability score, for example, because they have a limited impact on the KPI. For an organization producing semiconductors, a KPI for water usage is less relevant than a KPI for cumulative energy demand. For such an organization, it would make sense to attach less weight to a KPI for water usage and a heavier weight to the KPI of cumulative energy demand.

When deciding on which weight to attach, it is important to keep in mind how much a KPI contributes to the sustainability goals of the organization and the potential influence and thus difference the organization can make. This will cover design proposition 4, because the intervention of design proposition 4 is about portfolio management supporting tools to provide insights into all criteria and their weight, such that it becomes clear how much sustainability profits and how much this costs, and as a result, trade-offs are made transparently and can be substantiated.

In addition, organizations are free to choose how precisely they calculate and enter the data. In other words, they are free to choose how many digits they want to use for each score on the KPI. Organizations can also choose to work with ranges. Working with ranges, for example on a 5-point scale, will help to make project performance more visible. An example of how this could look like in Flightmap is shown in Figure 2.

Another choice organizations can make is on which unit they want to base the KPIs. Organizations can keep the same units that are already in place for the other non-environmental KPIs, this unit can for example be per project, per batch, per product, or per component.

Project Name	AM Goals: 1. Availability improvement	AM Goals: 2. Reliability improvement	AM Goals: 3. Production capacity improvement	AM Goals: 4. Lifetime extension	AM Goals: 5. Strategy improvement	AM Goals: 6. Compliance improvement	AM Goals: 7. Repuration improvement	AM Goals: 8. Employee well being improvement	AM Goals: 9. Maintenance costs reduction	AM Goals: 10. Material costs reduction	AM Goals: 11. Stock costs reduction	AM Goals: 12. Energy costs reduction	Contribution to Asset Management Goals
Base case - Latest Forecast	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected	Not selected
Data and Document Mgt	(3) Moderate	(3) Moderate	(2) Low	(4) High	(2) Low	(5) Excellent	(3) Moderate	(2) Low	(4) High	(3) Moderate	(2) Low	(2) Low	(3) Moderate
Asset Risk Management (ARM)	(3) Moderate	(4) High	(4) High	(5) Excellent	(4) High	(3) Moderate	(3) Moderate	(2) Low	(2) Low	(3) Moderate	(1) Absent	(2) Low	(3) Moderate
Implement Workflow and Shift Technician	(4) High	(4) High	(4) High	(1) Absent	(4) High	(3) Moderate	(3) Moderate	(4) High	(3) Moderate	(3) Moderate	(1) Absent	(2) Low	(3) Moderate
Improve collaboration	(3) Moderate	(4) High	(4) High	(5) Excellent	(4) High	(3) Moderate	(3) Moderate	(2) Low	(2) Low	(3) Moderate	(1) Absent	(2) Low	(3) Moderate
Set up Long Term Asset Replacement Plan	(3) Moderate	(3) Moderate	(1) Absent	(2) Low	(3) Moderate	(4) High	(3) Moderate	(2) Low	(3) Moderate	(4) High	(3) Moderate	(5) Excellent	(3) Moderate
Next Gen Knowledge Mgt	(3) Moderate	(3) Moderate	(4) High	(3) Moderate	(4) High	(3) Moderate	(3) Moderate	(4) High	(4) High	(3) Moderate	(3) Moderate	(2) Low	(3) Moderate
Rollout Flightmap Asset Portfolio Mgt	(4) High	(4) High	(4) High	(5) Excellent	(4) High	(3) Moderate	(3) Moderate	(4) High	(2) Low	(4) High	(1) Absent	(2) Low	(3) Moderate
Rollout SAP Mobile	(4) High	(4) High	(4) High	(3) Moderate	(3) Moderate	(3) Moderate	(4) High	(3) Moderate	(4) High	(4) High	(3) Moderate	(2) Low	(3) Moderate

Figure 2: Example portfolio project list from Flightmap demo version

When the organization has selected the environmental KPIs relevant to them and attached the weight to these KPIs, it is important to validate if the sustainability assessment is in line with the perception of the sustainability of the people responsible, such as project managers and higher management. To check if the assessment is correctly set or if adjustments are necessary, the data of past projects of which it is clear if they are sustainable or not is entered to see if they appear in the ranking as expected. For example, a very sustainable project of the past should appear at the top when ranking all projects on the total sustainability score. If this is not the case, adjustments need to be made to the sustainability assessment. This is an important part of integrating the sustainability assessment because there is not one perfect assessment for all high-tech organizations and there is thus relied on

the insights of every single organization. Since the solution depends on customization to fit the impact an organization can have, it is important to validate if the results from the assessment support the vision for sustainability of the organization.

To summarize, a list of environmental KPIs is proposed but organizations stay in charge of deciding what to include. To integrate the sustainability assessment into Flightmap, a guide is developed. This leads to the following steps that need to be followed for each organization:

Step 1: The organization chooses which of the 17 proposed environmental KPIs they want to include and if they want to integrate additional environmental KPIs.

Step 2: The organization chooses how much each KPI weighs towards the total sustainability score. The impact an organization can have with their projects should be in the lead, i.e. on which sustainability objectives has the organization the biggest impact. .

Step 3: A total sustainability indicator is added in Flightmap, which is calculated based on the used environmental KPIs and the attached weight as decided in step 2.

Step 4: The organization enters the project data for the KPIs in Flightmap.

Step 5: The organization enters data of a few past projects of which they know the sustainability impact, at least one very sustainable project, one medium sustainable project, and one less sustainable project. For this classification to work, it is important that the sustainability level amongst those projects differ enough to classify them into different categories. In addition, it is important that the sustainability ranking is in line with the intuition of the people in charge because this will increase the willingness to use the tool.

Step 6: The organization ranks the projects based on the total sustainability score by using the ranking function in Flightmap.

Step 7: The organization checks if the past exemplary projects perform as expected in the ranking. If so, the example projects from the past are deleted. If not, the organization reviews the weights attached to the KPIs and adjust them. When adjustments are made, step 6 is repeated.

Step 8: The KPIs and total sustainability score can now be used for sustainability assessment.

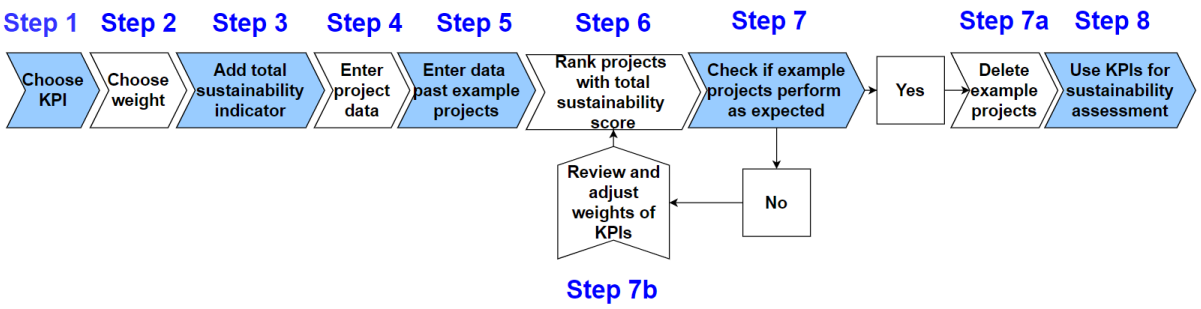

Figure 3: Guidelines for KPI integration and weight attachment

Now that sustainability KPIs are integrated into the DSS, it is important to underline the importance of using these sustainability indicators for the decision-making in the FEI and onwards. This is in line with the third design proposition, stating that sustainability should be part of the decision-making from the early phases of the innovation process and onwards. It is also important to frequently update the information, because when projects make progress, more information becomes available, making the analyses more accurate.

5.3 Setting targets and making formal commitments

Setting targets is a logical and important first step for most organizations. However, as explained in the previous section, a specific choice is made to first choose which KPIs to include, based on the impact an organization can have. This triggers organizations to look at sustainability from a broader perspective than what already is in place within their organization. For example, an organization can have already committed to zero emission and zero waste standards and easily get a tunnel vision on those sustainability aspects that correspond to these targets. However, sustainability, as defined by the environmental objectives of the EU Taxonomy Regulation, is broader than zero waste and zero emissions. So, by challenging organizations to also think of other aspects that they influence, more aspects of sustainability are integrated and therefore the sustainability total that is integrated is more comprehensive.

Before introducing new targets, the organization should look if there are already existing organizational sustainability targets for the environmental aspects that are reflected in the selected environmental KPIs. If so, they should try to translate these to targets for the PPM KPIs. After these are matched, new targets need to be set for the other sustainability KPIs. There should be started with a target for the total sustainability score. To set this target, there should be looked at the starting-point, i.e. the baseline measurement. Besides, organizations should think about the impact they can have with their projects. After the target for the total sustainability score is set, this should be translated back to targets for the KPIs which were not yet matched with organizational targets. The targets for the KPIs should be set in such a way that progress should be made on each KPI and if the targets for the KPIs are met, the target for the total sustainability score is also met.

In line with design proposition 1, it is important to make formal environmental commitments for decision-making. From theoretical and empirical research, it became clear that there often is a mismatch between the strategy and project portfolio decision-making. It is therefore important to translate the overall strategy to hard targets and formal commitments for PPM. This also supports taking sustainability to the front. If commitments are made, it will not be overlooked or ignored and it will receive more priority.

The performance on the KPIs can be followed, to see if the targets are met. It is advisable to not only use the total sustainability score for the selection and prioritization of projects but also to track the total sustainability score of the entire project portfolio and track the environmental KPIs on the portfolio level. By setting targets on the portfolio level, it remains possible to compensate a less sustainable project with a more sustainable project, and by setting portfolio targets for each KPI, none of the environmental aspects will be overlooked and compensated for each time. This leads to the following steps:

Step 9: Look at the organizational strategy, are there environmental goals that can directly be matched with KPIs? If so, match these KPIs with their targets.

Step 10: Calculate the baseline measurement by calculating the project portfolio sustainability score and the average scores for each KPI.

Step 11: Based on the baseline measurement, set a target for the total sustainability score of the portfolio.

Step 12: Translate the target for the total sustainability score of the portfolio back to the not yet filled-in targets for each KPI. Meaning that the targets for KPIs which are not matched to organizational targets in step 9 are now set. All targets for KPIs should add up to the total sustainability target.

Step 13: Decide on the frequency the scores will be presented and justified. Also, formulate what to do when targets are not met.

Step 14: Clearly communicate the commitments to stakeholders.

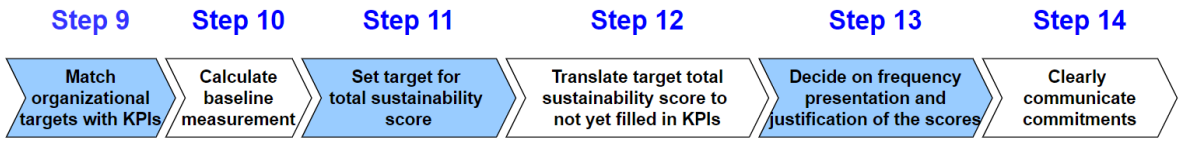

Figure 4: Guidelines setting targets

5.4 Using the environmental addition

By using the guidelines, sustainability assessment is integrated into Flightmap, in such a way that sustainability is part of the portfolio analyses, and targets and environmental commitments are made. Now, organizations need to use these tools provided to them. The tools are preferably used in multiple ways, which are:

- By using the total sustainability score, organizations can rank projects based on their sustainability. They can use the total sustainability score next to other criteria for project selection, e.g. using the total sustainability score, project costs, project risk, etc. to select and prioritize projects.

- By setting sustainability targets on the portfolio level, organizations can track their progress and keep an eye on whether they will meet their targets or if other choices are needed, such as attracting and selecting more sustainable projects.
- By setting portfolio targets on the KPI level, organizations are challenged to not only focus on 'easy wins' but also to make progress on more challenging KPIs.
- By having the insight into how each project scores on different sustainability aspects, organizations are challenged to look for sustainable alternatives for projects, for example, the material choice.
- By having all the data and the ability to show the meaning of the data, such as showing the progress made on sustainability and the sustainability targets which need additional attention to meet the targets, the organization can address this to its stakeholders. This not only challenges the managers in charge of selecting and prioritizing projects, but also the designers and other people involved in the innovation process. Being more aware of sustainability, explicitly considering sustainability, and actively putting it on the agenda, will trigger more sustainable thinking and doing throughout the organization and its supply chain.

To make the most optimal portfolio decisions, the available knowledge on sustainability should be reflected in the sustainability assessment. The knowledge of sustainability will increase over the years, there will be new ways to measure environmental aspects and other environmental aspects might become more important. Besides, when the portfolio becomes more sustainable, targets will be met and new targets will be needed. Therefore, in the long-term, it is advisable to repeat steps 1 to 14. Although this would ask for an updated list of proposed environmental KPIs, the proposed steps will still be useable.

5.5 Conclusion

This chapter elaborated on the solution design. In the solution design, all design propositions are covered. By using the guidelines, the PPM tools will explicitly include sustainability and organizations are challenged to make formal environmental commitments (design proposition 1). The guidelines support that there are checklists, scoring, and ranking tools integrated into the DSS, based on solid environmental indicators that organizations have an impact on (design proposition 2). The design supports including sustainability in the decision-making from the FEI and onwards (design proposition 3). After integrating the sustainability assessment in Flightmap, the PPM tools should provide insights into all criteria and attached weights to make the trade-offs transparent and have the ability to substantiate choices (design proposition 4). This solution sheds light on the bigger picture of sustainability and not on too many details, to not make the tool too complex (design proposition 5).

The solution design comprehends a list of potentially relevant environmental KPIs and guidelines for how these can be integrated into Flightmap. The guidelines provide answers to how an organization can best select KPIs and attach weight, to come to a total sustainability score for each project, that can be used for sustainability assessment.

A guideline to set targets and make environmental commitments is also part of the solution design. This guideline includes steps from measuring the baseline, setting targets on a portfolio level, and communicating where you want to go. Also, recommendations are presented on how sustainability can be taken into account when making project portfolio decisions. This solution will lead to a more sustainable project portfolio. In the long-term, it is advisable to repeat steps 1 to 14. This is to set new targets when the previously set targets are reached and because the knowledge on sustainability will increase over the years and these new insights can be used.

This solution design embraces the customization that Bicore offers its clients with Flightmap. Organizations stay in the lead in selecting the most relevant KPIs for them and setting their targets. In the next chapter, the validation of the solution design is discussed.

6. Validation

It is important to verify the solution design. In other words, it needs to be checked if all design propositions are covered and all requirements are met. To verify if the solution design helps solve the business problem of Bicore, the solution design is verified with the use of four interviews with organizations. Each interview took approximately 30 minutes. The interviews were held via Microsoft Teams. With the use of screen sharing, a PowerPoint presentation is shown to present and explain the solution design with the use of visuals in the form of mock-ups of Flightmap. The mock-ups can be found in Appendix E. The presentation and clarification questions took approximately 10 to 15 minutes. The other 15 to 20 minutes are used to ask questions about the helpfulness, usability, and points for improvement. The next questions are asked:

a) Does the solution help to consider sustainability in PPM?
b) Are there points for improvement?
c) How would you score the usability on a scale from 1 to 10 and why?

This chapter will also answer the sub-question (TestQ). This is done by including additional questions in the interview to find out to what extent organizations will let sustainability influence their project portfolio decision-making when the tools are available. The questions asked are:

d) What do you think the influence of these guidelines will be on PPM?
e) What do you think the influence of these guidelines will be on the time and resource planning of the projects and the project portfolio?

To make sure the four interviews provide a good view of different organizations, a validation matrix is used. The matrix is presented in Table 18. On the X-axis the level of sustainable maturity in PPM is presented, to make sure that the validation sample presents a good mix of organizations with different maturity levels. To be more specific, the level of maturity corresponds to the sustainability considerations in PPM instead of considering sustainability in their business operations and having sustainability high on the agenda. On the Y-axis, there are two options as well, if the interviewed organization is a Flightmap customer or not. The four organizations are selected from the ten organizations from the sample of the empirical research. This is because the maturity of these organizations is known. Each organization was represented by the same respondent as during the first interview.

Table 18: Validation matrix

	Less mature sustainability level in PPM	High mature sustainability level in PPM
Non-Flightmap customer	Validation 1	Validation 2
Flightmap customer	Validation 3	Validation 4

In addition to interviewing organizations to see if the solution design helps to include sustainability considerations in PPM and assessing the usability of the solution design, it is important to check if the design requirements are met. Since detailed knowledge of the software Flightmap is required for this validation, this part of the validation is executed by interviewing the Chief Technology Officer (CTO) of Bicore. This person knows all details of Flightmap and should be able to assess if the requirements are met. Since a list of design requirements can also serve as a checklist to check if all the requirements of the client's system are met (Van Aken et al., 2012), each of the requirements is checked if it is met. This interview took approximately 45 minutes and is held via Microsoft Teams. First, the solution design is presented with the use of a PowerPoint that is shown with screen sharing. Second, the design requirements are shown on the screen and each requirement is discussed. For each requirement it is asked if the CTO thinks the requirement is met and why.

This chapter starts with elaborating on the validation of the solution design. The main points from the respondents are discussed for each interview. Next, it is discussed if the design requirements are met according to the CTO of Bicore. An overview of the points for improvement and alterations that result from the validation is presented. This leads to the final solution. Last, the TestQ is answered.

6.1 Validation 1

The first validation is performed with a non-Flightmap client. This organization does have sustainability on its agenda, but it is not explicitly part of its PPM and is therefore in the low maturity category when it comes to having sustainability embedded in its portfolio approach. The respondent finds the solution is recognizable with how they handle things in their organization, such as looking first at what they do have an impact on and after that formulating targets. The respondent thinks it is helpful you can look at the performance on each environmental KPI because some KPIs receive naturally more attention than others. The respondent is very enthusiastic about making sustainability part of their project success, by integrating sustainability into the existing approach toward portfolio management. The respondent likes that sustainability KPIs are taken into account next to other important KPIs, such as costs, and that it is implementable within the current DSS. According to the respondent, providing insights into the sustainability impact of projects and portfolios and making it part of their success, will increase the relevance felt towards sustainability.

According to the respondent, the provided solution will also give insights into sustainability for the designers, and this will trigger their thinking on this subject. At this moment, the sustainability of projects is not yet clear and visible, and that is why it comes short in comparison to other KPIs that are part of PPM. For the usability of the solution, the respondent scores the solution an 8 out of 10, for organizations that are already known with sustainability. Organizations that do not yet have

sustainability expertise available in their organization might need additional support for going through the steps. Another important piece of advice from the respondent is the necessity to get higher management on board, their commitment is required to reach the targets.

The main take-away of this validation interview is that integrating sustainability assessment into the existing DSS and making sustainability part of the project's success will help, but support from higher management is required to make it successful and external expertise might be necessary.

6.2 Validation 2

The second validation is performed with a respondent from an organization that does not use Flightmap but another DSS that is comparable. This organization could be labeled as an organization with a high level of maturity when it comes to integrating sustainability in PPM. Even though the organization of the respondent does not use Flightmap, the respondent understands how this solution could be integrated into Flightmap and other DSS's for PPM. The respondent underlines the importance of making sustainability an integral part of PPM and thinks that the proposed guidelines will support this. The respondent scores the usability of the guidelines a 9 out of 10 for organizations that are already familiar with PPM. In addition, the respondent underlines the importance of such guidelines to have an impact on the sustainability of the project portfolio. The mock-up of the heat map makes the respondent enthusiastic because organizations can easily see how they are performing in which aspects. The list of proposed KPIs for organizations as part of the solution is received as a functional addition that is good for the process because an organization will immediately get a better understanding of how sustainability could be assessed and integrated.

The respondent understands why the first step is to choose KPIs instead of setting targets for PPM. However, the respondent notes that it is beneficial if the organization already has formulated a higher ambition for being sustainable at the company level. This will also help convince higher management, in charge of choosing KPIs, to work on the environmental ambition of the organization with their PPM. In addition to step 14 of the guidelines, the respondent underlines the importance of clearly communicating the commitments to the shareholders, as a measure of insurance.

The main take-away of this validation interview is that making sustainability an integral part of PPM is the right way to include sustainability and the proposed list of environmental criteria will help organizations to get a better understanding and is therefore good for the process.

6.3 Validation 3

The third validation interview is held with a Flightmap client. The respondent has a lot of knowledge on the topic of sustainability and portfolio management, sustainability is however not yet explicitly

part of their PPM. The respondent is enthusiastic about integrating sustainability in Flightmap, because the proposed solution will definitely help, for example, to create clarity and help rank projects. The method is clear, but the respondent underlines that 'the proof of the pudding is in the eating'. The respondent's opinion is that the usability can only be scored after integrating into Flightmap because only then you can see how it works and if refinement is needed. However, the respondent believes that the solution will support decision-making, which is required because resources are limited.

In addition, the respondent likes the list of KPIs that is part of the solution. However, this list could be extended with, for example, the indicators used in the IPCC-rapport (United Nations Intergovernmental Panel on Climate Change). The respondent would also like the possibility to make scenario analyses within projects. Currently, this is a limited functionality in Flightmap, but it would be beneficial to have the possibility to make sub-optimizations within projects. The respondent likes that sustainability can be set against other KPIs such as the project costs, for example in a bubble-graph.

The main take-away of this validation interview is that integrating sustainability into Flightmap will help the organization create clarity and rank projects but the usability of the solution will only become clear when using the addition in Flightmap and refinement might be necessary then.

6.4 Validation 4

The fourth validation interview is held with a Flightmap client. This client has sustainability embedded in their innovation projects and could therefore be labeled as sustainable mature. The respondent marks that not all organizations have all sustainability data for projects available and choosing the right KPIs is hard. The usability of the solution will depend on the willingness of organizations to invest in retrieving the data and choosing the right KPIs. The respondent also thinks that if this is not done, it can contribute to greenwashing. A benchmark for useful KPIs for sectors would be helpful, to give organizations an idea of what KPIs other organizations in their sector use. The respondent thinks that some improvements can be made. Steps 11 (set targets for total sustainability score) and 12 (translate the target for the total sustainability score to targets for the KPIs which are not yet filled in) could be switched. In addition, the respondent recommends linking the steps about deciding on the frequency for presentation and justification of the scores (step 13) and the step about clearly communicating the commitments (step 14) to formal moments in the organization. This solution is considered helpful to organizations to get insights into their sustainability. Flightmap can help by visualizing this. For example, the heat map shows multiple KPIs, such as the financial KPIs, but also sustainability KPIs.

The main take-away of this validation interview is the importance of selecting the right KPIs and the suggestion to link the presentation and justification of the results and making commitments to formal moments in the organization.

6.5 Validation design requirements

The list of design requirements is used to serve as a checklist to check if all the design requirements are met. Each of the requirements is discussed. As to why the CTO thinks the requirements are met, quotes of his arguments are provided in Table 19.

Table 19: Validation design requirements

Type of design requirement	Design requirements	Is the design requirement met? Why?
Functional requirement	The business problem should be solved by implementing the design solution	*"Yes, the solution is a framework that we can use to integrate sustainability into PPM. During integration, sub-choices will be made, but this is always the case when you start integrating it."* The four validation interviews with external organizations also confirmed that the solution design supports taking sustainability into account in PPM.
	The solution design should support environmental sustainability, as approached by the EU Taxonomy, to be part of PPM	*"Yes, the EU Taxonomy is still in motion, but for the framework that does not matter. Clearly used as a reference point."*
	The solution design should increase the environmental sustainability of the project portfolio	*"Yes, that is clear."* The four validation interviews with external organizations also confirmed that the solution design is expected to make the project portfolio more sustainable.
	The benefits of the solution design should exceed the costs	*"Yes, it fits in the current platform and therefore will keep the costs low."*
User requirements	Flightmap should remain user-friendly	*"Yes, clients can adjust themselves with little effort."*
	Current users of Flightmap should understand the additions and adjustments caused by the solution design	*"Yes, this fits in the customization that we offer. The consultants of Flightmap understand this, so this will be fine."*
	The design should be unambiguous	*"The consultants will understand this framework and that the guide should be followed, besides they will understand that the specificities are intentionally left open for organizations."* The four validation interviews with external organizations also confirmed that the solution design is clear and understandable.
	There should be possibilities for organization-specific prioritization related to environmental criteria	*"Yes, the design is modular, so organizations can make their own choices."*
	The design should support frequently updating the information	*"Yes, the design is modular and adjustable. The module will fit in the generic model that is supported in Flightmap".*
Boundary	The design should fit in the	*"Yes, the design is modular and adjustable. The*

conditions	software of Flightmap	*module will fit in the generic model that is supported in Flightmap".*
	The design should fit within the present business policies of Bicore	*"Yes, the policy of Bicore is to support the clients and offer exemplary modules for PPM. The solution design fits this policy."*
Design restrictions	The design should cause as little change to Flightmap as possible	*"Yes, we support generic models and this module fits these models."*
	The design should be implemented within the allocated time	*"Yes, the complexity can easily be scoped, it is manageable to fulfill within the allocated time, also because of the structure of the design".*
	The design should fit within the allocated budget	*"Yes, the complexity can easily be scoped, it is manageable to fulfill within the allocated budget".*

The requirements are all met. The sustainability addition fits in the generic models of Flightmap and will cause minimal changes to the users. The solution fits the customization that Flightmap offers and is in line with the business policies of Bicore. Therefore, this validation leads to no further alterations.

6.6 Conclusion validation

The solution design will provide insights into the sustainability of the projects and portfolio. The organizations express that they think that integrating sustainability into the DSS and making it part of the portfolio analyses, next to other criteria such as costs and project risks, will contribute to more sustainable decision-making. By making sustainability part of the project and portfolio success, it will be explicitly part of the decision-making. The visualizations of the solution, i.e. the mock-ups of Flightmap, make the respondents enthusiastic and it convinces them that visualization of the sustainability creates clear insights. The solution design is expected to be usable in practice. However, the 'proof of the pudding is in the eating'. Some alterations after implementing the new KPIs in Flightmap may be required. Besides, together with the CTO of Bicore it is checked if the design requirements are all met, which is the case.

From the validations, some points for improvements came to the surface. The suggestions and to what alterations these lead are shown in Table 20.

Table 20: Suggestions from validation

Suggestion	Alteration	Explanation	From
Define a higher ambition for sustainability before starting to select the KPIs	No alteration is made	All organizations spoken to during the empirical research have organization-wide sustainability ambitions. Organizations that are willing to consider sustainability in PPM are expected to have sustainability already embedded in their strategic goals. Their next step is to align their PPM approach to the sustainability goals of the organization.	Validation interview 2
Extend the list of KPIs with indicators from IPCC-report	No alteration is made	The proposed environmental KPIs should trigger organizations to look beyond what already is in place. The list could be	Validation interview 3

		extended with a great number of potentially useful indicators, also from other sources. The current list is sufficient for its purpose and organizations are free to add KPIs important to them.	
Provide a benchmark for KPI selection	No alteration is made	This could be interesting to do in the future, but additional research is needed to establish a benchmark.	Validation interview 4
Link presentation and justification of the sustainability scores and communicating environmental commitments to formal moments	Is used for an additional recommendation for executing steps 12 and 13	This is a good recommendation for organizations, to embed sustainability in their organization.	Validation interview 4
Support from higher management is required	This is formulated as a requirement to reach the targets	If higher management does not value the sustainability KPIs and targets, they will not agree with making other choices than what is best on the other previous set KPIs (e.g. finance and risk KPIs).	Validation interview 1
Support from external sustainability experts to select KPIs and attach weight when this expertise is not available in the organization	Is used for an additional recommendation for executing steps 1 and 2	It is important to integrate a fitting sustainability assessment in the DSS. When the knowledge is not available to do so, external knowledge is needed.	Validation interview 1
Switch steps 11 and 12	No alteration is made	The overall win on sustainability is valued higher than the win on each environmental aspect. Therefore, the total sustainability score comes first.	Validation interview 4
Have special attention to communicating the commitments to the shareholders in step 14	Shareholders are now specifically mentioned	With stakeholders, shareholders are also meant. Now they are mentioned, to make sure organizations do not forget to communicate it to them.	Validation interview 2
Have the possibility to make scenario analyses within projects	No alteration is made	Making sub-optimizations within projects is currently a limited functionality in Flightmap and the solution design cannot change this.	Validation interview 3

6.7 Influence of including criteria for environmental sustainability

The validation interviews are also used to answer the TestQ by elaborating on the influence of including criteria for environmental sustainability on the sustainability of the portfolio and on the time and resource planning of an innovation project and the project portfolio. All four respondents think that including criteria for environmental sustainability will increase the sustainability of the project portfolio. The main reason for this is that it will provide insights into the sustainability of projects, which is not yet provided for in each organization. The respondent of the first validation interview views that making sustainability part of the success of projects by taking it into account next to other KPIs, such as costs, will increase the relevance felt towards sustainability. Besides, the second

validation interview underlines the key role of including environmental criteria in DSS, to make sure it is part of the decision-making. The fourth validation interview also underlines that the addition of sustainability as part of the multi-criteria analyses will support organizations in sustainable decision-making.

On the answer to the second part of the question, about the influence on time and resource planning of an innovation project and portfolio, the respondents show less compliance. The respondent of the first validation interview does not expect that following the guidelines will influence the time and resource planning of the portfolio. However, this respondent expects that some organizations need additional resources in terms of sustainability knowledge when giving sustainability a bigger role in their projects. Therefore, some organizations will bring in sustainability experts, by hiring new employees. The second respondent is convinced that time and resource planning will not be affected by integrating sustainability because it will be an integral part of the PPM such as other criteria. The respondent of the third validation interview views the influence of integrating sustainably on time and resource planning as equivalent to making other choices for dividing resources over projects. The organization will look at which projects score best on their KPIs and divide the available resources over those projects. The respondent of the fourth validation interview finds that the influence on time and resource planning is hard to forecast on the project level. However, the respondent expects that other choices might be made on the portfolio level in the long run, if a certain part of the portfolio underperforms. To conclude, it is expected that some organizations will bring in new expertise when sustainability gets a bigger role in the innovation process and if sustainability is taken into account in decision-making it can lead to other choices for selection and prioritization.

What is the influence of including criteria for environmental sustainability on the a) sustainability of the portfolio, b) time and resource planning of an innovation project and the project portfolio?

The influence of including criteria for environmental sustainability will provide more insights into the sustainability of the project and the portfolio. It will make sustainability explicitly part of the decision-making and is expected to lead to more sustainable choices and thus a more sustainable portfolio. The influence of including criteria for environmental sustainability on the time and resource planning is expected to be minimal. Reasons for this are that when it is an integral part of the portfolio management approach, it will not take more time or resources. Organizations will try to achieve most goals and score optimally on their KPIs with the resources they have available. Integrating additional KPIs will influence the project scores and can in turn change the portfolio composition. Although the time and resource planning is not expected to be affected, if organizations are going to set targets for sustainability, some might need to invest more in their sustainable knowledge and thus new experts need to be hired.

Text box 9: Answer to test question

6.8 Final solution

The input from the validation is used to make adjustments. These adjustments are discussed in 6.6. The adjustments lead to the final solution. The final solution is visualized in Figure 5.

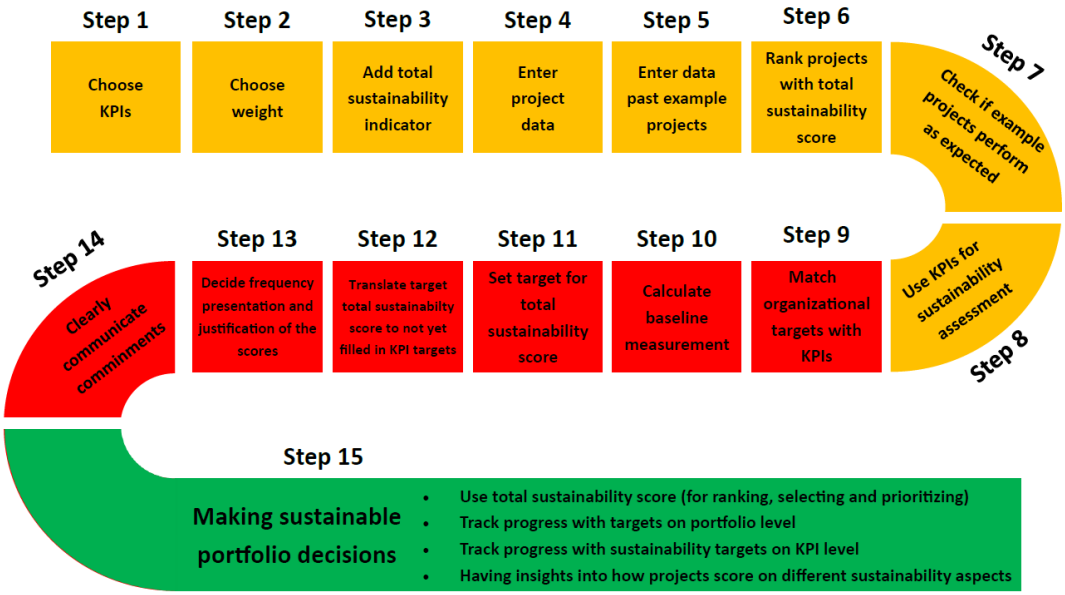

Figure 5: Final solution

7. Discussion

This chapter concludes the research by answering the research question, summarizing and presenting the final solution, elaborating on the implications of the research, and discussing the suggestions for future research and the limitations of this research.

7.1 Answer to the research question

The topic for this research is initiated by Bicore, to get more insights into how sustainability could, to a greater extent, be part of PPM. This led to the following research question:

How can organizations consider the sustainability of innovation projects when making portfolio decisions in the ideation phase?

For organizations to be able to consider sustainability, they should have the tools to assess the sustainability of projects. Organizations do have KPIs in place to, for example, assess the costs and risks of projects. Organizations must introduce environmental KPIs as well, to provide insights into sustainability and make it explicitly part of the decision-making. These KPIs should be solid environmental indicators that reflect the sustainability impact of the projects. This sustainability assessment tool should be integrated into the project portfolio DSS, to make sustainability an integral part of the multi-criteria analyses, used for project selection and prioritization. When the assessment tools are in place, decision-making should be directed towards making the portfolio more sustainable. To do so, sustainability targets and commitments for PPM are required. Although organizations do have targets for making, for example, their factories more sustainable, no hard targets are set for managing their project portfolio. For projects and portfolios, targets need to be formulated and commitments need to be made, for sustainability not to be a 'wish' but a 'must'. When the sustainability assessment and targets are integrated into the DSS, organizations can track their performance on sustainability and make the choices to meet the sustainability targets.

This study focused on the ideation phase because in this stage it is even more beneficial to take sustainability into account. Results from the SLR confirm this. For example, previous studies by Hallstedt and Isaksson (2017) and Villamil & Hallstedt (2018) show that sustainable product development should be implemented in the early stages of the innovation process. Also, Goffin (2012) and Brones et al. (2015) underline the importance of integrating environmental requirements, throughout the key stages and gates, from the early and particularly decisive stages. The importance of taking sustainability into account as early as possible was also underlined by the empirical research, however, organizations prefer to consider sustainability from the ideation phase and on through the

rest of the innovation funnel. To do so, the sustainability KPIs and project data for these KPIs should be available from the FEI, such that sustainability is part of the KPIs for ranking the projects and that determine which projects are selected and which are stopped or revised in the ideation phase.

To conclude and answer the research question, organizations should integrated sustainability assessment into their DSS for PPM in the form of environmental KPIs to make sustainability an integral part of their PPM, set sustainability targets, and make commitments to direct the decision-making toward a more sustainable project portfolio.

7.2 Description of the final solution

The answer to the research question leads to the final solution. The solution is a guide to support organizations in selecting KPIs for sustainability assessment of projects, integrating these KPIs in the decision support tools, setting targets, and finally making more sustainable project portfolio decisions. In addition, recommendations are provided for executing the steps in the guide. This guide consists of 15 steps. The steps can be divided into three parts. The first part is about KPI integration and weight attachment, which contains steps 1 to 8. The second part contains steps 9 to 14 and is used for setting targets and making commitments. After the steps are executed, the third part of the solution offers support on how organizations can use the sustainability assessments and targets when they are set, which is step 15. Figure 6 shows the final solution. In this figure, the first part of the solution is in yellow, the second part in red, and the third part in green.

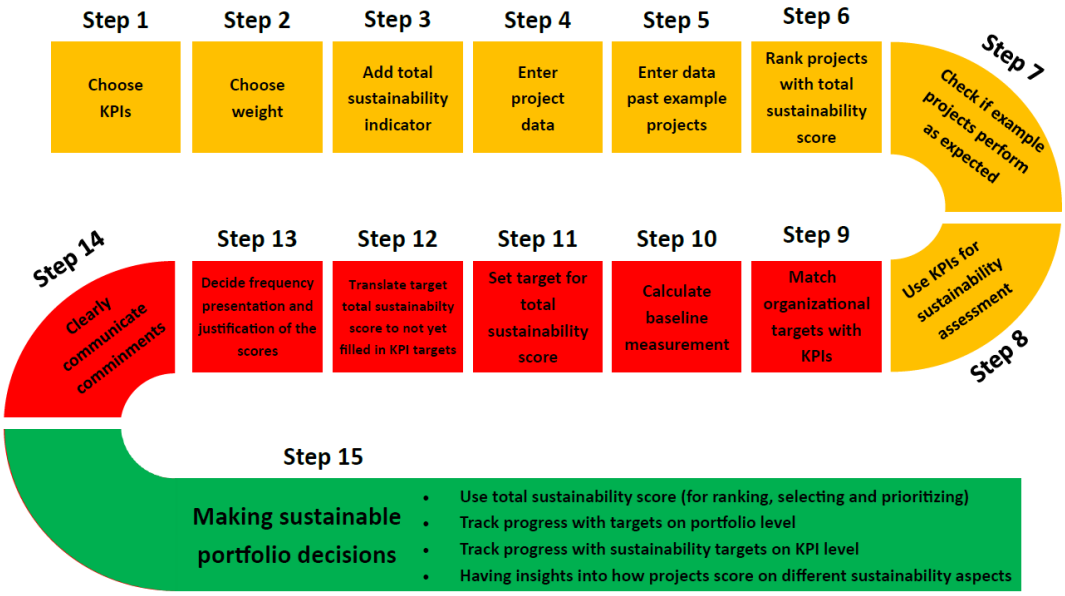

Figure 6: Final Solution

From the results gathered from the SLR and empirical research, some recommendations can be provided to organizations for executing these actions. These are summarized in Table 21.

Table 21: Steps and Recommendations

Step	Recommendation
1 Choose KPIs	- Select the KPIs on which the organization has an influence. Choose KPIs from a broad perspective of sustainability. - A list with proposed KPIs is provided to trigger looking beyond what is already in place. - The KPIs are selected for the portfolio, and every project within the portfolio will be scored on the same KPIs - If no sustainability expertise is available within the organization to support the selection of environmental KPIs, it would be best to get external advice on this.
2 Choose weight to link to KPI	- The weight should express the relevance of the KPIs for the organization. Attach more weight to KPIs for the environmental aspects with which the organization can have a bigger influence on the environment and less weight to those the organization has minimal influence on. For example, if a lot of water is used, attach more weight to water usage and if energy usage is minimal, attach a lower weight to that. - If no sustainability expertise is available within the organization to support the relevance assessment, it would be best to get external advice on this.
3 Add total sustainability score	- All selected KPIs and the attached weight will lead to the total sustainability score.
4 Enter project data	- As well as enter the data about the finance and risks, also enter the project data about environmental sustainability.
5 Enter data past example projects	- Make sure to enter project data of at least one NOT sustainable project, one medium sustainable project, and one very sustainable project. Adding more projects in these three categories will make the validation more reliable.
6 Rank projects using the total sustainability score	- This is executed by the DSS.
7 Check if example projects perform as expected	- If example projects perform as expected, delete the past projects from the set. - If example projects do not perform as expected, the attached weights need to be adjusted.
8 Use KPIs for sustainability assessment	- Use the KPIs for sustainability assessment of innovation projects and the project portfolio.
9 Match (already present) organizational targets with selected KPIs	- If there already are organizational targets that match the selected KPIs from step 1, fill in these targets for the KPIs.
10 Calculate baseline measurement	- This is executed by the DSS.
11 Set target for total sustainability score	- Look at the baseline measurement and set an ambitious but achievable target for a defined period.
12 Translate target for total sustainability score back to targets for the single KPIs	- Look at the target for the total sustainability score and translate this target back to targets for the single KPIs. - Set ambitious but achievable targets for a defined period.
13 Decide on frequency, presentation, and justification of the sustainability scores	- Decide how received results are presented and to whom. - Decide the frequency for presenting the results. - Decide who is responsible for justifying the (not) achieved results. - Link this to formal moments in the organization.

14 Communicate the commitments	-	Communicate the commitments to stakeholders, especially to the employees, other players in the supply chain, clients, and shareholders. - Link this to formal moments within the organization.
15 Making sustainable portfolio decisions	-	Use the sustainability assessment and targets to make more sustainable portfolio decisions.

In addition, a list of 17 proposed environmental KPIs is provided to organizations, to support the selection of KPIs in step 1. Table 22 provides an overview of these KPIs.

Table 22: Proposed environmental KPIs

Climate change mitigation 1. Energy consumption in manufacturing in MJ per unit 2. Energy consumption in use in MJ per unit 3. Global warming in Kg CO_2 per unit	**Pollution prevention and control** 9. Life-cycle greenhouse gas (GHG) emissions in weight 10. NO_x air emissions in weight 11. SO_x air emissions in weight 12. PM10 and PM2,5 in weight	**Protection and restoration of biodiversity and ecosystems** 15. Acidification in Kg SO_x and NO_x 16. Impacts on biodiversity (low/medium/high)
Transition to a circular economy 4. Cumulative energy demand in MJ per unit 5. Total number and volume of significant spills (calculated per unit) 6. Product life in days/months/years 7. Percentage of materials used that can be recycled (in %) 8. Life-cycle raw material consumption (excluding water and renewable or recycled materials) in Kg	**Sustainable use and protection of water and marine resources** 13. Water used in the production process per unit in m^3 14. Project life-cycle water requirement in m^3	**Climate change adaptation** 17. The contribution of the project to climate change adaptation (low/medium/high)

When the sustainability assessment is integrated and the targets are set, the tools can be used for decision-making, step 15. In Table 23 recommendations are presented on how sustainability can be taken into account when making project portfolio decisions.

Table 23: Recommendations for sustainable decision-making

Way of using provided tools	Recommendations
Using the total sustainability score	Organizations can rank projects on their sustainability. They can use the total sustainability score next to other criteria for project selection, e.g. using the total sustainability score, project costs, project risk, etc. to select and prioritize projects.
Using the sustainability targets on the portfolio level	Organizations can track their progress and keep an eye on whether they will meet their targets or if other choices are needed, such as attracting and selecting more sustainable projects.
Using portfolio targets on the KPI level	Organizations are challenged to not only focus on 'easy wins' but also to make progress on more challenging KPIs.
By having the insight into how each project scores on different aspects	Organizations are challenged to look for sustainable alternatives for projects, for example, the material choice.

By having all the data and the ability to show the meaning of the data	Organizations can show the progress on sustainability targets and see which need additional attention to meet. This not only challenges the managers in charge of selecting and prioritizing projects, but also the designers and other people involved in the innovation process.

To conclude, this solution will lead to a more sustainable project portfolio by integrating sustainability assessment into the DSS and making it an integral part of PPM, and by directing choices to reach the set sustainability targets. However, also the support from higher management is necessary to reach the targets. Besides, in the long-term, it is advisable to repeat steps 1 to 14. This is because when the portfolio becomes more sustainable and in time the previous set targets are met, this asks for setting new targets. Also, the knowledge of sustainability will increase over the years, there may become new ways to measure environmental aspects, and other environmental aspects might become more important. Although this would ask for an updated list of proposed environmental KPIs, the proposed steps will still be useable.

Organizations are getting more aware of their impact on the environment. This was also recognized by Bicore and caused them to initiate this study. With this solution design, Bicore can provide its clients with an extension of the current possibilities in Flightmap and support them in the need to make more sustainable decisions within their project portfolio.

7.3 Implications of the research

The importance of including sustainability in portfolio management is investigated in the literature, however, guidelines on how organizations could do this are missing. The next two sections elaborate on the theoretical implications and practical recommendations.

7.3.1 Theoretical implications

A contribution that is made to the literature is that this study describes the characteristics of sustainable innovation projects and how a sustainable innovation project could be defined. This adds to the existing literature because there is no clear definition or common standards found in previous studies for what an environmental sustainable innovation project encompasses. This even though there is a big variety of definitions in literature for topics similar to sustainable innovation projects, for example, the definition of GPD by Albino et al. (2009), the definition for a life-cycle approach by Helling (2015), the definition of a green product by Ottman et al. (2006) or the definition of a sustainable product portfolio by Villamil and Hallstedt (2018). This study combines the insights into characteristics of sustainable products from Jugend et al. (2017b), Albino et al. 2009), Helling (2015), Dangelico and Pjuari (2010), Ottman et al. (2016), Brones et al. (2020) and Goffin (2012) to define what a sustainable innovation encompasses.

Another contribution to the literature is that this study offers a broad gathering of ways in which sustainability can be assessed. Especially the elaborated list of environmental KPIs retrieved from previous research is a contribution to the sustainable project literature. Although previous studies by Koboyashi et al. (2011), de la Cruz et al. (2021), Jugend et al. (2017), Brook & Pagnanelli (2014), Peralta et al. (2021), Garcez et al. (2016b), and Helling (2015) provide several potential relevant KPIs for assessing sustainability, none of these studies addresses each of the six environmental objectives of the EU Taxonomy Regulation with indicators for sustainability. Meaning that even though their indicators are relevant for assessing the sustainability of projects, these are not comprehensive enough to assess the sustainability from a broad perspective. This study gathered indicators to demonstrate how environmental sustainability could be assessed from a broad perspective on sustainability, which adds to the existing literature by being more comprehensive.

7.3.2 Practical recommendations

For organizations that are looking for a way to make sustainability considerations more explicitly part of PPM, the provided guidelines lay the foundation. These guidelines embody the most important practical recommendations. Organizations do not need to reinvent the wheel, but instead, follow the steps in the guidelines and the recommendations for executing these steps. This study also paves the way for Bicore to integrate sustainability assessment into their decision support software, Flightmap, to support their clients to make sustainability explicitly part of decision-making.

Besides the provided guidelines, some other practical recommendations can be made. This study shows that organization-wide goals are not always reflected in PPM when it comes to sustainability. The final solution provides a way to overcome the mismatch between organization-wide sustainability goals and sustainability targets in PPM. It is however important to also reflect the other organization-wide goals into PPM. Organizations should be more aware of the importance of aligning their PPM with their organizational goals and examine if and to what extent this needs improvement.

In addition, this research shows there is a big variety of definitions for sustainability. Organizations should ask themselves what sustainability means to them and what it involves in their organization. There are no wrong answers, but from the empirical research it appeared that some views on sustainability seem rather small. Organizations should challenge themselves to come to an understanding of what they do want to achieve when it comes to sustainability and make this known throughout the entire organization.

Another important recommendation is that higher management should fulfill their leading role while finding a new balance between important targets for PPM. Introducing new KPIs and targets for sustainability in the PPM will cause a shift in focus. When introducing sustainability in PPM, higher

management should support this and should give space to projects that before would not have been selected, prioritized, or continued.

Employees working on the innovation projects must be made aware of new sustainability KPIs when they are integrated into PPM. In addition, these employees would benefit from additional knowledge in the field of sustainability when it gets a bigger role in the innovation process. It is therefore recommended that organizations try to increase the knowledge of the project designers, for example, through workshops, to get more feeling with the topic and get to know more sustainable alternatives, for example material choice. Additional knowledge will in turn help designers come up with more sustainable ideas and concepts, which will then score better on the sustainability KPIs.

7.4 Suggestions for future research and limitations

Although this study provides good insights into the current literature and how high-tech organizations are currently working on sustainable PPM, no study is flawless. The key limitations of this study are discussed and suggestions for future research are provided.

First, most literature focused on NPD, instead of focusing on innovation projects, meaning that those findings needed to be translated to the project level. Although this study made that translation, this could be further investigated. During the research, it also became clear that in the field of PPM, there is not yet one standard for how to approach sustainability, not in literature nor practice. In addition, the empirical research indicated that organizations are currently looking for ways to consider sustainability in PPM and explicitly take it into account. In addition, organizations like to compare themselves to other organizations, especially competitors. However, for the solution to work, customization is required and this stands in the way of providing that benchmark. The solution of this study is therefore especially helpful for internal use, instead of using it as a benchmark for comparison. A suggestion for future research could be to focus more on similar aspects of sustainability that organizations can influence, to design a format that can withstand as a benchmark.

Second, although 10 qualitative interviews led to many insights into the role of sustainability in organizations and their PPM, other high-tech organizations may encounter other difficulties with considering sustainability. Therefore, a limitation of this study is the sample used for the empirical research. It is expected that the biggest barriers and needs for integrating sustainability are addressed by the sample and are thus covered by the provided solution. However, the solution could be further fine-tuned with more empirical results from a bigger sample. The same holds for the validation process. The solution could be validated and tested on a bigger sample, to receive more feedback and to make more adjustments before coming to the final results. It would also be interesting to follow

organizations and their portfolio during and after following the guidelines, to see the results in real-time, and measure the effects over a longer period.

Third, this study focused on the high-tech industry. Other industries using portfolio management, such as real estate, could also benefit from taking sustainability into account to a greater extent. Even though the guidelines themselves can be helpful for them, the list of proposed KPIs will need adjustment. A suggestion for future research would therefore be to check for the generalizability of the guidelines and set up a broad gathering of useful KPIs for other sectors.

References

Albino, V., Balice, A., & Dangelico, R. M. (2009). Environmental strategies and green product development: an overview on sustainability-driven companies. *Business strategy and the environment, 18*(2), 83-96.

Ammenberg, J., & Sundin, E. (2005). Products in environmental management systems: drivers, barriers and experiences. *Journal of Cleaner Production, 13*(4), 405-415.

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, 11*(9), 2664.

Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *Journal of cleaner production, 45*, 1-8.

Brockhaus, S., Petersen, M., & Knemeyer, A. M. (2019). The fallacy of "trickle-down" product sustainability: Translating strategic sustainability targets into product development efforts. *International Journal of Operations & Production Management, 39*(9), 1166-1190.

Brones, F., Zancul, E., & Carvalho, M. M. (2020). Insider action research towards companywide sustainable product innovation: ecodesign transition framework. *International Journal of Managing Projects in Business.*

Brook J. W., & Pagnanelli F. 2014. Integrating sustainability into innovation project portfolio management – a strategic perspective. *Journal of Engineering and Technology Management 34*. 46–62.

Brundtland, G. (1987). Report of the World Commission on Environment and Development: Our Common Future. United Nations General Assembly document A/42/427.

Collado-Ruiz, D., & Ostad-Ahmad-Ghorabi, H. (2013). Estimating environmental behavior without performing a life cycle assessment. *Journal of Industrial Ecology, 17*(1), 31-42.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1997). Portfolio management in new product development: Lessons from the leaders—I. *Research-Technology Management, 40*(5), 16-28.

de la Cruz López, M. P., Cartelle Barros, J. J., del Caño Gochi, A., & Lara Coira, M. (2021). New Approach for Managing Sustainability in Projects. *Sustainability, 13*(13), 7037.

Daneshpour, H., & Takala, J. (2017). Decision making towards integration of sustainability into project management; A multilevel theory building approach. *Management and Production Engineering Review, 8*(3), 13-21.

Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of business ethics, 95*(3), 471-486.

Denyer, D., Tranfield, D., & Van Aken, J. E. (2008). Developing design propositions through research synthesis. *Organization studies*, *29*(3), 393-413.

Dyllick, T., & Hockerts, K. (2002). Beyond the business case for corporate sustainability. *Business strategy and the environment, 11*(2), 130-141.

Europese Wetgeving Luchtverontreiniging, Rijksinstituut voor Volksgezondheid en Milieu. Retrieved from https://www.rivm.nl/ggd-richtlijn-medische-milieukunde-luchtkwaliteit-en-gezondheid/wet-en-regelgeving-luchtkwaliteit/europese-wetgeving-luchtverontreiniging#:~:text=De%20WHO%20heeft%20een%20gezondheidskundige%20advieswaarde%20van%2010%20%C2%B5g%2Fm,hier%20niet%20aan%20te%20toetsen.

Eling, K. (2020). Green, social and profitable-the role of front end of innovation decision making in achieving more sustainable new products. In *Managing Innovation in a Global and Digital World* (pp. 305-319). Springer Gabler, Wiesbaden.

Ellis, J., Colin-Jones, A., Solvay, J., & Washer, M. (2021-03-04). Solvay Chemical: A Tool for Identifying and Planning Sustainable Business Strategies. *Putting Purpose Into Practice: The Economics of Mutuality.* Oxford University Press.

EU Taxonomy Regulations*. Retrieved from:* https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

Fragola, J. (2010). Know your portfolio: Project portfolio management can support an expected recovery by linking strategic plans with organizational programs and investments. *Information Management, 20*(1), 22.

Garcez, M. P., Junior, F. H., & Farah, D. (2016). Green plastics: analysis of a firm's sustainability orientation for innovation. *Revista de Gestão Ambiental e Sustentabilidade, 5*(3), 21-35.

Goffin, K. (2017). Sustainability and new product development. *Cranfield on corporate sustainability* (105-118). Routledge.

Hakkarainen, K., & Talonen, T. (2014). The innovation funnel fallacy. *International Journal of Innovation Science, 6(*2), 63-72

Helling, R. (2015). Driving innovation through life-cycle thinking. Clean Technologies and *Environmental Policy, 17*(7), 1769-1779.

Heising, W. (2012). The integration of ideation and project portfolio management—A key factor for sustainable success. *International Journal of Project Management, 30*(5), 582-595.

Hiebl, M. R. (2021). Sample selection in systematic literature reviews of management research. *Organizational research methods*

Johansson, G., & Magnusson, T. (1998). Eco-innovations: a novel phenomenon? *Journal of Sustainable Product Design, 7*, 7–18

Jugend, D., Figueiredo, J., & Pinheiro, M. A. P. (2017b). Environmental sustainability and product portfolio management in biodiversity firms: A comparative analysis between Portugal and Brazil. Contemporary Economics, 11(4), 431-442.

Jugend, D., Rojas Luiz, J. V., Chiappetta Jabbour, C. J., a Silva, S. L., Lopes de Sousa Jabbour, A. B., & Salgado, M. H. (2017a). Green product development and product portfolio management: empirical evidence from an emerging economy. *Business Strategy and the Environment*, *26*(8), 1181-1195.

Kobayashi, H., Kato, M., Maezawa, Y., & Sano, K. (2011). An R&D management framework for eco-technology. *Sustainability, 3*(8), 1282-1301.

Keskin, D., & Romme, G. (2020). Mixing oil with water: How to effectively teach design science in management education?. *BAR-Brazilian Administration Review*, *17*(1).

Kock, A., Heising, W., & Gemünden, H. (2015). How ideation portfolio management influences front-end success. *Journal of Product Innovation Management, 32*(4), 539-55.

Koen, P. A., Bertels, H. M., & Kleinschmidt, E. (2014). Managing the front end of innovation—Part I: Results from a three-year study. *Research-Technology Management, 57*(2), 34-43.

Lee, C. K. M., Lui, L., & Tsang, Y. P. (2021). Formulation and Prioritization of Sustainable New Product Design in Smart Glasses Development. *Sustainability, 13*(18), 10323.

Letens, G. (2015). Lean Product Development—Faster, Better… Cleaner?. *Frontiers of Engineering Management, 2*(1), 52-59.

Montalvo, C., Tang, P., Mollas-Gallart, J., Vivarelli, M., Marsilli, O., Hoogendorn, J., ... & Braun, A. (2006). Driving Factors and Challenges for EU Industry and the Role of R&D and Innovation. *European Techno-Economic Policy Support Network, Brussels (ETEPS AISBL Report to the European Commission Directorate General Joint Research Centre e IPTS, Seville.*

Ottman, J. A., Stafford, E. R., & Hartman, C. L. (2006). Avoiding green marketing myopia: Ways to improve consumer appeal for environmentally preferable products. *Environment: science and policy for sustainable development, 48*(5), 22-36.

Paillé, P., & Halilem, N. (2019). Systematic review on environmental innovativeness: A knowledge-based resource view. *Journal of cleaner production, 211*, 1088-1099.

Peralta, M. E., Alcalá, N., & Soltero, V. M. (2021). Weighting with Life Cycle Assessment and Cradle to Cradle: A Methodology for Global Sustainability Design. *Applied Sciences, 11*(19), 9042.

Pigosso, D. C., Rozenfeld, H., & McAloone, T. C. (2013). Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. *Journal of Cleaner Production, 59*, 160-173.

Pinheiro, M. A. P., Jugend, D., Dematthê Filho, L. C., & Armellini, F. (2018). Framework proposal for ecodesign integration on product portfolio management. *Journal of Cleaner Production, 185*, 176-186.

Pittaway, L., Robertson, M., Munir, K., Denyer, D., & Neely, A. (2004). Networking and innovation: A systematic review of the evidence. *International Journal of Management Reviews, 5–6*(3–4), 137-168

Romme, A. G. L. (2003). Making a difference: Organization as design. *Organization science, 14*(5), 558-573.

Sihvonen, S., & Partanen, J. (2016). Implementing environmental considerations within product development practices: a survey on employees' perspectives. *Journal of Cleaner Production, 125,* 189-203.

Silvius, A.G., Kampinga, M., Paniagua, S., & Mooi, H. (2017). Considering sustainability in project management decision-making; an investigation using q-methodology. *International Journal of Project Management, 35*(6), 1133-1150.

Topleva, S. A., & Prokopov, T. V. (2020). Integrated business model for sustainability of small and medium-sized enterprises in the food industry: Creating value added through ecodesign. *British Food Journal, 122*(5), 1463-1483.

Van Aken, J.E., Berends, H., & van der Bij, H. (2012). Problem solving in organizations, methodological handbook for Business and Management students. Cambridge: Cambridge University press.

Van Aken, J. E., & Romme, G. (2009). Reinventing the future: Adding design science to the repertoire of organization and management studies. *Organization Management Journal, 6(*1), 2-12.

Vandaele, N. J., & Decouttere, C. J. (2013). Sustainable R&D portfolio assessment. *Decision Support Systems, 54*(4), 1521-1532.

Villamil, C., & Hallstedt, S. I. (2018). Sustainability product portfolio: a review. *European Journal of Sustainable Development, 7*(4), 146-146

Appendix A: Articles and relevance assessment

Title	Authors	Publication Year	Source Title	Retrieved from Proquest	Retrieved from Web of Science	Retrieved from Scopus	Relevance score
From 50 To 1: Integrating Literature Toward A Systemic Ecodesign Model	Brones, F.; de Carvalho, M.M.	2015	Journal Of Cleaner Production	No	Yes	No	A
The Integration Of Ideation And Project Portfolio Management - A Key Factor For Sustainable Success	Heising, W.	2012	International Journal Of Project Management	No	Yes	No	A
Integrating Sustainability Into Innovation Project Portfolio Management - A Strategic Perspective	Brook, J.W.; Pagnanelli, F.	2014	Journal Of Engineering And Technology Management	Yes	Yes	Yes	A
Sustainable R&D Portfolio Assessment	Vandaele, N.J.; Decouttere, C.J.	2013	Decision Support Systems	No	Yes	No	A
25 Years Of 'Sustainable Projects'. What We Know And What The Literature Says	Sabini, L.; Muzio, D.; Alderman, N.	2019	International Journal Of Project Management	No	Yes	No	A
Systematic Review On Environmental Innovativeness: A Knowledge-Based Resource View	Pham, D.D.T.; Paille, P.; Halilem, N.	2019	Journal Of Cleaner Production	No	Yes	No	A
Framework Proposal For Ecodesign Integration On Product Portfolio Management	Pinheiro, M.A.P.; Antonio, M.; Jugend, D.; Dematte Filho, L.C.; Armellini, F.	2018	Journal Of Cleaner Production	No	Yes	Yes	A
Green Product Development and Product Portfolio Management: Empirical Evidence from an Emerging Economy	Jugend, D.; Rojas Luiz, J.V.; Chiapetta Jabbour, C.J.; a Silva, S.L.; Lopes de Sousa Jabbour, A.B.; Salgado, M.H.	2017	Business Strategy And The Environment	Yes	Yes	Yes	A
Environmental Sustainability and Product Portfolio Management in Biodiversity Firms: A Comparative Analysis between Portugal and Brazil	Jugend, D.; Figueiredo, J.; Pinheiro, M.A.P.	2017	Contemporary Economics	No	Yes	No	A
Decision Making Towards Integration Of Sustainability Into Project Management; A Multilevel Theory Building Approach	Daneshpour, H.; Takala, J.	2017	Management and Production Engineering Review	No	Yes	No	A
Sustainability Product Portfolio: A Review	Villamil, C.; Hallstedt, S.I.	2018	European Journal Of Sustainable Development	No	Yes	No	A
Formulation and Prioritization of Sustainable New Product Design in Smart Glasses Development	Lee, C.K.M.; Lui, L.; Tsang, Y.P.	2021	Sustainability	Yes	Yes	Yes	A
New Approach for Managing Sustainability in Projects	de la Cruz Lopez, M.P.; Cartelle Barros, J.J.; del Cano Gochi, A.; Lara Coira, M.	2021	Sustainability	No	Yes	No	A
Lean Product Development-Faster, Better ... Cleaner?	Letens, G.	2015	Frontiers of engineering management	No	Yes	No	A
Building a Conceptual Model for Analyzing Sustainability Projects Aiming at Technology Transfer: A Terminological Approach	Martins dos Santos Oliveira, D. R.; Naas, I.A.; Pierozzi Junior, I.; Vendrametto, O.	2013	Advances In Production Management Systems: Competitive Manufacturing For	No	Yes	No	A

			Innovative Products And Services, Amps 2012, Pt I				
Sustainability-Oriented Portfolio Management	Garcez, M.P.; Houmeaux Junior, F.	2009	Proceedings Of The 6th International Conference On Innovation And Management, Vols I And II	No	Yes	No	A
Solvay Chemical: A Tool For Identifying And Planning Sustainable Business Strategies	Ellis, J.E.; Colin-Jones, A.; Solvay, J.-M.; Washer, M.	2021	Putting Purpose Into Practice: The Economics of Mutuality	No	No	Yes	A
Integrating Sustainable Development Into Project Portfolio Management Through Application Of Open Innovation	Daneshpour, H.	2017	Optimal Management Strategies in Small and Medium Enterprises	No	No	Yes	A
Weighting with Life Cycle Assessment and Cradle to Cradle: A Methodology for Global Sustainability Design	Peralta, M.E.; Alcalá, N.; Soltero, V.M.	2021	Applied Sciences	Yes	No	No	A
Insider Action Research Towards Companywide Sustainable Product Innovation: Ecodesign Transition Framework	Brones, F.; Zancul, E.; Carvalho, M.M.	2021	International Journal of Managing Projects in Business	Yes	No	No	A
Monitoring The Implementation Of Exponential Organizations Through The Assessment Of Their Project Portfolio: Case Study	Ortega-Fernández, F.; Morán-Palacios, H.; Rodríguez-Montequín, V.	2021	Sustainability	Yes	No	No	A
Integrated Business Model For Sustainability Of Small And Medium-Sized Enterprises In The Food Industry: Creating Value Added Through Ecodesign	Topleva, S.A.; Prokopov, T.V.	2020	British Food Journal	Yes	No	No	A
Sustainable Project Management: A Conceptualization-Oriented Review And A Framework Proposal For Future Studies	Armenia, S.; Dangelico, R.M.; Nonino, F.; Pompei, A	2019	Sustainability	Yes	No	No	A
Green Plastics: Analysis Of A Firm's Sustainability Orientation For Innovation	Garcez, M.P.; Hourneaux, F. J.; Farah, D.	2016	Revista de Gestão Ambiental e Sustentabilidade	Yes	No	No	A
Driving Innovation Through Life-Cycle Thinking	Helling, R.	2015	Clean Technologies and Environmental Policy	Yes	No	No	A
An R&D Management Framework for Eco-Technology	Kobayashi, H.; Kato, M.; Maezawa, Y.; Sano, K.	2011	Sustainability	Yes	No	No	A
Mainstreaming Green Product Innovation: Why and How Companies Integrate Environmental Sustainability: JBE	Dangelico, R.M.; Pujari, D.	2010	Journal of Business Ethics	Yes	No	No	A
Value Management in Project Portfolios: Identifying and Assessing Strategic Value	Martinsuo, M,; Killen, C.P.	2014	Project Management Journal	No	Yes	No	B
Opening the Market for Impact Investments: The Need for Adapted Portfolio Tools	Brandstetter, L.; Lehner, O.M.	2015	Entrepreneurship Research Journal	No	Yes	No	B

Cleaner Production, Project Management And Strategic Drivers: An Empirical Study	Ferro de Guimaraes, J.C.; Severo, E.A.; Vieira, P.S.	2017	Journal Of Cleaner Production	No	Yes	No	B
Augmenting Innovation Project Portfolio Management Performance: The Mediating Effect Of Management Perception And Satisfaction	Spieth, P.; Lerch, M.	2014	R&D Management	Yes	Yes	Yes	B
Project Portfolio Management Systems: Business Services and Web Services	Stantchev, V.; Franke, M.R.; Discher, A.	2009	2009 Fourth International Conference On Internet And Web Applications And Services	No	Yes	Yes	B
An Intelligent Approach For The Evaluation Of Innovation Projects	Samanlioglu, F.; Ayag, Z.	2020	Journal Of Intelligent & Fuzzy Systems	No	Yes	No	B
An Integrated Tool To Support Sustainable Toy Design And Manufacture	Shin, K.L.F.; Colwill, J.	2017	Production And Manufacturing Research-An Open Access Journal	No	Yes	No	B
Sustaining Innovation Is Challenge For Incumbents	Braganza, A.; Awazu, Y.; Desouza, K.C.	2009	Research-Technology Management	Yes	Yes	Yes	B
R&D Project Valuation Considering Changes of Economic Environment: A Case of a Pharmaceutical R&D Project	Park, J.H.; Shin, K.	2018	Sustainability	No	Yes	No	B
Project Approach as a Tool for Improving Business Performance	Lapunka, I.; Jagoda-Sobalak, D.; Marek-Kolodziej, K.	2018	Vision 2020: Sustainable Economic Development And Application Of Innovation Management	No	Yes	No	B
Lean And Green NPD In The Latin American Aluminium Industry	Adamczuk, G. O.; Tan, K. H.	2017	24th International Conference On Production Research (Icpr)	No	Yes	Yes	B
Primary Roadmap Towards a Project and Portfolio Management Framework to Support Innovation-Driven SMEs	Mishly, M.A.; Tereso, A.	2016	Vision 2020: Innovation Management, Development Sustainability, And Competitive Economic Growth, 2016, Vol I - VII	No	Yes	Yes	B
Project Portfolio Management As A New Management Tool	Vyslouzilova, D.; Fiala, P.	2015	Innovation Management And Corporate Sustainability (Imacs 2015)	No	Yes	No	B
Design Driven Portfolio Management	Petersen, S.I.; Steinert, M.; Beckman, S.	2011	Proceedings Of The 18th International Conference On Engineering Design (Iced 11): Impacting Society Through Engineering Design, Vol 3: Design Organisation And Management	No	Yes	Yes	B

Knowledge Management for IT Project Portfolio	Rosselet, U.; Jolliet, Y.; Wentland, M.	2009	Proceedings Of The 10th European Conference On Knowledge Management , Vol 1 And 2	No	Yes	Yes	B
Managing Sustainable Innovation: The Driver For Global Growth	Maxwell, I.E.	2009	Managing Sustainable Innovation: The Driver for Global Growth	No	No	Yes	B
Ranking Sustainable Projects through an Innovative Hybrid DEMATEL-VIKOR Decision-Making Approach Using Z-Number	Akhavein, A.; RezaHoseini, A.; Ramezani, A.; BagherPour, M.	2021	Advances in Civil Engineering	Yes	No	No	B
Organizational Ambidexterity and Performance: Assessment Approaches and Empirical Evidence	Dranev Y.; Izosimova, A.; Meissner, D.	2020	Journal of the Knowledge Economy	Yes	No	No	B
ISO 14001 Certification and Corporate Technological Innovation: Evidence from Chinese Firms: JBE	He, W.; Shen, R.	2019	Journal of Business Ethics	Yes	No	No	B
Does Reduction of Material and Energy Consumption Affect to Innovation Efficiency? The Case of Manufacturing Industry in South Korea	Shin, J.; Kim, C.; Yang, H.	2019	Energies	Yes	No	No	B
Sustainable Innovative Project Management: Response to Improve Livability and Quality of Life: Case Studies: Iran and Germany	Doost Mohammadian, H.; Rezaie, F.	2019	Inventions	Yes	No	No	B
Developing An Indicator Framework For Measuring Sustainable Logistics Innovation In Retail	Andersson, P.; Forslund, H.	2018	Measuring Business Excellence	Yes	No	No	B
Innovation And Its Potential In The Context Of The Ecological Component Of Sustainable Development	Bakhtina, V.A.	2011	Sustainability Accounting, Management and Policy Journal	Yes	No	No	B
Changing R&D Models In Research-Based Pharmaceutical Companies	Schuhmacher, A.; Gassmann, O.; Hinder, M.	2016	Journal Of Translational Medicine	Yes	Yes	Yes	C
Smart City Intellectual Capital: An Emerging View Of Territorial Systems Innovation Management	Dameri, R.P.; Ricciardi, F.	2015	Journal Of Intellectual Capital	No	Yes	No	C
How Innovation Management Techniques Support An Open Innovation Strategy	Igartua, J.I.; Garrigos, J.A.; Hervas-Oliver, J.L.	2010	Research-Technology Management	Yes	Yes	No	C
Multi-Period Mean-Variance Portfolio Optimization With High-Order Coupled Asset Dynamics	He, J.; Wang, Q.G.; Cheng, P.; Chen, J.; Sun, Y.	2015	IEEE Transactions On Automatic Control	No	Yes	No	C
Optimization Models For Financing Innovations In Green Energy Technologies	Tan, R. R.; Aviso, K. B.; Ng, D. K. S.	2019	Renewable & Sustainable Energy Reviews	No	Yes	No	C
Implementation Of Business Process Innovations: An Agenda For Research And Action	Smeda, R	2001	International Journal Of Technology Management	No	Yes	No	C
Mobilizing Investors for Blue Growth	van den Burg, S.W.K.; Stuiver, M.; Bolman, B.C.; Wijnen, R.; Selnes, T.; Dalton, G.	2017	Frontiers In Marine Science	Yes	Yes	No	C

Copula-Based Agricultural Conditional Value-At-Risk Modelling For Geographical Diversifications In Wheat Farming Portfolio Management	Nguyen-Huy, T.; Deo, R.C.; Mushtaq, S.; Kath, J.; Khan, S.	2018	Weather And Climate Extremes	No	Yes	No	C
R&D Project Selection Incorporating Customer-Perceived Value and Technology Potential: The Case of the Automobile Industry	Lee, S.; Cho, C.; Choi, J.; Yoon, B.	2017	Sustainability	No	Yes	No	C
Refurbishment In Educational Buildings - Methodological Approach For High Performance Integrated School Refurbishment Actions	Oesterreicher, D.; Geissler, S.	2016	Sustainable Built Environment Tallinn And Helsinki Conference SBE16 Build Green And Renovate Deep	No	Yes	No	C
Environmental Performance And Firm Strategies In The Dutch Automotive Sector	van der Vooren, A.; Alkemade, F.; Hekkert, M. P.	2013	Transportation Research Part A-Policy And Practice	No	Yes	No	C
Investment Beliefs - Every Asset Manager Should Have Them.	Slager, A.; Koedijk, K.	2007	Journal Of Portfolio Management	Yes	Yes	No	C
Assessing the Impact of Patient-Facing Mobile Health Technology on Patient Outcomes: Retrospective Observational Cohort Study	Bruce, C.R.; Harrison, P.; Nisar, T.; Giammattei, C.; Tan, N.M.; Bliven, C.; Shallcross, J.; Khleif, A.; Nhan, T.; Kelkar, S.; Tobias, N.; Chavez, A.E.; Rivera, D.; Leong, A.; Romano, A.; Desai, S.N.; Sol, J.R.; Gutierrez, K.; Rappel, C.; Haas, E.; Zheng, F.; Park, K.J.; Jones, S.; Barach, P.; Schwartz, R.	2020	JMIR Mhealth And Uhealth	No	Yes	No	C
Take A Portfolio View Of CRADAs	Munson, J.M.; Spivey, W.A.	2006	Research-Technology Management	Yes	Yes	Yes	C
Apsim In The Marketplace: A Tale Of Kitchen Tables, Boardrooms And Courtrooms	Hochman, Z.; Carberry, P.S.; McCown, R.L.; Dalgliesh, N.P.; Foale, M.A.; Brennan, L.E.	2001	International Symposium On Applications Of Modelling As An Innovative Technology In The Agri-Food-Chain - Model-It	No	Yes	No	C
Prioritizing Decision Factors of Energy Efficiency Retrofit for Facilities Portfolio Management	Medal, L.A.; Sunitiyoso, Y.; Kim, A.A.	2021	Journal Of Management In Engineering	No	Yes	No	C
Measuring Firms' Imitation Activity	Doha, A.; Pagell, M.; Swink, M.; Johnston, D.	2017	R&D Management	No	Yes	No	C
Effects Of Bonuses On Diversification In Delegated Stock Portfolio Management	Hedesstroem, M.; Gaerling, T.; Andersson, M.; Biel, A.	2015	Journal Of Behavioral And Experimental Finance	No	Yes	No	C
Shared Management of Product Portfolio	Garbi, G.P.; Loureiro, G.	2014	Moving Integrated Product Development To Service Clouds In The Global Economy	No	Yes	Yes	C
Project Management Standards	Rehacek, P.	2016	Innovation Management And Education Excellence Vision 2020: From Regional	No	Yes	Yes	C

			Development Sustainability To Global Economic Growth, Vols I - VI				
Project Portfolio Resource Risk Assessment considering Project Interdependency by the Fuzzy Bayesian Network	Bai, L.; Zhang, K.; Shi, H.; An, M.; Han, X.	2020	Complexity	No	Yes	No	C
Product Portfolio Management through Integrated Green Practices in Supply Chain Practices for Operational Performance	Galahitiyawe, N.W.K.; Jayakody, R.	2019	Education Excellence And Innovation Management Through Vision 2020	No	Yes	No	C
Leading Approaches to Managing Organizational Portfolio in a Dynamically Changing Environment	Tkachenko, I.; Evseeva, M.	2019	Sustainable Leadership For Entrepreneurs And Academics, Esal2018	No	Yes	No	C
Robust Data Analysis In Innovation Project Portfolio Management	Titarenko, B.; Hasnaoui, A.; Titarenko, R.; Buzuk, L.	2018	International Science Conference Spbwosce-2017 Business Technologies For Sustainable Urban Development	No	Yes	No	C
Project Management Office for Program and Portfolio Management	Rehacek, P.	2015	Innovation Management And Sustainable Economic Competitive Advantage: From Regional Development To Global Growth, Vols I - VI, 2015	No	Yes	No	C
Sports Event Portfolios: An Innovative Tool And A New Management Paradigm	Salgado-Barandela, J.; Barajas, A.; Sanchez-Fernandez, P.	2021	International Journal Of Sports Marketing & Sponsorship	No	Yes	Yes	C
Impact Investing And Philanthropic Foundations: Strategies Deployed When Aligning Fiduciary Duty And Social Mission	Zolfaghari, B.; Hand, G.	2021	Journal Of Sustainable Finance & Investment	No	Yes	No	C
Ecological Environment Management System Based On Artificial Intelligence And Complex Numerical Optimization	Niu, L.; Xiao, L.	2021	Microprocessors And Microsystems	No	Yes	Yes	C
The Project-Based Firm: A Theoretical Framework for Building Dynamic Capabilities	Hermano, V.; Martin-Cruz, N.	2020	Sustainability	No	Yes	No	C
Approaches To Project Portfolio Formation By Pharmaceutical Products Producers	Derenska, Y.	2019	Economic Annals-XXI	No	Yes	Yes	C
Improved Innovative Product Strategy Assessment Model In Market Research Context	Braslina, L.; Batraga, A.; Skiltere, D.; Legzdina, A.; Braslins, G.; Cildermane, E.	2019	New Challenges Of Economic And Business Development - 2019: Incentives For Sustainable Economic Growth	No	Yes	No	C
Project Portfolio Management in Romanian R&D Organizations	Simion, C.P.; Verboncu, I.; Savga, L.	2018	Vision 2020: Sustainable Economic Development And	No	Yes	No	C

			Application Of Innovation Management				
Methods and Models for Analysis the Effectiveness of Industrial Enterprises	Tolstykh, T.; Savon, D.; Safronov, A.; Shkarupeta, E.; Ivanochkina, T.	2018	Vision 2020: Sustainable Economic Development And Application Of Innovation Management	No	Yes	No	C
U.Openlab Methodology: A Conceptual Model And Flowchart For The Dynamic Co-Production And (Re) Use Of Digital Contents	Pinto, M. M.; Medina, S.; Matos, R.; Fontes, P.	2016	ICERI2016: 9th International Conference Of Education, Research And Innovation	No	Yes	No	C
Innovation And Communicative Action: Health Management Networks And Technologies	Rivera, U.F.J.; Artmann, E.	2016	Cadernos De Saude Publica	No	Yes	No	C
Controlling Key Figures Process of Project Prioritisation Management	Scheiblich, M.; Pamfilie, R.; Olaru, M.	2015	Innovation Management And Sustainable Economic Competitive Advantage: From Regional Development To Global Growth, Vols I - VI, 2015	No	Yes	No	C
Integrated Investment Management Structure. Associated Risks Mitigation Tools	Sandru, M.; Keppler, T.; Maier, D.; Keppler, S.	2014	2014 International Conference On Production Research - Regional Conference Africa, Europe And The Middle East And 3rd International Conference On Quality And Innovation In Engineering And Management (ICPR-AEM 2014)	No	Yes	No	C
The Importance of Knowledge Waste for Intellectual Capital Management and Enterprise Performance	Ferenhof, H.A.; Selig, P.M.	2013	Proceedings Of The 10th International Conference On Intellectual Capital, Knowledge Management And Organisational Learning (ICICKM-2013)	No	Yes	No	C
Essential Elements of Risk to Which is Exposed the Portfolio of Financial Instruments	Man, M.; Minea, V.; Neagu, M.L.; Loghin, D.	2013	Entrepreneurship Vision 2020: Innovation, Development Sustainability, And Economic Growth, Vols 1 And 2	No	Yes	No	C
Impact of Cloud Computing on the IT Portfolio Management: UAE Case Study	Khan, S.N.	2012	Innovation Vision 2020: Sustainable Growth, Entrepreneurship, And Economic Development, Vols 1-4	No	Yes	No	C

Challenges for Strategic Management of Innovation in a High-Tech Firm: The Case of CPqD	Leal, V.; Lima, R.	2012	Proceedings Of The 9th International Conference On Innovation And Management	No	Yes	No	C
Evaluation Research On Management Capability Of Avigation R&D Enterprise With Ecological Perspective	Kexin, H.; Lixiong, O.; Xiangyuan, S.	2008	Proceedings Of The 38th International Conference On Computers And Industrial Engineering, Vols 1-3	No	Yes	No	C
Project Portfolio Management In Strategy Implementation Of Banking	Li, G.; Zhang, H.	2007	Entrepreneurial Strategy Innovation And Sustainable Development	No	Yes	No	C
Collaborative Product Pre-Development: An Architecture Proposal	Moeckel, A.; Forcellini, F.A.	2007	Complex Systems Concurrent Engineering: Collaboration, Technology Innovation And Sustainability	No	Yes	No	C
Asset Pricing Based On The Relationship Of Principal-Agent	Sheng, J.L.	2007	Entrepreneurial Strategy Innovation And Sustainable Development	No	Yes	No	C
A Business Transformation Model for Legacy Carriers as a Response to the Rise of Low-Cost Carriers	Markopoulos, E.; Hesse, F.J.F.	2021	Lecture Notes in Networks and Systems	No	No	Yes	C
IP and Innovation Strategy For Developing Next-Generation Automotive Technologies	Joshi, A.; Venugopal, S.	2015	SAE Technical Papers	No	No	Yes	C
Rethinking Project Management Goals And Methods To Suit Service Systems	Sankaran, S.; Agarwal, R.	2012	56th Annual Meeting of the International Society for the Systems Sciences 2012	No	No	Yes	C
Leading Pharmaceutical Innovation	Gassmann, O., Reepmeyer, G., Von Zedtwitz, M.	2008	Leading Pharmaceutical Innovation	No	No	Yes	C
Connectivity, HMI, & System Integration - 3 Interdependent Trends Which Are Re-Shaping The World Of Vehicle Interior Electronics	Matschi, H., Brainard, M.	2007	VDI Berichte	No	No	Yes	C
The Generics R&D Challenge: Seeking The Elusive Profit Margin	Hansen, N., Tunnah, P.	2003	Journal of Generic Medicines	No	No	Yes	C
Implementation Of Business Process Innovations: An Agenda For Research And Action	Smeds, R.	2001	International Journal of Technology Management	Yes	No	Yes	C
Successful Implementation Of Project Risk Management In Small And Medium Enterprises: A Cross-Case Analysis	de Araújo Lima, P.F.; Marcelino-Sadaba, S.; Verbano, C.	2021	International Journal of Managing Projects in Business	Yes	No	No	C
Initiating and Defining a Sustainable Project on the Example of Rare Disease	Juchniewicz, M.; Rzempała, J.; Skweres-Kuchta, M.	2021	European Research Studies	Yes	No	No	C

Our Future In The Anthropocene Biosphere	Folke, C.; Polasky, S.; Rockström, J.; Galaz, V.; Westley, F.	2021	Ambio	Yes	No	No	C
Two Sides of the Same Coin: EU Financial Regulation and Private Law	Cherednychenko, O.O.	2021	European Business Organization Law Review	Yes	No	No	C
Drug Discovery Firms and Business Alliances for Sustainable Innovation	Harada, Y.; Wang, H.; Kodama, K.; Sengoku, S.	2021	Sustainability	Yes	No	No	C
A Collaborative Trans-Regional R&D Strategy for the South Korea Green New Deal to Achieve Future Mobility	Lee, D.	2021	Sustainability	Yes	No	No	C
Research Hotspots and Frontiers of Product R&D Management under the Background of the Digital Intelligence Era—Bibliometrics Based on Citespace and Histcite	Liu, H.; Luo, Y.; Geng, J.; Yao, P.	2021	Applied Sciences	Yes	No	No	C
Artificial Intelligence in the Industry 4.0, and Its Impact on Poverty, Innovation, Infrastructure Development, and the Sustainable Development Goals: Lessons from Emerging Economies?	Mhlanga, D.	2021	Sustainability	Yes	No	No	C
Digital Transformation of Energy Companies: A Colombian Case Study	Giraldo, S.; la Rotta, D.; Nieto-Londoño, C.; Vásquez, R. E.; Escudero-Atehortúa, A.	2021	Energies	Yes	No	No	C
Africanisation Of International Investment Law For Sustainable Development: Challenges	Laryea, E.T.; Fabusuyi, O.O.	2021	Journal of International Trade Law & Policy	Yes	No	No	C
Ownership (Lost) and Corporate Control: An Enterprise Entity Perspective	Biondi, Y.	2020	Accounting, Economics, and Law	Yes	No	No	C
Risk Analysis Of A Hedge Fund Oriented On Sustainable And Responsible Investments For Emerging Markets	Prelipcean, G.; Boscoianu, M.	2020	Amfiteatru Economic	Yes	No	No	C
Power Distribution Reforms: Delhi's Public–Private Partnership Model: A Boost To The Sector	Sinha, P.; Shankar, R.; Vrat, P.; Mathur, S.	2020	Journal of Advances in Management Research	Yes	No	No	C
An Eco-Systematic View of Cross-Sector Fintech: The Case of Alibaba and Tencent	Zhang-Zhang, Y.; Rohlfer, S.; Rajasekera, J.	2020	Sustainability	Yes	No	No	C
Sustainability in Mineral Exploration—Exploring Less Invasive Technologies via Patent Analysis	Ruiz-Coupeau, S.; Jürgens, B.; Keßelring, M.; Herrero-Solana, V.	2020	Sustainability	Yes	No	No	C
Characteristics and Influencing Factors of Green Finance Development in the Yangtze River Delta of China: Analysis Based on the Spatial Durbin Model	Xie, H.; Ouyang, Z.; Choi, Y.	2020	Sustainability	Yes	No	No	C
Key Factors for Project Crowdfunding Success: An Empirical Study	Fernandez-Blanco, A.; Villanueva-Balsera, J.; Rodriguez-Montequin, V.; Moran-Palacios, H.	2020	Sustainability	Yes	No	No	C

Proactive Divestiture and Business Innovation: R&D Input and Output Performance	Lee, K.; Roh, T.	2020	Sustainability	Yes	No	No	C
Proposal of a Holistic Framework to Support Sustainability of New Product Innovation Processes	Dias, A.S.M.E; António, A.; Navas, H.V. G.; Santos, R.	2020	Sustainability	Yes	No	No	C
Public and Private Partnership: Innovation-Driven Growth of Agriculture at the Regional Level	Nikolaevich, M.; Fedorovich, O.; Vladimirovna, N.; Igorevna, D.	2019	Journal of Environmental Management & Tourism	Yes	No	No	C
Erosion of Complement Portfolio Sustainability: Uncovering Adverse Repercussions in Steam's Refund Policy	Siu, S.; Inoue, Y.; Tsujimoto, M.	2019	Journal of Open Innovation	Yes	No	No	C
The Impact of Industry–University–Research Alliance Portfolio Diversity on Firm Innovation: Evidence from Chinese Manufacturing Firms	Shuman, Z.; Wang, Y.	2019	Sustainability	Yes	No	No	C
The Roles and Measurements of Proximity in Sustained Technology Development: A Literature Review	Shih-Hsin, C.	2019	Sustainability	Yes	No	No	C
Early Stage Investing in Green SMEs: The Case of the UK	Owen, R.; Lehner, O.; Lyon, F.; Brennan, G.	2019	ACRN Journal of Finance and Risk Perspectives	Yes	No	No	C
Sustainable Investing Exchange-Traded Funds: Us And European Market	Marszk, A.	2019	Journal of Economics & Management	Yes	No	No	C
The Impact Of Supplier Performance Measurement Systems On Supplier Performance: A Dyadic Lifecycle Perspective	Maestrini, V.; Luzzini, D.; Caniato, F.; Maccarrone, P.; Ronchi, S.	2018	International Journal of Operations & Production Management	Yes	No	No	C
The Relationship between Organizational Ambidexterity and Family Business Performance	Gözen, A.	2018	International Journal of Commerce and Finance	Yes	No	No	C
Technology and Innovation Management in Higher Education—Cases from Latin America and Europe	Arciénaga Morales, A.A.; Nielsen, J.; Bacarini, H.A.; Martinelli, S.I.; Kofuji, S.T.; García Díaz, J.F.	2018	Administrative Sciences	Yes	No	No	C
Sustainability-Themed Mutual Funds: An Empirical Examination Of Risk And Performance	Ielasi, F.; Rossolini, M.; Limberti, S.	2018	The Journal of Risk Finance	Yes	No	No	C
Model Of Urban Water Management Towards Water Sensitive City: A Literature Review	Maftuhah, D. I.; Anityasari, M.; Sholihah, M.	2018	IOP Conference Series. Materials Science and Engineering	Yes	No	No	C
A Systematic Review of Smart Real Estate Technology: Drivers of, and Barriers to, the Use of Digital Disruptive Technologies and Online Platforms	Ullah, F.; Sepasgozar, S.M.E.; Wang, C.	2018	Sustainability	Yes	No	No	C
Advances in Multiple Criteria Decision Making for Sustainability: Modeling and Applications	Kao-Yi, S.; Tzeng, G.H.	2018	Sustainability	Yes	No	No	C
Goal Directed Portfolio Management: The Case for Sustainability	Lashgari, M.	2017	The Journal of Applied Business and Economics	Yes	No	No	C

Investor-Centric Strategies For Indian Mutual Fund Industry: Inferring From The Behavior Of Individual Investors	Saji, T.G.; Nair, R.K.	2017	Decision	Yes	No	No	C
Value Generation From Industry-Science Linkages In Light Of Targeted Open Innovation	Meissner, D.; Carayannis, E.G.	2017	Journal of Knowledge Management	Yes	No	No	C
Innovation Districts at the Crossroad of the Entrepreneurial City and the Sustainable City	Read, D.; Sanderford, D.	2017	Journal of Sustainable Real Estate	Yes	No	No	C
2nd International Management Conference 2016	Mohapatra, A.K.; Pandey, A.	2017	FIIB Business Review	Yes	No	No	C
Impacts of Leadership on Project-Based Organizational Innovation Performance: The Mediator of Knowledge Sharing and Moderator of Social Capital	Zheng, J.; Wu, G.; Xie, H.	2017	Sustainability	Yes	No	No	C
Industry Partnerships, Key Success Factor to Win in the Biosimilars Space: Research and Regulation	Godrecka-Bareau, C.	2016	Journal of Commercial Biotechnology	Yes	No	No	C
The Evolution of Integrating ESG Analysis into Wealth Management Decisions	Roselle, P.	2016	Journal of Applied Corporate Finance	Yes	No	No	C
How Green Management Influences Product Innovation in China: The Role of Institutional Benefits: JBE	Shu, C.; Zhou, K.Z.; Xiao, Y.; Gao, S.	2016	Journal of Business Ethics	Yes	No	No	C
Toward An Innovation-Based Perspective On Company Performance	Lichtenthaler, U.	2016	Management Decision	Yes	No	No	C
Special Investment Vehicles for Hybrid Financing of SMEs in Domain of Manufacturing Engineering	Calefariu, E,; Buda, T.A.; Boşcoianu, M.; Prelipcean, G.	2015	Applied Mechanics and Materials	Yes	No	No	C
On the R&D Giants' Shoulders: Do FDI Help To Stand On Them?	Montresor, S.; Vezzani, A.	2015	Economia e Politica Industriale	Yes	No	No	C
Advancing an Innovation Orientation in Organizations: Insights from North American Business Leaders	Dobni, C.B.; Klassen, M.	2015	Journal of Innovation Management	Yes	No	No	C
Corporate Environmental Responsibility and Equity Prices: JBE	Cai, L.; He, C.	2014	Journal of Business Ethics	Yes	No	No	C
Impact Investment Funds For Frontier Markets In Southeast Asia: Creating A Platform For Institutional Capital, High-Quality Foreign Direct Investment, And Proactive Policy	Stagars, M.	2014	Journal of Asset Management	Yes	No	No	C
The Dark Side of Passive Investing	Blitz, D.	2014	Journal of Portfolio Management	Yes	No	No	C
The Little Problem of Longevity: Searching for Answers to Uncertainty	Swarup, B.	2014	The Journal of Alternative Investments	Yes	No	No	C

Refocusing on R&D Model Or Redefining Marketing Strategy? Anticipating Sustainability For Generic Pharmaceutical Industry	Barei, F.; Le Pen, C.	2014	Journal of Medical Marketing	Yes	No	No	C
Economic Performance, Export, Systemic Barriers And Equity Investments In Innovative Companies: Evidence From Poland	Prorokowski, L.	2014	Qualitative Research in Financial Markets	Yes	No	No	C
Investment Decisions in Global Financial Markets: the Experience of Lithuania	Rutkauskas, A.V.; Kvietkauskiene, A.	2013	Entrepreneurial Business and Economics Review	Yes	No	No	C
Innovation and Portfolio Management	Cohen, A.J.	2013	Journal of Portfolio Management	Yes	No	No	C
Creating A Sustainable Innovation Environment Within Large Enterprises: A Case Study On A Professional Services Firm	Kliewe, T.; Davey, T.; Baaken, T.	2013	Journal of Innovation Management	Yes	No	No	C
A Fuzzy Quantitative VRIO-Based Framework For Evaluating Organizational Activities	Lin, C,; Hua-Ling, T.; Ya-Jung, W.; Kiang, M.	2012	Management Decision	Yes	No	No	C
Sustainable Business Solutions Through Lean Product Lifecycle Management	Gecevska, V.; Stefanic, N.; Veza, I.; Cus, F.	2012	Acta Technica Corviniensis - Bulletin of Engineering	Yes	No	No	C
Sustaining Breakthrough Innovation	O'Connor, G.C.	2009	Research Technology Management	Yes	No	No	C
Socially Responsible Property Investment (SRPI): An Analysis Of The Relationship Between Equities SRI and UK Property Investment Activities	Rapson, D.; Shiers, D.; Roberts, C.; Keeping, M.	2007	Journal of Property Investment & Finance	Yes	No	No	C
Using the Supply-Side Approach to Understand and Estimate Equity Returns	Jones, C.P.; Wilson, J.W.	2006	Journal of Portfolio Management	Yes	No	No	C
Beyond Re-Engineering And Restructuring	Anonymous	1996	Logistics Information Management	Yes	No	No	C
Growth Opportunities vs. Growth Stocks	Statman, M.	1984	Journal of Portfolio Management	Yes	No	No	C

Appendix B: List of selected articles SLR

1. Brones, F., & de Carvalho, M. M. (2015). From 50 to 1: integrating literature toward a systemic ecodesign model. *Journal of Cleaner Production*, *96*, 44-57.

2. Heising, W. (2012). The integration of ideation and project portfolio management—A key factor for sustainable success. *International Journal of Project Management*, *30*(5), 582-595.

3. Brook, J. W., & Pagnanelli, F. (2014). Integrating sustainability into innovation project portfolio management–A strategic perspective. *Journal of Engineering and Technology Management*, *34*, 46-62.

4. Vandaele, N. J., & Decouttere, C. J. (2013). Sustainable R&D portfolio assessment. *Decision Support Systems*, *54*(4), 1521-1532.

5. Sabini, L., Muzio, D., & Alderman, N. (2019). 25 years of 'sustainable projects'. What we know and what the literature says. *International Journal of Project Management, 37*(6), 820-838.

6. Paillé, P., & Halilem, N. (2019). Systematic review on environmental innovativeness: A knowledge-based resource view. *Journal of cleaner production*, *211*, 1088-1099.

7. Pinheiro, M. A. P., Jugend, D., Demattê Filho, L. C., & Armellini, F. (2018). Framework proposal for ecodesign integration on product portfolio management. *Journal of Cleaner Production*, *185*, 176-186.

8. Jugend, D., Rojas Luiz, J. V., Chiappetta Jabbour, C. J., a Silva, S. L., Lopes de Sousa Jabbour, A. B., & Salgado, M. H. (2017). Green product development and product portfolio management: empirical evidence from an emerging economy. *Business Strategy and the Environment*, *26*(8), 1181-1195.

9. Jugend, D., Figueiredo, J., & Pinheiro, M. A. P. (2017). Environmental sustainability and product portfolio management in biodiversity firms: A comparative analysis between Portugal and Brazil. *Contemporary Economics*, *11*(4), 431-442.

10. Daneshpour, H., & Takala, J. (2017). Decision making towards integration of sustainability into project management; A multilevel theory building approach. *Management and Production Engineering Review, 8*(3), 13-21.

11. Villamil, C., & Hallstedt, S. I. (2018). Sustainability product portfolio: a review. *European Journal of Sustainable Development, 7*(4), 146-146.

12. Lee, C. K. M., Lui, L., & Tsang, Y. P. (2021). Formulation and Prioritization of Sustainable New Product Design in Smart Glasses Development. *Sustainability, 13*(18), 10323.

13. de la Cruz López, M. P., Cartelle Barros, J. J., del Caño Gochi, A., & Lara Coira, M. (2021). New Approach for Managing Sustainability in Projects. *Sustainability*, *13*(13), 7037.

14. Letens, G. (2015). Lean Product Development—Faster, Better… Cleaner?. Frontiers of Engineering Management, 2(1), 52-59.

15. dos Santos Oliveira, D. R. M., de Alencar Nääs, I., Júnior, I. P., & Vendrametto, O. (2012). Building a Conceptual Model for Analyzing Sustainability Projects Aiming at Technology Transfer: A Terminological Approach. In *IFIP International Conference on Advances in Production Management Systems* (pp. 701-707). Springer, Berlin, Heidelberg.

16. Garcez, M. P., & Junior, F. H. (2016). Sustainability-Oriented Portfolio Management. *School of economics, Management and Accountancy, University of Sao, Paulo, Brazil*

17. Ellis, J., Colin-Jones, A., Solvay, J., & Washer, M. (2021-03-04). Solvay Chemical: A Tool for Identifying and Planning Sustainable Business Strategies. In Putting Purpose Into Practice: The Economics of Mutuality. : Oxford University Press.

18. Daneshpour, H. (2017). Integrating sustainable development into project portfolio management through application of open innovation. In *Optimal Management Strategies in Small and Medium Enterprises* (pp. 370-387). IGI Global.

19. Peralta, M. E., Alcalá, N., & Soltero, V. M. (2021). Weighting with Life Cycle Assessment and Cradle to Cradle: A Methodology for Global Sustainability Design. *Applied Sciences*, *11*(19), 9042.

20. Brones, F., Zancul, E., & Carvalho, M. M. (2020). Insider action research towards companywide sustainable product innovation: ecodesign transition framework. *International Journal of Managing Projects in Business*.

21. Díaz-Piloneta, M., Ortega-Fernández, F., Morán-Palacios, H., & Rodríguez-Montequín, V. (2021). Monitoring the Implementation of Exponential Organizations through the Assessment of Their Project Portfolio: Case Study. *Sustainability*, *13*(2), 464.

22. Topleva, S. A., & Prokopov, T. V. (2020). Integrated business model for sustainability of small and medium-sized enterprises in the food industry: Creating value added through ecodesign. *British Food Journal, 122*(5), 1463-1483

23. 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*, *11*(9), 2664.

24. Garcez, M. P., Junior, F. H., & Farah, D. (2016). Green plastics: analysis of a firm's sustainability orientation for innovation. *Revista de Gestão Ambiental e Sustentabilidade*, *5*(3), 21-35.

25. Helling, R. (2015). Driving innovation through life-cycle thinking. *Clean Technologies and Environmental Policy*, *17*(7), 1769-1779.

26. Kobayashi, H., Kato, M., Maezawa, Y., & Sano, K. (2011). An R&D management framework for eco-technology. *Sustainability*, *3*(8), 1282-1301.

27. Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of business ethics, 95*(3), 471-486.

Appendix C: Interview guide

INTERVIEW GUIDE

ENVIRONMENTAL SUSTAINABLE PORTFOLIO MANAGEMENT

COMPANY INFORMATION

Company name:

Company description:

RESPONDENT INFORMATION

Name:

Job description:

The respondent gave informed consent: yes/no

PROJECT MANAGEMENT

Q1: In the project development process, how does the company select the projects to be developed?

Q2: Which stages comprise the process of project development in the company?

Q3: Does the company use decision support software?
If so, what does this software comprehends?

If not, are there others tools used?

ENVIRONMENTAL CRITERIA

Q4: Does the company have environmental concerns in the project development process? How are these identified?

Q5: Does the company consider environmental criteria when making decisions about which projects it selects? How does this process work?

EU TAXONOMY

In appendix C.1 the six environmental objectives of the EU Taxonomy are presented. These objectives are shown during the interview with the use of screen sharing.

Q6: To what extent does the company take (all) the objectives of the EU Taxonomy into account and how?

Q7: Can you rank the six objectives of the EU Taxonomy, from the objective the company pays the most attention to – to the objective that receives the least attention?

Q8: To what extent does your company strives to:
a) prevent harming the environment?
b) improve the quality of environment?
c) adapt to climate change?

Q9: What role do the EU Taxonomy objectives have in the current project development process of your company?

Q10: Do you think the role of the EU Taxonomy objectives should be enlarged in the project development process of your company? If so, how do you think this could be done?

ENVIRONMENTAL DECISION-MAKING

Q11: Does the company adopt specific environmental methods to support decision-making on which projects to develop? Please elaborate.

Q12: (this question is only relevant if the company uses decision support software or other decision support tools for making portfolio decisions) How is sustainability embedded in the decision support software (or other decision support tools)?

Q13: What are the main barriers or needs in the incorporation of environmental aspects in the project development process? Please elaborate.

Q14: In your opinion, how can environmental aspects influence decision-making on which projects to develop?

Q15: In your opinion, in which stage of the project development process it is important to consider sustainability? Why?

ADDITIONAL TOOLS FOR EVALUATING SUSTAINABILITY

Q16: Is there a need for additional tools to consider sustainability in your project portfolio management? And what kind of tools would you prefer?

Q17: On which aspects of sustainability should these tools focus?

Q18: If you had access to these tools that you prefer, to what extent would you let them influence the decision-making?

APPENDIX C.1: EU TAXONOMY REGULATIONS

THE TAXONOMY REGULATION ESTABLISHES SIX ENVIRONMENTAL OBJECTIVES

1. Climate change mitigation
2. Climate change adaptation
3. The sustainable use and protection of water and marine resources
4. The transition to a circular economy
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystems

Appendix D: Illustrative quotes organizations A - J

Category	Code	Illustrative quotes - Organization A
Project management	Method	"The organizational unit sets the strategy for three to five years and in the strategy the broad outline of their innovation framework is set. … On a yearly basis there is considered what will be done in the next year."
	Structure	"We distinguish between two types of innovation processes. The innovation process for things we know are within our strategy and our roadmaps, so we are sure we want it. Then the development process is step-by-step and the decisions and gates are focused on looking back and asking if everything done till that moment is ok. The second innovation process is focused on things we think would fit our strategy but are not yet on our roadmap, something really new for us. For that we have a classic stage-gate process with four stages and at every gate you look backwards, did we do everything we needed to do till now, but also forward, and ask ourselves, with everything we know, are we still willing to invest in the next phase? So the incremental innovation process and the more radical one."
	Tools	"Software tool to execute portfolio analyses, comparable to Flightmap."
Environmental concerns	Concerns	"We have concerns."
	Identifications	"Robust commitments are made, which are solidly substantiated through the value chain."
	Criteria	"Those commitments are translated to performance criteria for the management. So top-down it is an accomplished fact that we should achieve our goals."
	Usage	"For every choice there is regularly asked 'are we going to achieve this', add the projects and the expected impact, 'do we achieve it'? So it is already quite part of the thinking and choices about projects and programs."
EU Taxonomy	Mitigation	"We committed to the 1.5 degree."
	Adaption	"Adaption is not that relevant for us."
	Water	"Part of what we do."
	Circular	"Extremely important for us. Embraced it as our new business model. It is more than an ambition, we publicly committed."
	Pollution	"Not a point for discussion. We committed to zero waste till land fill and all other norms."
	Biodiversity	"We do not really have an impact on it."
	Goals	"Given that 2 and 6 do not play a role. 5 is a fact and not debatable. 1 and 3 are requirements and 4 is where we focus on the most. In 4 you can see where choices are based upon in the innovation area."
	Preventing	"With our production processes and use of equipment, it is more about the energy and resources we use."
	Restoring	"We do not really have impact on it."
	Current	-
	Future	"When looking at other companies, it should be more explicit and robust included in the portfolio management. It should be one of the conditions an innovation should meet, otherwise we should not continue it."
Environmental decision-making	Environmental tools	"We use tools. One for circularity. And a second category for products which take a leap towards sustainability for example by using less or recycled materials. All based on scientific evidence."
	Environmental DS	"Currently in development."

	Barriers	"To figure out how to work on your products to make them sustainable and how to translate sustainability into numbers."
	Needs	-
	Influencing	"It should be part of your portfolio management approach."
	Stage	"It should be taken into account from day one. It could even be an impulse for projects to enter the funnel."
Additional tools	Additional	"Currently in development."
	Focus	"It should be part of the scorecard."
	Willingness	"Yes."

Category	**Code**	**Illustrative quotes - Organization B**
Project management	Method	"There are two levels. Every year we go through a strategic cycle and we decide what our focus areas are and which areas we want to leave. Second, we have the projects within those focus markets, what products can we develop and what do we need to do that. For that we make business cases and compare them. Then we consider when and what we can do, push things forward or backward, or stop things. That is what we call PPM."
	Structure	"A funnel, this process holds for everything. We distinguish the next phases: pre-project initiation, with raw ideas with milestones and product idea validated, project initiation, concept, definition, planning and release. … Biggest investment is between planning and release, about 80% of the investment."
	Tools	"We use Flightmap."
Environmental criteria	Concerns	"For employees it is also important to work for a company that tries to make the world a better place. It is important for maintaining the current employees but also to attract new employees."
	Identifications	"It is also about market segmentation, in some markets you do not aspire to grow. In other markets there is growth and we can really add something sustainable. When both components are available, you just want to be part of the market, we want to be a big part of it and also allocate money to it. … There is also an incentive in place within the organization, that we can lend money cheaper for green investments."
	Criteria	"Not very explicit, more implicit. We have a checkbox for if the project is green, if so, you can cheaper lean money."
	Usage	"Now it is more a plus if it is green. … I can imagine in five years it will be more explicit."
EU Taxonomy	Mitigation	"Yes, less emissions, less use of resources."
	Adaption	"It is now primarily preventing climate change. It is no deliberate focus, but I can imagine that the things we are now making, will be used when the world changes and the climate becomes different."
	Water	"Limited. We also have some factories, where they are working on this, making sure that we are handling resources responsibly, with little waste and little water. But considering the whole scope, it is a small part."
	Circular	"Much more. There is a drive to extend the lifetime of our products."
	Pollution	"It is approached from different angels, it is about smartness, making products energy efficient and that our factories try to prevent making waste."
	Biodiversity	"I don't see it like that."
	Goals	"1 - 5 - 4- 3 - 2 and 6."
	Preventing	"Focus on prevent damaging the environment."
	Restoring	-

	Current	-
	Future	"Yes, by making it more explicit instead of implicitly giving it low profile."
Environmental decision-making	Environmental tools	"We have one checkbox for if it is green or NOT green … there is a longer checklist underneath."
	Environmental DS	"You can see if the project is qualified as green, so you can take that into account."
	Barriers	"The multidimensionality. You need to take care of 100.000 things and this is one of them. There are a lot of trade-offs."
	Needs	"You want to be able to steer the consideration, shift the balance. … It helps if you can make it simple, but you also want to engage the people, it is not all about profit, it is about more"
	Influencing	"We need to take it more to the foreground and take it into account more often and put more weight on it. Also with the use of quantifiable goals."
	Stage	"As soon as possible."
Additional tools	Additional	"Yes, to make considerations more explicit. Flightmap could help with that. Make it transparent in what you invest in sustainable initiatives. Take it to the front."
	Focus	"To cluster it on where we can have the most impact on, energy is obvious, mobility as well, smartness. … It is a weighted judgment on what we can have an impact, with the technology that we make."
	Willingness	"Yes, if we put something on the table, make something transparent. Then it has an impact. How much impact also depends on the people around the table."

Category	**Code**	**Illustrative quotes - Organization C**
Project management	Method	"The top management of the company gives a strategic direction. We keep that in mind when looking for projects that fit us."
	Structure	"We start at the front-end of innovation. Then we look at what should go into our innovation funnel. We make a selection with the use of a stage-gate model. In gate 0 a project enters the funnel. The project continues from stage 0 to stage 4, in which the product is launched."
	Tools	"With Excel sheets, with some criteria and by filling in a type of decision analysis format."
Environmental concerns	Concerns	"We have concerns."
	Identifications	"Identified at the front. For example a sustainable basis infrastructure for the factory."
	Criteria	"We have some procedures. We check the environmental impact with some kind of decision tree."
	Usage	"We have checklists. For every iteration we look at all criteria to see if it suffices. It sometimes leads to stopping a project, because they are outside of a permit or do not contribute enough."
EU Taxonomy	Mitigation	"By efficiently organizing our production processes, using as much sustainable energy as we can and aligning our products to it."
	Adaption	"Yes. We try to support the transition with the products that we make."
	Water	"Yes. We look at how we can decrease our water usage and reuse the water and we also develop technology for water purification."
	Circular	"Minimize packaging. With our design we try to make it as easy as possible. But we are not very advanced at this yet."
	Pollution	"Input for our processes or as resource, is really evident in our procedures."
	Biodiversity	"No direct link with what we do."

	Goals	"3 - 5 - 1 is our top three."
	Preventing	"Prevent doing harm. We recycle our own water and try to use less energy and the energy we use comes as much as possible from no-fossil sources or green energy sources."
	Restoring	-
	Current	"Trying to balance economy and ecology. Finding the balance between how much you do, how much you invest, how much you can do, but it something that we are constantly talking about."
	Future	"You can always do more, but it already has a big role in our company."
Environmental decision-making	Environmental tools	"Yes. The Excel sheets."
	Environmental DS	-
	Barriers	"Technical barriers, sometimes there is no alternative and economic because it is not economically viable."
	Needs	"Some pressure or force, with regulations from politics, can cause a breakthrough. There already are more technical possibilities, but often they are blocked by laws and regulations or by exceptions made for companies in consortia."
	Influencing	"As a requirement. It is also being steered from the strategic global direction. So we actively seek sustainable projects."
	Stage	"In every step. In every step you get further, making it more specific, so taken into account in every step."
Additional tools	Additional	"I do not think so. Current used tools like Excel and PowerPoint are for now sufficient."
	Focus	"It could be an administrative tool, that could potentially be the need, because now the document disappears in the digital folder of the person in charge."
	Willingness	-

Category	**Code**	**Illustrative quotes - Organization D**
Project management	Method	"Specific teams decide what should be on the development roadmaps for the coming 2 years. Every two years budget rounds take place to decide on which funds are allocated to which projects. … The criteria are driven by the customer."
	Structure	"Stage-gate model with 9 stage gates."
	Tools	"No software for managing the beginning of the innovation till the end-of-life of all projects. In our innovation funnel we use our own software. … Currently we are implementing a new software tool to manage our innovations."
Environmental criteria	Concerns	"The company is aware that it plays a role and that our impact should be minimized and brought to zero in the long run. The company acknowledges it on the highest level and is coming out with it. … Company signed climate pledge to achieve climate goals in 2040."
	Identifications	"Targets are being set, to make sure employees will act on it."
	Criteria	"Not fixed."
	Usage	"Currently it is not fixed. It is formulated as a wish."
EU Taxonomy	Mitigation	"This is also part of our goals. And specifically limiting CO_2-emissions of our business operations. Both what we do as a company, our offices and the systems we sell. So also helping our customers to have sustainable operations."
	Adaption	"Adaption is not something we are working on."
	Water	"Not sure. It is also part of consciously dealing with resources. But I am not sure if it is a specific pillar in our project organization. At our offices

		it is, we try to run the offices as sustainable as possible."
	Circular	"Yes. This is definitely on our agenda. It is a pillar."
	Pollution	"Very big focus on. Reducing energy usage, compensate everything, doing most possible with sun and wind energy, our offices soon need to be CO_2-neutral."
	Biodiversity	"I am not aware of what we do when we manage projects. Our offices yes."
	Goals	"1 - 5 - 4 - 6 - 3 – 2."
	Preventing	-
	Restoring	"The only thing now is planting trees, but that is more about compensating. … You first need to take your business operations to 0, and then you can start doing extra. If you are now in the negative it is hard to something extra, because everything is then compensation anyways."
	Current	-
	Future	"It should get a bigger role, but you can see that it takes time."
Environmental decision-making	Environmental tools	"Not as a standard. We sometimes use LCA, but not as a standard. … Currently we are in that transition, we try to get the circular design principles in our development organization, as some kind of checklist or guidelines to support decision-making. It is not yet standard."
	Environmental DS	"It is scored on how it contributes to the sustainability goals, more the idea. If it does not contribute, there is no reason to drop the project. … It is about gut feeling, no hard proof."
	Barriers	"Knowledge."
	Needs	"Software to help calculate the impact and that can advise on changes and guidelines for circular design and checklists."
	Influencing	"Now it is a wish, but it should be a must."
	Stage	"It should always be a topic. Most important when specifications and requirements are defined, which is at the beginning."
Additional tools	Additional	"Yes."
	Focus	"It should give insights. Show real-time what its impact is. Also sustainability in relation to costs, price and usability."
	Willingness	"Yes."

Category	**Code**	**Illustrative quotes - Organization E**
Project management	Method	"Senior management sets strategic goals and related objectives on the company level, those are projected top-down. … Senior management is also part of the cycle in which every three months the objectives are adjusted."
	Structure	"We work in an agile model, which means we think 3 months ahead. It does not come without problems because our clients work with stage-gate."
	Tools	"Mainly Excel."
Environmental concerns	Concerns	"As part of our ethics."
	Identifications	"It is implicitly part of our roadmaps."
	Criteria	"I do not think there are explicit goals."
	Usage	-
EU Taxonomy	Mitigation	"We have something to do with it. It is mainly about CO_2 and what our products can contribute to that."
	Adaption	"We are not specifically working on it, but our products can help."
	Water	"I cannot think of anything."
	Circular	"Do not think we have explicit goals, but we do something."

	Pollution	“Yes. Look what we can contribute with our products.”
	Biodiversity	“No direct relation with what we do.”
	Goals	“1 -2 - 5 - 4 – 6.”
	Preventing	“We are a responsible company, but we cannot really do much about it.”
	Restoring	“It is a theoretical question, I do not know what we could do about it.”
	Current	“Not an explicit part of our processes.”
	Future	“No bigger role, because I do not see how it could be translated into objectives with which we could make a difference.”
Environmental decision-making	Environmental tools	“Not explicit, because we make products for our clients.”
	Environmental DS	“Our product managers do not take the objectives into account because they explicitly come with the customer.”
	Barriers	“Waiting for someone to take the lead.”
	Needs	-
	Influencing	“We only use the requirements from our clients. And we take our own requirements into account with which we think we can earn money in the future.”
	Stage	“We only take into account requirements of the customer, and requirements that we ourselves can make money with in the future. Sustainability is not given as a requirement by our customers, so not taken into account.”
Additional tools	Additional	“No need.”
	Focus	-
	Willingness	-

Category	**Code**	**Illustrative quotes - Organization F**
Project management	Method	“Most of the time it starts with a study with a client, about what is the need, for which products is there a market or the client comes with a question for a specific solution. … Most of the time the market needs, how competitive it is, if we have a gap in our portfolio, determines if we continue a project. We need to meet their requirements as well as our own requirements.”
	Structure	“We have stages and gates, but distinguish two different processes. Just product development including the phases of market exploration, business review to decide if continued, product launch, commercial launch, start of production and finally the customer support phase. And specific projects for which clients ask for specific product that needs to meet certain requirements, this starts with a request for proposal, followed by certain gates, we start if the project is promising and fits us, solution orientation review, preliminary design review, critical design review, production phase, test phase.”
	Tools	“I have never seen one holistic software tool. But we use simple tools like PowerPoint for our production plan.”
Environmental criteria	Concerns	“At this moment it is starting to increase.”
	Identifications	“We realize we need to take steps and we see that awareness is increasing. At the beginning of this year we want to create intern guidelines on how we should include sustainability and also how we should consider it.”
	Criteria	“We look at the emissions our products cause.”
	Usage	“Not yet hard KPI's, we are still looking how we can review and influence it.”

EU Taxonomy	Mitigation	"We do this in two ways, on our sites and operations we do it for a while, for example flush toilets with rainwater and use sustainable energy. And now we are also starting to take it into account for our products, so that is more indirect and it will help our clients achieve their sustainable goals."
	Adaption	"More indirect. Our market can change due to a changing geopolitical situation and more extreme weather can lead to additional requirements for our products."
	Water	"Not sure. On our sites and operations we try to reduce water usage. And if you look at the use of our systems, we try to make it more energy efficient and emit less emissions and less need to use water or energy."
	Circular	"Currently looking at this, what happens with our products after 30 years. Can we recycle, can we make the products more in modules so that we can do updates and upgrades during the lifetime instead of replacing the whole system at once, so to use it better."
	Pollution	"First during the production, and we follow how the whole supply-chain performs. And for our products, we try to be more aware of it. We are looking for a way to do so."
	Biodiversity	"We have guidelines for the use and disposal of hazardous substances. For restoration I am not so sure, if we cannot prevent it, we can try to restore or limit the harm."
	Goals	"5 - 1 - 6 - 3 - 4 – 2."
	Preventing	"Focus on preventing doing harm."
	Restoring	-
	Current	"Goals are limitedly taken into account. Legal and customer related requirements weigh heavily. You can see it is now becoming more important due to goals on a company level. We are still at the beginning."
	Future	"Yes, now it is something additional. I expect that soon eco-design will be part of our development process, making sure we take it into account from the beginning."
Environmental decision-making	Environmental tools	"We have a tool to calculate the environmental impact, but do not use it that much."
	Environmental DS	-
	Barriers	"Money, what are the costs and it is not clear what it contributes. … And how can we create additional value for the customer."
	Needs	"Get insights on how much you could reduce or enhance."
	Influencing	"Look at the bigger picture. Perhaps it is not the best business case for the product itself but for the company it can be very interesting to achieve the goals and for other products it may be even more complex."
	Stage	"In every phase. It starts at the early beginning."
Additional tools	Additional	"Yes."
	Focus	"You would like to assess the sustainability of your product. Also some sort of classifications, because a bigger product will always use more than a smaller, so per category different standards and a benchmark with competitors, to see how it works in the whole market. … Some sort of toolbox or practices that we should develop to see what choices we can make, and what the alternatives are."
	Willingness	"Yes."

Category	Code	Illustrative quotes - Organization G
Project management	Method	"Driven by what the possibilities are in the market and what the customers ask for. … We base decisions on business opportunities."
	Structure	"Standard stage-gate process. It starts with exploration, next phase we look at the feasibility, then the development phase and the launch phase. Including the necessary checklists for certain swimming lanes."
	Tools	"We use Flightmap."
Environmental concerns	Concerns	"Yes. Yes. Shareholders also told us to go greener."
	Identifications	"The Parent company also formulated goals and activities."
	Criteria	"Not explicitly for the whole company."
	Usage	"It is not yet incorporated in guidelines and develop procedures."
EU Taxonomy	Mitigation	"We have a roadmap with a net-zero goal, so mainly focus on CO_2 and greenhouse gas."
	Adaption	"Not really relevant for our company, it is more about mitigating."
	Water	"We produce almost no waste water. Not really relevant for our company."
	Circular	"Definitely relevant. One of the things included in the program. We try to get products back that need replacement, to make sure they are disposed properly and we try to reuse as much components as possible."
	Pollution	"It is about more than only CO_2. For example the use of chemicals, you do not want it to end up in the environment."
	Biodiversity	-
	Goals	"1 and 5 and 4 on the same level. Followed by 6. And then 3 and 2 on the same level."
	Preventing	-
	Restoring	"Outside the scope, if we do not reach our goals in 2040 there will be looked at compensation."
	Current	"Not explicit, but the intention is there, but not yet taken into account to the extent that we wish for."
	Future	"You should take it into account in product development, there are steps we need to take. Internally we did not yet decide on everything regarding the implementation."
Environmental decision-making	Environmental tools	"Not standard, but are familiar with LCA. Important to not get lost in the details."
	Environmental DS	"Not explicitly part of it."
	Barriers	"Motivation of employees and higher management. … Practical things, such as regulation that do not allow to get your product shipped back for recycling."
	Needs	-
	Influencing	"You could paramize it and include it in the trade-offs between different factors."
	Stage	"As soon as possible."
Additional tools	Additional	"Yes."
	Focus	"What you get is a long list of ideas, projects and proposals which you need to rank. A portfolio tool like Flightmap could be really useful for this, but some criteria should be added to take into account sustainability. … At this time CO_2 and net-zero are most important. … The more complex your model is in the portfolio management tool, the harder it is for people to understand why certain choices are made. If the choices are also supported by intuition, the use of the tool is reinforced."
	Willingness	"Yes. If you are not willing, why use the tool."

Category	Code	Illustrative quotes - Organization H
Project management	Method	"We have a strategic plan with the topics that are important to us. These topics are further elaborated on in sub-plans. And then in a few steps it is made more specific. Then there are roadmaps with the plans for the coming 3 or 4 years and those roadmaps address where we want to be in the coming 3 to 4 years for these topics and derived from that the technologies and knowledge we need to get there. … So step for step we look at what projects we need and sometimes the projects present themselves or sometimes a client or partner comes with a problem and asks for our help."
	Structure	"Projects are clustered in Product Market Combinations (PMC). The PMC's go through the funnel with phases, we have a pre-PMC phase, and then from exploring to implementing and exploiting at the end. … Sometimes if a PMC is further in the funnel it goes back to a previous stage, because we redirect the path, so it is not solely a linear process. … Every year we review where the PMC's stand 3 or 4 times."
	Tools	"We use Flightmap for our PMC's."
Environmental criteria	Concerns	"The climate is important for our organization."
	Identifications	"We need to make choices where to work on. There are multiple environmental topics addressed in our strategic plan."
	Criteria	"We are working on it. We are developing criteria linked to the SDG's to take into account when we take on a project."
	Usage	"Use the criteria for selecting."
EU Taxonomy	Mitigation	"Highly important, receives much attention in the strategic plan."
	Adaption	"We pay attention to adaptation, for example on the drought and the land subsidence and how to handle that."
	Water	"Not really, other organization is specialized in that."
	Circular	"We even have a unit called circular economy and environment. We are working on the transition agendas as proposed by the Ministry, to provide it with more specific content."
	Pollution	"We are working on it. For example on industrial safety and micro plastics."
	Biodiversity	"Nitrogen is an example of where we are working on related to biodiversity. For the ecosystems we are also concerned with noise emissions."
	Goals	"1 - 4 - 2 - 5 - 6 – 3."
	Preventing	-
	Restoring	"Not really working on it, we mostly work on making dirty processes more clean."
	Current	"These objectives are very important to us. The objectives formulated in our strategic plan and there the derivatives of are already much more specific. So we select projects that that we think can contribute, but we do not check if they relate one-on-one to these 6 objectives."
	Future	"The topics are known to us, we know what is going on. We are currently working on translating it to figure out what these means to us."
Environmental decision-making	Environmental tools	"Currently developing tools to screen projects before taking them on, to screen the client and the content of the project for risks and its potential."
	Environmental DS	"Currently developing tools to screen projects before taking them on."
	Barriers	"Technological reasons, economical reasons and psychological reasons. Bringing new criteria to take into account is difficult if you are focused on other things."

	Needs	"You need a cultural shift. … We need a light tool to get the conversation going internally and externally to our clients and partners."
	Influencing	-
	Stage	"Especially in the beginning, but sometimes it can also be helpful during the innovation process."
Additional tools	Additional	"I do not see the solution for us as an addition in Flightmap. We are working on taking it into account in the procurement process."
	Focus	"Just a checklist, no hard technology, to get the conversation going."
	Willingness	-

Category	**Code**	**Illustrative quotes - Organization I**
Project management	Method	"The strategy is led by sales. So sales is in the lead to indicate the direction in which we want to further develop, in which market, what kind of work do we want to do."
	Structure	"It starts with a proposal. That needs to become more detailed. Followed by allocating budget, what do we need, who do we need and where do they come from. Then we form a consortium, with partners within the bigger company or within our supply chain. Then there is a project plan that needs to be approved."
	Tools	"We do not use software. We use Excel and other tools for progress reports."
Environmental concerns	Concerns	"Our clients are our drive, so we need to be green for commercial reasons."
	Identifications	"Our current clients make sure we stay active on this topic. And we can use it as advertisement towards new clients."
	Criteria	"We have no criteria."
	Usage	"We do not assess sustainability, only if the project is solely about sustainability."
EU Taxonomy	Mitigation	"Of course."
	Adaption	"We are not involved, probably in the design phase on company level."
	Water	"We have rules how to use water, rules from the control group."
	Circular	"We do a lot. For a long time already, not something introduced recently."
	Pollution	"It is obligatory within our company, it is obligated by our control group."
	Biodiversity	"Not yet addressed this."
	Goals	"5 - 3 - 4 - 1 - 2 and 6."
	Preventing	-
	Restoring	"Only in research projects and in our own think tank."
	Current	"Limited. Some objectives are standard and are implemented under the label of quality management."
	Future	"I do not think the role should be larger, but commerce remains the main drive."
Environmental decision-making	Environmental tools	"No, we have no system for it. Unless it is connected to the system of our client. Or we use Excel to capture information … information about energy usage and materials used."
	Environmental DS	"Not standard. Only if the client asks for."
	Barriers	"The environment we work in. The availability of new possibilities."
	Needs	"Sustainable alternatives, for example for the materials."
	Influencing	"It could be a requirement. But I think that decisions become easier when it is imposed from above (Government). Then the market is a one

		level playing field."
	Stage	"After the first two stages, the design phase of the model and looking for availability of resources. Then you start thinking about how you can test it. In the third phase you are testing on the availability of resources and you can easily also take into account sustainability."
Additional tools	Additional	"Not solely for sustainability. Everything should be combined in one tool."
	Focus	"Not a static but a living document. It should focus on the environmental aspects that we can have impact on."
	Willingness	"It would help."

Category	**Code**	**Illustrative quotes - Organization J**
Project management	Method	"We have an innovation process, which we split in different phases. And at the end of each phase, we evaluate if the project goes to the next phase or needs to be killed or needs to be reworked. So it is a Stage-Gate process basically. The decisions are based on the strategy of the business groups and where do they want to go. The steering committee are the ones deciding if the project goes to the next phase. But it's based on the strategy, vision and mission of the business group and the company."
	Structure	"We have an ideation phase, concept phase, feasibility, scale-up and realization or introduction, so 5 stages."
	Tools	"We use Flightmap as a tool to visualize all the projects we have, so as portfolio management tool. Also, to help us in the process of decision-making. We use more tools, we use our internal tools that we have developed. We use also external tools and the business groups tools."
Environmental concerns	Concerns	"The company is more aware and concerned."
	Identifications	"So the company is more aware and concerned to include those parameters into the decision-making process. You start taking it into consideration from concept phase or from the second stage, unless there are really big red flags in the ideation phase, but normally we start considering sustainability key indicators from concept phase. So the second phase. We also have sustainable targets, for which we have roadmaps for the whole company, for example for water usage and CO_2-emmissions."
	Criteria	"We start considering sustainability parameters in concept phase and after concept we start building up the LCA-study. After development then we should have already very good indication of the impact of the process or project or product."
	Usage	"The decision is normally taken by the steering committee. Currently the decision is mainly based on the business case. The LCA-studies and all LCA-information is extra information that it is required, but it is not the main parameter to kill a project. It is used to ask the project team to rework the project or to rethink the project, in case the indicators are not suitable or not good."
EU Taxonomy	Mitigation	"We do take it into account. We pay a lot of attention to our CO_2-emissions, so our current CO_2-emissions, and to our future CO_2-emission. We do have plans to decrease our CO_2-emissions."
	Adaption	"Being a company that deals with natural products and natural raw materials, we need to change slightly our processes due to the fact that they change. And we see the change also reflected in our processes. If we do something about that, we try to adapt. We do follow several parameters that actually tell us what is expected. So we do monitor that also."

	Water	"Yes, this is important for us. We have projects aiming to reduce our water consumption, water usage."
	Circular	"We have several projects that are dealing with this. We want to become more green, use for example bio gas in our factories, recycle more of the materials we use and produce more bio based products."
	Pollution	"We also pay a lot of attention to this, we control them. We take measures to do that. For new projects this is an important parameter. Pollution, CO_2-emissions, nitrogen depositions, that are key indicators."
	Biodiversity	"I am not sure."
	Goals	"1 - 5 - 4 - 3 - 2 – 6."
	Preventing	"We prevent doing harm and we try to basically improve by implementing new techniques, to be more efficient and use less resources."
	Restoring	-
	Current	"I am not sure if this whole EU taxonomy has a role in there directly, but indirectly I do think we are tackling some of this or most of these goals."
	Future	"Some of them, yes. I do think some of them are very important for project development phases. Some others maybe are more important at a later stage. I do think they should be considered either one way or the other."
Environmental decision-making	Environmental tools	"We use our LCA-tool."
	Environmental DS	"Not embedded in the tools. The data is available and discussed during out meetings, but it is not on our current portfolio management tools. The data is updated every phase, but that is done offline."
	Barriers	"It is mainly about using one tool. All the business groups are using different tools, different methods also. We try to unify them and that is part of the process that we are actually working on right now. So I think it's mainly an issue of being one basically."
	Needs	"We use it as a KPI so it should be included in the system. Internal alignment on how to deal with projects and the process of decision-making."
	Influencing	"That is what we do right now. So if we see a red flag in a mature CO_2-emissions, then we try to find a way how to tackle that issue. Or if it is an unexpected large amount of water use, we rework the project. That's how we use those parameters, to decide to let the project go through to the next phase or not."
	Stage	"I do think it needs to be incorporated as soon as possible. As soon as the data is available, it needs to be incorporated there. It needs to be used as a guideline for decision-making through the whole process and it will become more and more important through later stages. Start considering it in in our second phase is the correct way I think and from that moment on we should keep just updating the data. More data becomes available, then the case becomes stronger."
Additional tools	Additional	"Besides incorporating the sustainability KPIs into our PPM tool. No, I don't see the need in our organization for an extra tool."
	Focus	"Incorporating the sustainability KPI into our PPM tool. CO_2-emmisions, water, nitrogen deposition, energy, impact parameters."
	Willingness	"I don't think it will influence the decisions, but it will influence the visibility of the impact of the projects."

Appendix E: Mock-ups for validation

During the validation interviews, mock-ups were shown to visualize how the solution will look like in Flightmap. The first mock-up, shown in Figure 7, shows the heat map with projects and environmental KPIs. The second mock-up shows how to attach weights to the KPIs in Flightmap, shown in Figure 8. Besides these two mock-ups, a part of the proposed list of environmental KPIs is shown, to give an idea of what KPIs are proposed and how they are categorized.

Figure 7: Mock-up Heat Map Projects and Environmental KPIs

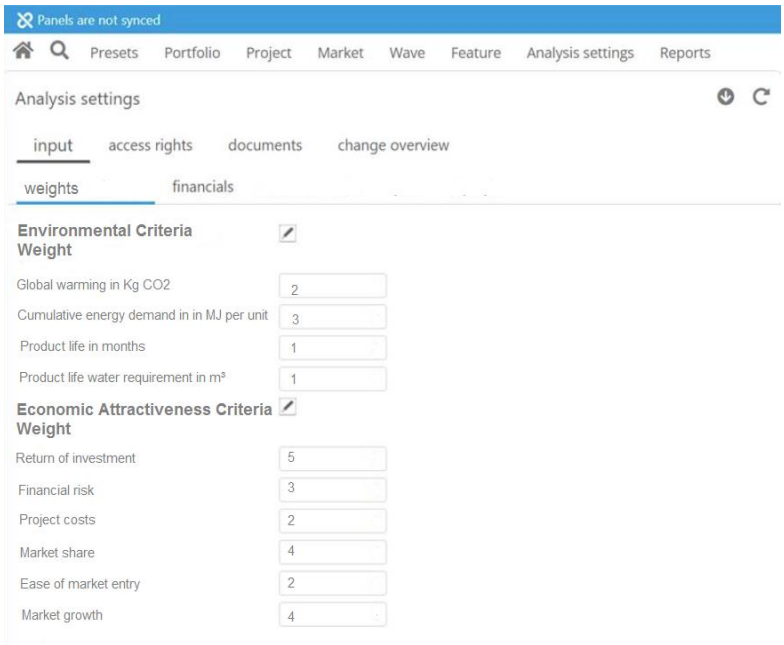

Figure 8: Mock-up Attaching Weight