# Stimulating Sustainable Corporate Real Estate

## Developing a sustainability reference model for the Preference-based Accommodation Strategy

Olivia Wechsler, Master Thesis, 24 June 2022

Master of Science Architecture, Urbanism & Building Sciences,
Delft University of Technology, the Netherlands

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# Colophon


## Student

| | |
|---|---|
| Name | **Olivia Louise Wechsler** |
| Student number | 5367425 |

## University

| | |
|---|---|
| Name | Delft University of Technology |
| Study program | Master Management in the Built Environment |
| Faculty | Architecture and the Built Environment |
| Address | Julianalaan 134, 2628 BL, Delft |

## Supervisors

| | |
|---|---|
| First mentor | **Dr. ir. M.H. (Monique) Arkesteijn MBA**<br>MBE, Real Estate Management |
| Second mentor | **Dr. Ir. R. (Ruud) Binnekamp**<br>Faculty of Civil Engineering and Geosciences<br>Integral Design and Management |

## Graduation Organization

| | |
|---|---|
| Organization | Colliers |
| Mentor | **Marjon van Bree**<br>Director Corporate Real Estate Solutions |

# Preface

The thesis “Stimulating Sustainable Corporate Real Estate” you are about to read is my final assignment before graduating from the master program Management in the Built Environment at TU Delft. This project marks the ending of my five year university education that I have enjoyed at EPFL, Switzerland and TU Delft, the Netherlands.

Early in my high school years, I followed courses in economics where I learned that supply follows demand. This simple economic theory has always interested me and led me to think that the low supply of sustainable buildings could easily be increased when also increasing the demand for sustainable buildings. So if market actors would be stimulated to demand more sustainable buildings, the supply would follow. Of course the matter is more complex than that but it sparked my interest in the actual demand for environmentally sustainable buildings. When I presented this topic to my first mentor Dr. ir. Monique Arkesteijn, she immediately saw a link to her own research on preference measurement in corporate reals estate decision-making. She connected me to my second mentor Dr. ir. Ruud Binnekamp and Marjon van Bree for a graduation internship at Colliers where I was able to conduct my research under prolific conditions.

Even though I had never experienced major difficulties in my previous education, writing this thesis has challenged me in ways I did not expect. I had to learn to use the practical and visual approach from architecture school in an academic research project. Thanks to my mentors and to Miro (yes, a whiteboard tool), I have accomplished to illustrate and write my research down on paper. It became a project that I am proud of and that has taught me a lot on an academic and personal level.

Lastly I would like to express my deepest gratitude to the people that have supported me during the past nine months. To Monique for guiding me in the right direction when my sometimes teary eyes made it difficult to see the next steps. To Marjon for facilitating the organization of the pilot study and telling me that writing a thesis is in essence about managing your own feelings of guilt. This phrase weirdly helped me put things into perspective. To Ruud for trusting the process and starting insightful discussions. To Eline who taught me how to deal with stress and perfectionism. To my friends and the CRES team at Colliers for being great study buddies. And lastly to my family and my boyfriend for their support and trust in my abilities.

I hope you enjoy reading my thesis,

Olivia Wechsler

Delft, June 24, 2022

## Abstract

Environmental sustainability has become an urgent matter on the Dutch political agenda, which will affect the built environment in the near future. Consequently, organizations have to adapt their real estate to new regulations for building performance and their own sustainability goals. The Preference-based Accommodation Strategy (PAS) is a decision-making strategy that aids organizations in finding a Corporate Real Estate Portfolio (CREP) that aligns with the organization's values. This research aimed to stimulate organizations to improve the environmental sustainability of their CREP by changing the decision-making process. Therefore a sustainability reference model (SuRMo) was developed for PAS and tested on the CREP of Colliers, an international real estate consultancy firm with multiple offices in the Netherlands. In the pilot study, PAS and the SuRMo were used to evaluate three alternatives for a new office space in Utrecht. In an iterative process using the operation research methodology four tests were conducted which compared the outcome of the different decision-making processes. The four tests analysed 1) the current decision-making process, 2) the decision-making process and outcome using PAS, 3) the decision-making process and outcome using PAS with the SuRMo 2.0 and 4) the sustainability performance of Test 1-3 compared to Dutch sustainability goals for 2050. In the three tests the decision outcome resulted in the same office building that performed best in terms of environmental sustainability and matches the governmental goals for 2050. However, between Test 1 and Test 2 the total number of criteria increased from 7 to 37 and from two implicit environmental sustainability criteria to five explicit criteria. The outcome of this research shows that PAS increased the number of environmental sustainability criteria and changed the decision-making process of Colliers from implicit to explicit. The stakeholders expressed the need for the SuRMo because they lack knowledge about environmental sustainability in CREP but concluded that it requires further development for user-friendliness and suitability with PAS. The three actionable conclusions for practise are that PAS should be used in decision-making about CRE with a further developed SuRMo, Green Building Rating Systems should be used for sustainability in CRE decision-making instead of greenhouse gas emissions and project developers and investors can use the explicit outcome of PAS to adapt the supply to the demand on the real estate market.

# Abbreviations

| | |
|---|---|
| BENG | Bijna Energieneutrale Gebouwen (EN: Almost energy neutral buildings) |
| BREEAM | Building research establishment assessment method |
| COO | Chief Operating Officer |
| CRE | Corporate Real Estate |
| CREP | Corporate Real Estate Portfolio |
| CRES | Corporate Real Estate Services |
| DGBC | Dutch Green Building Council |
| FC | Financial Controller |
| GBRS | Green Building Rating System |
| P | Policy |
| PAS | Preference-based Accommodation Strategy |
| PBD | Preference Based Design |
| PCHIP | Piecewise Cubic Hermite Interpolating Polynomial |
| PFM | Preference Function Modeling |
| RE | Real Estate |
| RVO | Rijksdienst voor Ondernemend Nederland (EN: Netherlands Enterprise Agency) |
| SDG | Sustainable Development Goal(s) |
| SuRMo | Sustainability Reference Model |
| TM | Technical Manager |
| U | User |
| UFA | Useable floor area |

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# 1

# Introduction

# 1. Introduction

In the introduction, the problem of this research is announced and its relevance is explained on a scientific and a societal level. Additionally, the research questions and the research method, which structure this study, are presented.

## 1.1. Problem and Relevance

The topic of this research covers environmental sustainability in corporate real estate portfolio (CREP) decision-making. This subchapter will elaborate on the three key words that are sustainability, Corporate Real Estate (CRE) and decision-making and highlight the societal and scientific relevance of this research.

### 1.1.1. Problem Statement

In 2015, the United Nations defined a set of Sustainable Development Goals (SDGs) to improve living conditions around the globe for future generations. The goals were set to be achieved before the year 2030. The Dutch government has committed to reaching these goals. However, a roadmap that highlights the progress of the Netherlands in achieving these goals shows that the 13$^{th}$ goal targeting climate action is lagging far behind. In other words, ambitions to reduce the country's CO2 emissions are not sufficiently translated into actions (SDG Nederland, 2021). To achieve the SDG on climate action, a quick response is required in all sectors. When looking at the main contributors of current greenhouse gas emissions, the built environment is responsible for 13% in the Netherlands. Although the current trend of these numbers is negative, the speed of improvement needs to increase in the following years (Centraal Bureau voor de Statistiek, 2020). To ensure that buildings keep improving their environmental performance, the Dutch government has announced new regulations on the energy use of office buildings. In practise, this means that office buildings can only continue to be used if they have an energy label C by January first 2023 and an energy label A by 2030 (RVO, 2018b).

Every organization has the power to act against climate change by intervening in their Corporate Real Estate Portfolio (CREP). Making sustainable changes to the CREP hereby presents itself as an opportunity for organizations to align their buildings with their corporate strategy and, more importantly, with their Corporate Social Responsibility (Haynes et al., 2017).

Research implies that organizations focus on financial aspects, such as the valuation of property, when choosing their RE (Mansfield, 2009). However, Mansfield (2009) has shown that sustainable CRE brings many benefits for an organization, including financial benefits. To implement a variety of benefits in the decision making about CRE, a simple and user-friendly decision-making method could help stakeholders evaluate alternative buildings that align with the organizations' corporate sustainability goals.

One evaluative strategy for CRE alignment that could potentially contribute to this problem is the Preference-based Accommodation Strategy (PAS). PAS is a design and decision approach whereby stakeholders define and weigh goals and criteria for the CRE of their organization (Arkesteijn, 2019).

### 1.1.2. Societal Relevance

The societal relevance of this research mainly concerns the urgency of making CRE in the Netherlands more sustainable. Figure 1 shows that the greenhouse gas emissions of the built environment have already been decreasing since 1990 (Centraal Bureau voor de Statistiek, 2020). However, the current emissions would still require a forest 2.6 times the size of the Netherlands to compensate for the air pollution they create (US EPA, 2015). According to the Dutch climate agreement, the emissions of the built environment should be reduced by 18.2% by the year 2030 (Klimaatakkoord, 2018). For the calculations the weight of other greenhouse gases such as methane and nitrous oxide (NL: *lachgas*) has been converted to CO2 (Klimaatakkoord, 2018). The contribution of CRE to these emissions are not neglectable. Figure 2 illustrates that the current CRE stock requires a forest 0.75 times the size of the Netherlands to compensate for its emissions. For reference, Figure 6 shows a map of the actual forest area in the Netherlands. These comparisons show that the current CRE is not environmentally sustainable, meaning that the buildings used by organizations exploit more resources than the planet can provide (Cambridge Dictionary, n.d.-b). As the Netherlands has agreed to the Paris Agreement which is "the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015" it is required by law that the climate goals are met (European Comission, n.d.).

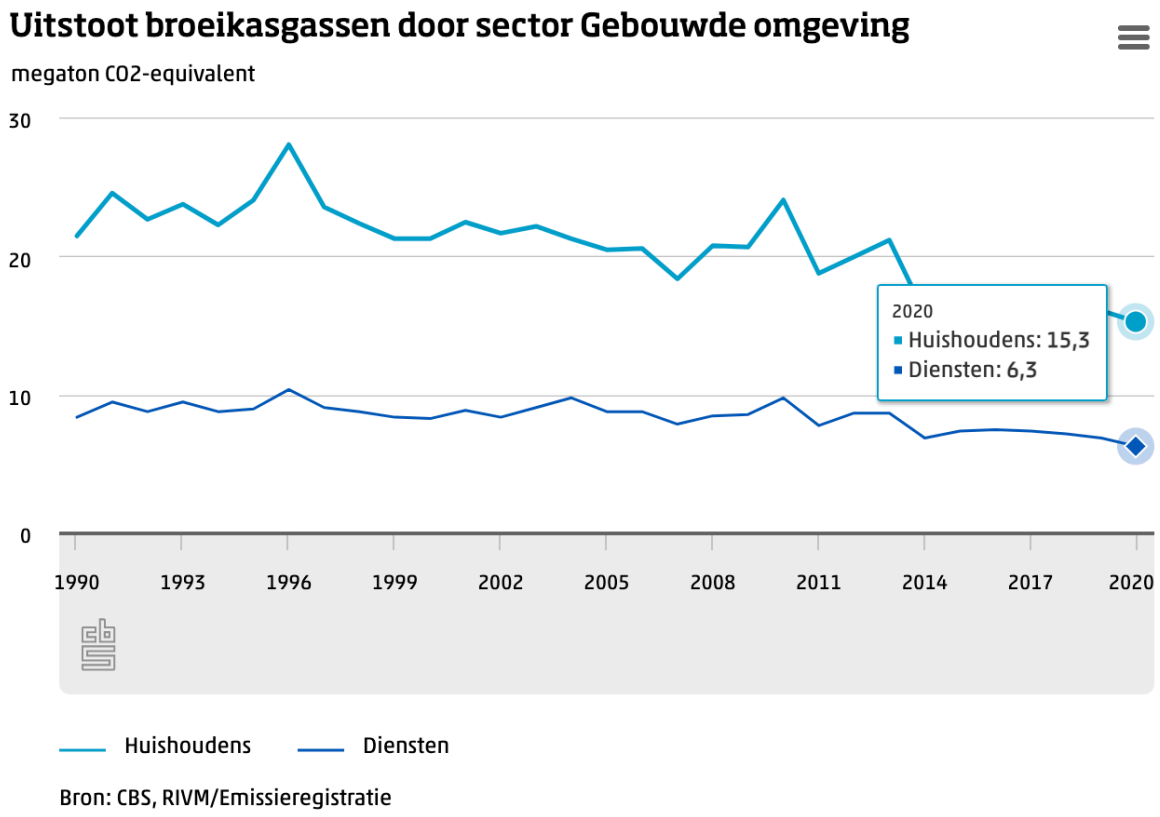



Figure 1 - Greenhouse gas emissions by the built environment in the Netherlands (Centraal Bureau voor de Statistiek, 2020)

Figure 2 - Forest area needed per year to compensate for the current emissions of Dutch CRE (own illustration based on data from Centraal Bureau voor de Statistiek (2020), calculations from US EPA (2015) and icon from Ted Grajeda (n.d.)

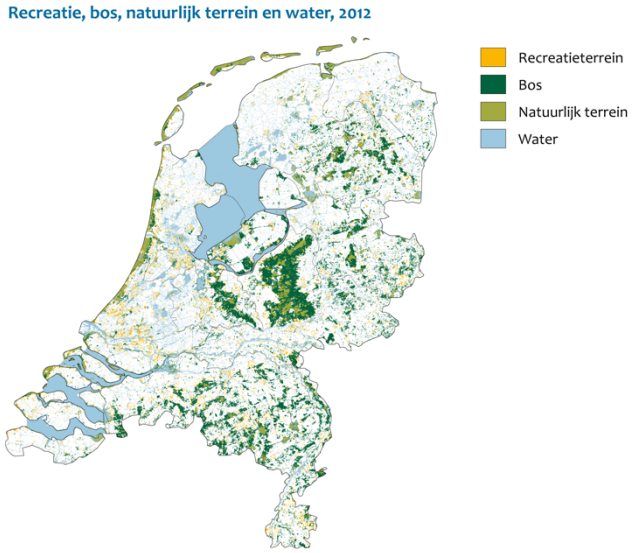



Figure 3 – Map of forest area and natural terrain in the Netherlands (CBS, Kadaster, 2016)

### 1.1.3. Scientific Relevance

The scientific relevance of this research relates to the continuation of preference measurement in design and decision-making about RE projects. Barzilai (2010) advanced preference measurement research by making it possible to mathematically calculate people's preference in decision-making. This method of Preference Function Modelling (PFM) has since served as a foundation for the application of PFM in different fields. In architecture, Binnekamp (2010) tested PFM in complex design problems which resulted in the Preference Based Design (PBD) method. In comparison to the evaluative PFM method, PBD is a design method that uses preference measurement to generate a new design. According to Binnekamp, this method can be used for design problems that require stakeholders to develop an artifact instead of evaluating existing designs. In further research by Arkesteijn (2019), preference measurement is used by stakeholders who are at the centre of finding the right accommodation strategy for an organization. The PBD method can be used for building designs or area development but was not developed for a CRE level. Arkesteijn therefore developed the Preference-based Accommodation Strategy (PAS), a design and decision-making tool that can be used to solve problems in CRE practise. The applicability is improved in PAS by the active use of preference curves which help stakeholders to define and adapt their preferences during the development of a CRE portfolio (Arkesteijn, 2019). For CRE managers this means that the manager or consultant takes a guiding role and facilitates the use of the model in the design and decision-making process. In other words, the role of the consultant changes to the role of a neutral facilitator ( Arkesteijn, 2022b). Involving stakeholders and their preferences in RE projects at early stages of design projects promises better decisions and less conflicts in complex construction projects. Using optimization in the design process can facilitate the decision process of these complex

projects (Zhilyaev et al., 2022). The purpose of this research is to test how CRE can become more sustainable based on the existing preference research in decision making. Therefore, the scientific relevance is to test the PAS design and decision-making approach for its applicability to make CRE more sustainable.

## 1.2. Definitions

In order to understand the following research, the terms *Sustainability, Corporate Real Estate Management, Decision making* and *Preference* require a clear definition.

### Sustainability

Sustainability is a widely used term, which for this research will be limited to environmental sustainability and measured in CO2 emissions (SDG Nederland, 2021). This measurement is also used by organizations to measure the environmental sustainability of their operations (Expert 3, personal communication, December 5, 2022). The Cambridge Dictionary defines environmental sustainability as follows: «the quality of causing little or no damage to the environment and therefore able to continue for a long time» (Cambridge Dictionary, n.d.-b). In other words, the lower the total greenhouse gas emissions of a building are, the more sustainable it is.

### Corporate Real Estate Management (CREM)

«Corporate real estate is the real property used by a company for its own operational purposes. It provides corporations with a productive environment to house employees, manufacture and distribute products and provide services to the market.» (CoreNet Global, n.d.) Therefore, Corporate real estate management (CREM) can be defined as the management of the real estate portfolio for an organization that does not mainly work in the real estate industry. The aim of CREM is that the RE should align with all aspects of the corporate strategy of the organization to support business operations and processes (Bon, 1992).

### Decision Makining

The dictionary defines decision-making as «the process of making choices, especially important choices» (Cambridge Dictionary, n.d.-a). In operation research, decision-making is described as the process of solving problems in a managerial context (Barendse et al., 2012).

### Preference

According to the Cambridge Dictionary, preference is «the fact of liking or wanting one thing more than another». This relates to Barzilai (2010), who describes that preference in a subjective variable synonymous to value, utility or choice.

## 1.3. Research Questions

The research questions consist of one main research question and six sub questions, which follow the five steps of operation research (Ackoff & Sasieni, 1968). The steps of operation research are numbered, while the corresponding research sub questions are lettered. The main research question is part of the first step of operation research.

1. Formulating the problem

Main research question: How can environmental sustainability be integrated in the decision-making of Corporate Real Estate Portfolios when using the Preference-based Accommodation Strategy?

   a. What is the state of the art in decision-making about environmentally sustainable CRE?
2. Setting a base line
   a. How do decision makers include environmental sustainability in the CREP when using PAS?
3. Making the model
   a. How can a reference model for PAS stimulate decisionmakers to choose criteria that lead to environmentally sustainably CREP?
4. Testing and evaluating the model
   a. How does the reference model change the decision outcome about CREPs?
   b. Do the decisions of the decision makers meet the sustainability goals of the Dutch government for 2050?
5. Implementing and maintaining the solution
   a. How can PAS and the reference model be implemented in future decision-making processes?

## 1.4. Research Method

To study the decision-making process for sustainable CRE, this thesis is based on operation research. The research method combines the Design Science Research Cycles by Hevner et al. (2004) and the five steps of Operation Research by Ackoff and Sasieni (1968). These two concepts are explained and followed by the elaboration on the research method of this thesis.

### 1.4.1. Operation Research and Design Science Research

This research uses operation research, in which "how to…" problems in decision making are solved by analysing them analytically and mathematically. This is done through a design process that results in a material or immaterial product contrarily to empirical research, which provides further knowledge on a topic (Barendse et al., 2012).

The Design Science Research Cycles are illustrated in detail in Figure 4. These cycles show that design problems are connected to their environment with the Relevance Cycle and to the Knowledge Base with the Rigor Cycle. The Design Cycle in the middle of the illustration can be described as the design process (Hevner, 2007). This thesis uses the Design Science Research Cycles and the research areas (Environment, Design Science Research and Knowledge Base) that are connected by the cycles to develop a Sustainability Reference Model (SuRMo).

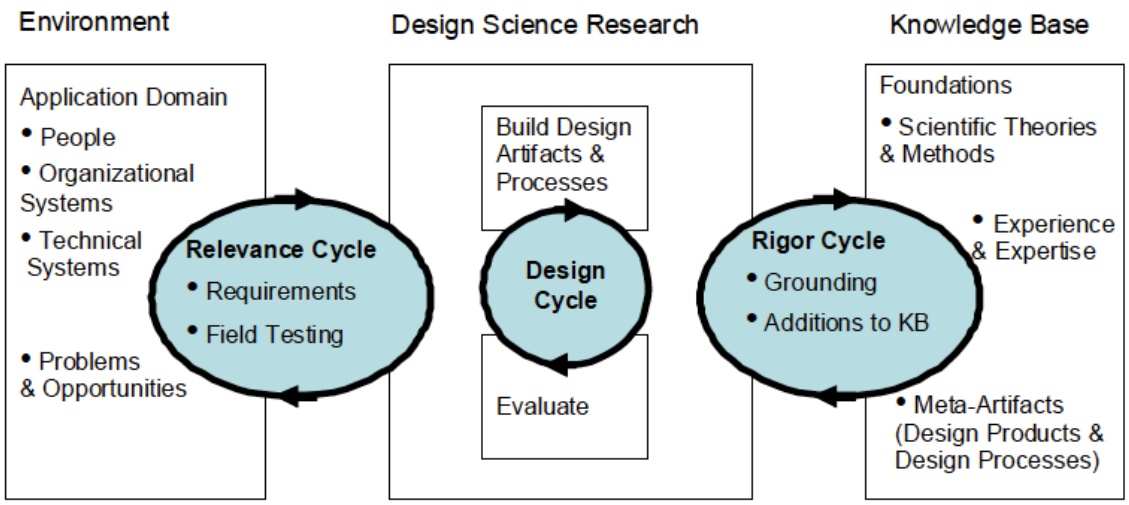



Figure 4 - The three design science research cycles (Hevner, 2007, p. 88)

The five steps of operation research were renamed (Figure 5) to better fit this research and to avoid confusion. Additionally, the numbering was removed in the research method to strengthen the iterative approach that this research used. The first step of operation research *Formulating the problem* was not changed. The second step was reformulated from *2. Constructing the model* to *Setting a base line*. It was renamed because Ackoff and Sasieni (1968) wrote a definition for the *model* and the *solution* that differs from the definitions in this thesis. In their context of operation research, the model represents "the system and its operations" of the research (Ackoff & Sasieni, 1968, p. 9). In this thesis, PAS is used (see Test 2) to model the current decision making process which sets a baseline for the development of the sustainability reference model. Ackoff & Sasieni further wrote that "Once the model is constructed, it can be used to find, exactly or approximately, the optimal values of the controlled variables –values that produce the best performance of the system for specified values of the uncontrolled variables; that is, we can

derive a solution to the problem from the model." (Ackoff & Sasieni, 1968, p. 9). However in this thesis, the solution to the problem is the sustainability reference model and it's applicability in decision-making about CRE. Therefore the third step of operation research was renamed from *3. Deriving the solution* to *Making the model*. The fourth step changed from *Testing the model and evaluating the solution* to *Testing and evaluating the model* and the last step remained unchanged.

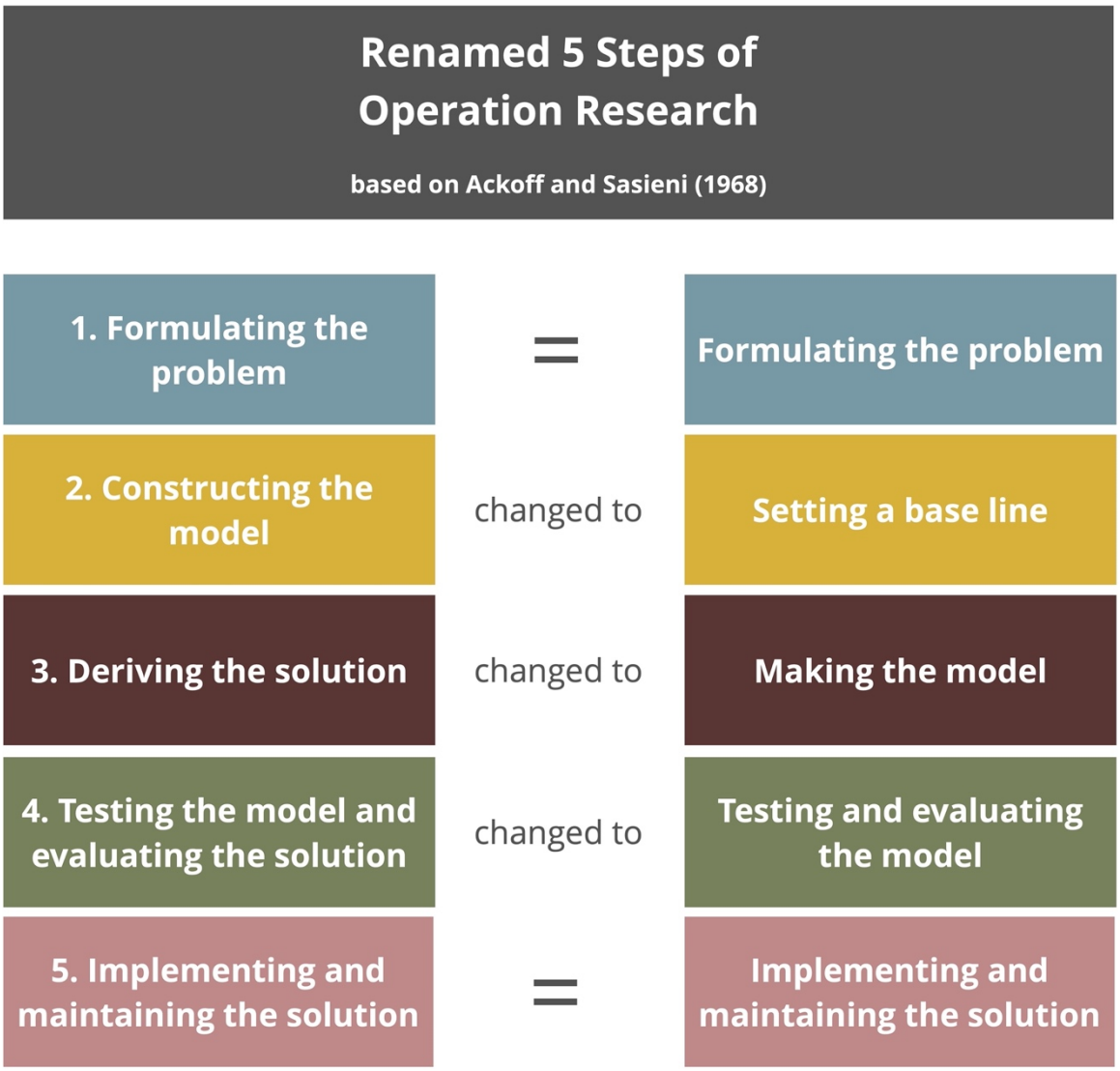



Figure 5 - The five steps of operation research renamed for this thesis (based on Ackoff and Sasieni (1968))

In the research method the steps of this research are horizontally grouped to three research areas of Hevner et al. (2004) and vertically attributed to the five steps of operation research (Ackoff & Sasieni, 1968). Figure 6 shows the research method as a flow chart of different steps.

1. The first chapter introduces the research.
2. In the first step, the main research question was formulated to structure and guide the research. The question was informed by the literature review, which identified a scientific gap in literature about environmental sustainability, CRE and decision-making. The main research question was also linked to the environment to determine whether the

requirements form practice differ from the scientific findings. Therefore, current decision-making was studied in a pilot study and the state of the art was studied in literature (Test 1).

3. In the second step of operation research, PAS was tested for its applicability as a possible solution to increase the importance of sustainability in decision-making on CRE. Test 2 was based on the research of Arkesteijn (2019) and performed during the pilot study.
4. Based on the findings from Test 1, 2 and literature about sustainable CRE, the SuRMo was developed to supplement PAS (Arkesteijn, 2019). The development of the SuRMo happened in an iterative process which connects the third step of operation research to the fourth step.
5. The SuRMo was tested with the stakeholders of the pilot study to find out if it adds value to the decision-making process compared to the use of PAS. In the fourth test, the decisions from Test 1-3 were compared to hard boundary conditions to check if they fulfill the Dutch sustainability goals for 2050.
6. In the last step of operation research, possibilities are explored to implement the research findings in practice. Additionally, the outcomes are linked back to the knowledge base to see to what extent the findings fill the research gap.

A pilot study was conducted to find similarities and differences in the importance of sustainability in the decision-making process separated in four tests:

- Test 1 studied the current approach of Colliers in selecting the new office space in Utrecht. This was studied during the first round of interviews with the four stakeholders.
- Test 2 used the PAS webtool by Arkesteijn (2019). This step consisted of the first round of interviews using PAS, followed by calculating the preference scores which were presented to the stakeholders during the presentation of Model 2.0.
- Test 3 consisted of PAS and the SuRMo 2.0. The SuRMo was presented to the stakeholders to see if they would change their input in the PAS webtool after newly gained information on sustainability.
- Test 4 compared the outcome of tests one to three to the sustainability goals of the United Nations for 2050.
- Validation: To validate and interpret the results from test one to four, two experts were interviewed.

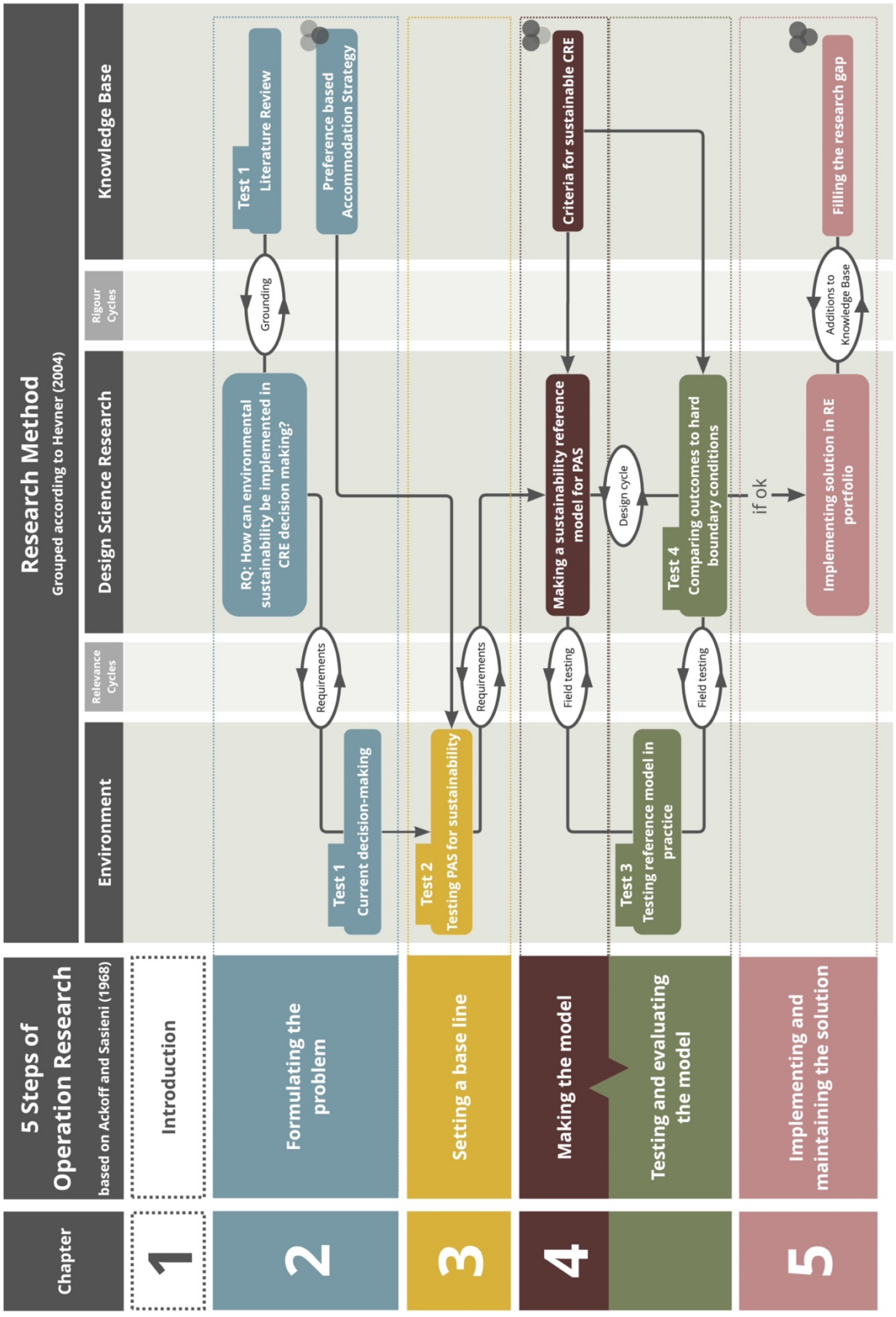



Figure 6 - Research method combining the three Design Science Research Cycles by Hevner (2004) and the 5 steps of Operation Research by Ackoff and Sasieni (1968) (own illustration)

Figure 7 shows that the research method is connected to the research questions from chapter 1.3. The main research question is the first step in formulating the problem based on the first sub question and the first findings form the pilot study. The second sub question is answered with the outcomes of Test 2. The third sub question is answered with the results of the SuRMo which is tested with the stakeholders of the pilot study in Test 3. The outcomes of Tests 1-3 are interpreted and checked using the sustainability goals of the Dutch government. The relevance of the findings is studied in the last sub question which links back to the main research question.

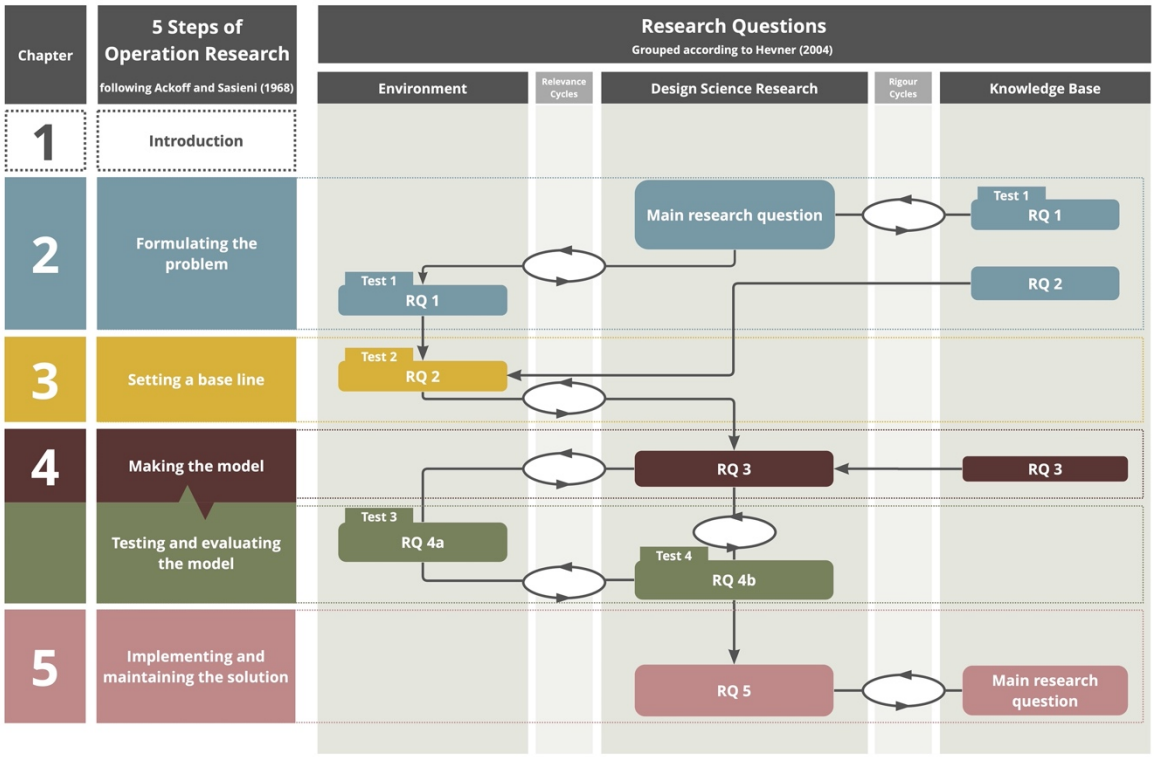



Figure 7 - Connection between the research method and the research questions (own illustration)

Figure 8 shows the four tests that were used to answer four of the six research sub questions. The four tests of this research were performed during a pilot study at Colliers, an international real estate consultancy company. Test 1 studied the current approach of Colliers to decision-making about buildings in their CREP. This was studied to compare the outcome with the performance of PAS and the SuRMo. The second test used the PAS design and decision approach to evaluate if the outcome of the decision changed compared to the current decision making approach of Colliers. Additionally, this test was used to set a baseline to compare Test 3 to. In the third test, the stakeholders were presented the SuRMo and asked if based on its information they wished to change their input in PAS. Test 3 was therefore the test of the Sustainability Reference Model that was developed alongside the four tests. The last test, Test 4, compared the outcome of the first three tests to the 2050 Dutch sustainability goals to see if the decisions match the bar of future regulations.

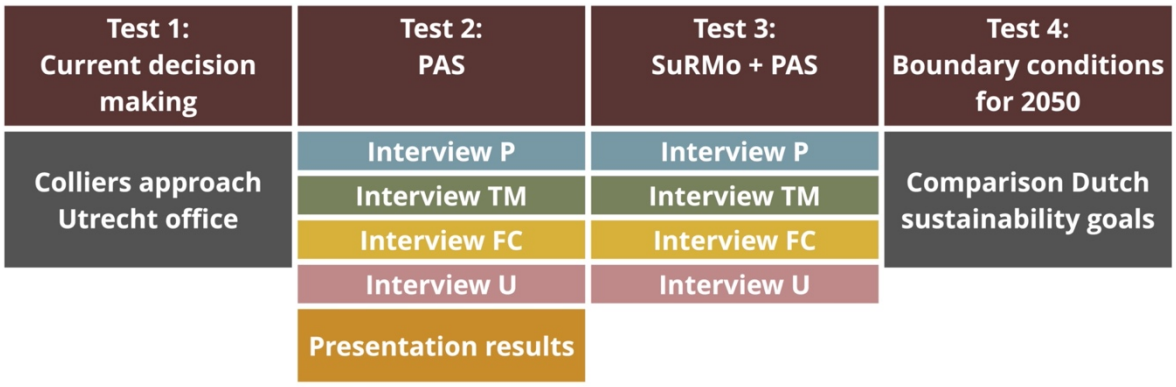



Figure 8 - Overview of the four tests (own illustration)

During the pilot study, four stakeholders of Colliers were interviewed twice individually. The first interview was used to ask them for input for the PAS. The outcomes of Test 2 were presented to the four stakeholders in a hybrid session. During the second interview, the interviewees were asked to evaluate their experience of Test 2 and react to the presentation of the SuRMo. Two experts were interviewed to validate the outcomes of the tests. Figure 9 shows different research steps and the input provided by the interviewees from the pilot study. The illustration shows that the two versions of SuRMo were developed parallel to the interviews and that Test 4 was not based on interview input. The interviews are labeled with a code in this report. The specifications of the interviews can be found in Appendix I: List of interviews.

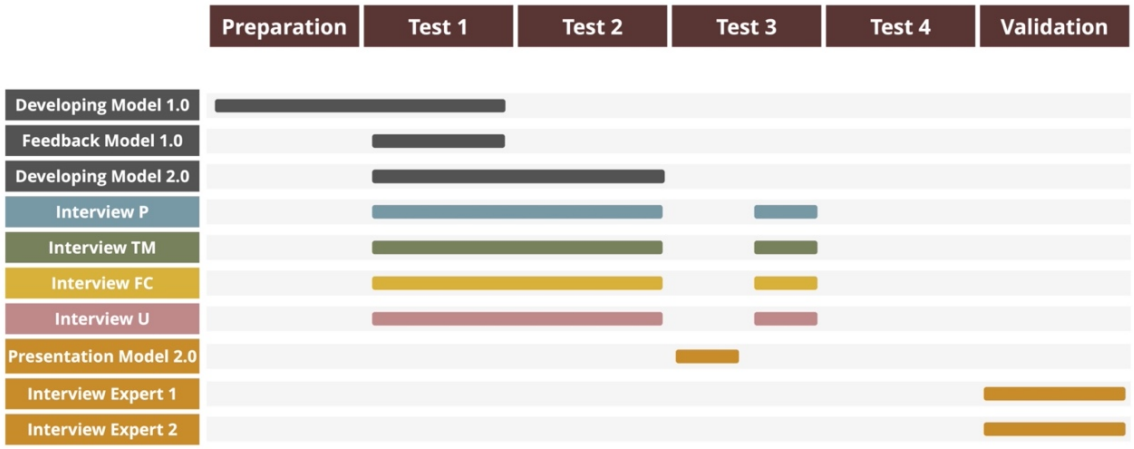



Figure 9 - illustration of pilot study input and research steps (own illustration)

### 1.4.2. Data Management

The data management plan was made using the questionnaire on the TU Delft website DMPonline (*DMPonline*, n.d.). This thesis is a collaboration with Colliers for a graduation internship of Olivia Wechsler (hereafter referred to as the author).

For this study, research papers were used from research databases on the internet in .pdf formats. They provided data for the literature research and theoretical background for developing the SuRMo. The files were stored on the TU Delft Onedrive and the personal computer of the author.

The Technical Manager of the pilot study provided building specifications as .xlsx files after the first interview. The data was used as input for PAS and saved on the TU Delft Onedrive and the personal computer of the author.

Interviews and presentations of the pilot study and expert consultations were recorded and saved as .mov and .mp4 files on the TU Delft Onedrive and the personal computer of the author. They were used for recollection of the work process and input in PAS. They will be saved and passed on to Monique Arkesteijn, supervisor of this thesis, for eventual further research.

The interviews provided input for the PAS webtool, which was used to do the tests of the pilot study. The data is stored in the PAS webtool and accessible by Monique Arkesteijn (supervisor), Mathida du Preez (postdoctoral researcher) and Gijs de Jong (webtool developer) for supervision and potential further research.

This research involved human subjects, but their personal data was neither relevant to the study nor used. The human participants were asked about their CRE portfolio from a professional perspective. This means that they answered the interview questions according to their role in the organization of the pilot study. The names of the participants are known to the author, supervisor, postdoctoral researcher and webtool developer.

The interviewees have been anonymized to publish the document in the TU Delft repository according to the wishes of Colliers. At the end of the research project the raw data will be shared with the thesis supervisor and the postdoctoral researcher.

# 2

# Formulating the Problem

# 2. Formulating the Problem

The second chapter explores the literature about sustainability, CRE and decision-making. Additionally, the pilot study is introduced and Test 1 is conducted to show the needs and requirements for the development of the sustainability reference model.

## 2.1. Literature Study on Sustainability, CRE and Decision-making

The literature study connects relevant literature about sustainability, CRE and decision-making. The purpose of the literature study was to identify the scientific problem that needed to be solved by the SuRMo. For that reason, the literature about sustainability and CRE was studied and connected to literature on decision-making. These findings were then reinforced by additional literature on decision-making which supports the making of the SuRMo in Figure 10.

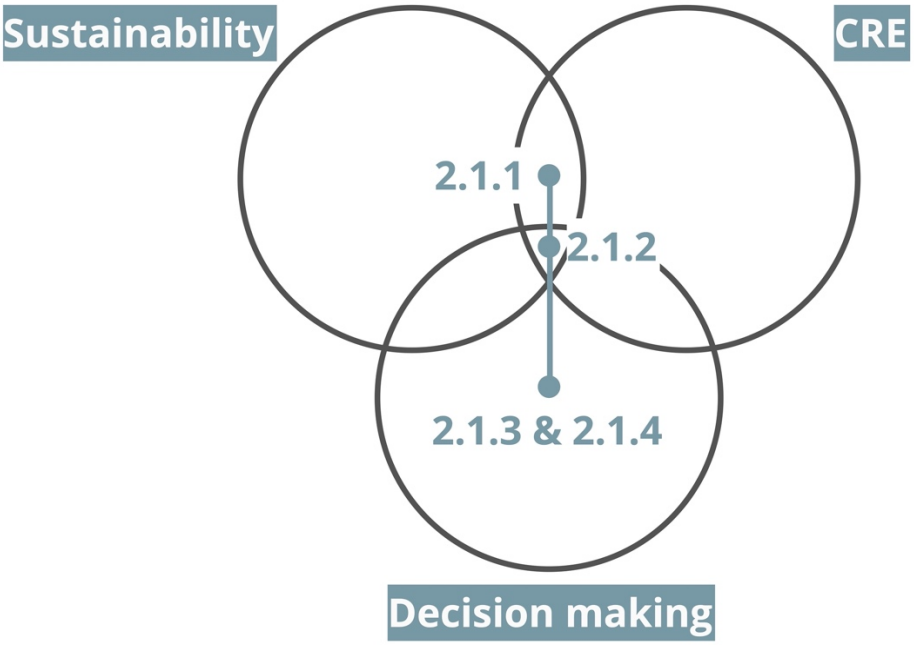



Figure 10 - Connection of key words in the literature study sub chapters (own illustration)

### 2.1.1. Sustainability in CRE

The national approach to reaching the goals of the Paris agreement of 2015 is to reduce the greenhouse gas emissions of the built environment by 18,2% (Klimaatakkoord, 2018). This sub chapter will highlight the current and future rules set by the Dutch government for organizations to reach those goals. Additionally, the current performance of CRE is analyzed.

Every few years, the Dutch government introduces stricter rules for organizations to make their CRE more sustainable. As stated on the website of the Rijksdienst voor Ondernemend Nederland, every office building needs to have an energy label C by January first of 2023. This means that the energy use of an office building cannot exceed 225 kWh per $m^2$ per year. If a building does not comply with this new rule, it becomes illegal to be used as an office space. However, for some cases exemptions exist. For example, in buildings where the office space covers less than half of the useable floor area (UFA), where the total UFA is less than $100m^2$, when the building is under monumental protection or when the office space will go out of use in less than two years (RVO, 2018b).

The energy label is an official and easy to follow indication of the energy performance of a building (RVO, n.d.). The best label a building can acquire is A+++++ and the worst is label G. The energy label also indicates the effectiveness of the insulation and installations for heating, electricity and ventilation. Therefore, the label shows the energy performance of the building and at the same time highlights the weak points that could be improved in the future (RVO, n.d.).

A report by the Colliers has analyzed the number of office buildings that currently adhere to the rules that will come into in (January 2023). The results show that only half of the office buildings meet the requirement of having an energy label C. Of those that do not meet the criteria yet, 38% still needs to get rated. According to the report, half the number of buildings that still need to be rated are expected to meet the goals because they were built after the year 1989 (Bloemers et al., 2021).

Another way to measure the environmental sustainability of buildings are Green Building Rating Systems (GBRS) which "[...] equipped designers and stakeholders with suitable advice schemes on performing sustainability in the various stages of building life span." (Ferrari et al., 2022, p. 1). As shown in Table 1 BREEAM is the oldest GBRS in Europe and to this day the most used in many European countries (Ferrari et al., 2022). Compared to LEED, CASBEE, DGNB, WELL and HQE, the BREEAM certification knows a Dutch version (Bernardi et al., 2017; Cole & Jose Valdebenito, 2013; van Eeckhoven, 2021). Additionally, the requirements are in the metric measurement system which makes the work of Dutch BREEAM experts less time consuming and therefore less expensive (van Eeckhoven, 2021). The popular use of BREEAM in the Netherlands makes it the preferable GBRS to use in the SuRMo.

In summary, the Dutch government sets high standards for sustainability in the built environment. The measurement thereof is based on reaching low yearly greenhouse gas emissions and should therefore be enriched by GBRS such as BREEAM to show a more complete picture of sustainability in CRE. Next, this research will be linked to decision-making.

| Green Building Rating Systems (GBRS) | Origin | Nr. of certifications | Year | Countries | NL version | Language | Measurement system |
|---|---|---|---|---|---|---|---|
| Building research establishment assessment method (BREEAM) | UK | >570'000 | 1992 | 85 | Yes (*;**;***) | NL (**) | Metric (**) |
| Leadership in energy and environmental design (LEED) | US | >69'066 | 1998 | 160 | No (*;**;***) | EN (**) | US (**) |
| Comprehensive assessment system for built environment efficiency (CASBEE) | Japan | 466 in Japan, international unknown | 2015 (international) | Unknown | | | |
| Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) | Germany | >5'000 | 2007 | 29 | | | |
| WELL | US | >454 | 2014 | Unknown | | | |
| Haute Qualité Environmentale (HQE) | FR | 380'000 | 1997 | Unknown | | | |

(Ferrari et al., 2022)
* (Cole & Jose Valdebenito, 2013)
** (van Eeckhoven, 2021)
*** (Bernardi et al., 2017)

Table 1 - Evaluation of GBRS (own illustration)

### 2.1.2. Decision-Making for Sustainable CRE

This subchapter addresses the current process of decision-making for sustainable CRE and the relation to the mismatch between supply and demand of office space. It highlights the motivations of the responsible stakeholders in decision-making for or against making CRE more sustainable and analyses the role of the users in sustainable CRE.

The circle of blame is a model which highlights the reasons why not more sustainable buildings are constructed and rented. It explains that the suppliers (RE developers and constructors) of sustainable buildings see no demand, whereas investors and occupiers lack sustainable options on the RE market to choose from (Keeping & Cadman, 2000). This mismatch between supply and demand exists for multiple building characteristics and often leads to structural vacancy. However, sustainability is not among the leading characteristics for structural office vacancy. Leading characteristics are tied to the location and the building with the six leading characteristics being a monofunctional location, lacking status and facilities of the location, bad design of the interior and exterior and lacking flexibility of the office layout. (Remøy, 2010). The two perspectives make it easy for each party to lay the responsibility on another party, which is why this circle needs to be interrupted to align supply and demand on the office market and to bring more sustainable buildings on the market. This separation of responsibility for sustainability in CRE shows that the decision-making process is currently often interrupted by blaming the problem on another party.

The motivation of making a building portfolio more sustainable can come from financial benefits, CRE alignment or Corporate Social Responsibility (CSR). When looking at organizations that have implemented sustainability in their CRE portfolio, lower cost of operation and productivity of the employees are the first two arguments and a positive corporate identity or brand is mentioned as a third argument (Khanna et al., 2013). To implement the corporate identity in the CRE, the values that organizations wish to reflect in their CRE are namely “sustainability, reliability, transparency, innovation and people oriented” (Khanna et al., 2013, p. 213). This argument is supported by Mansfield (2009) who writes, that the benefits of sustainable buildings are of both tangible and intangible nature. The tangible benefits relate to the valuation of RE and thus to the

measurable financial benefits that executives can take easy decisions over in the boardroom. On the other hand, the intangible benefits such as the quality of the workplace for employees, the culture of the company and the corporate identity are not taken into account in the valuation of RE. Mansfield (2009) argues that although these benefits have been identified the decisions are still made based on the valuation of RE. He adds that there needs to be a method that implements the intangible benefits in the valuation calculation to make sustainable RE more attractive for organizations because organizations still base their decisions on financial aspects. Contrarily to the argument of expanding the valuation method, other researchers argue that the assessment of RE needs to go beyond its valuation suggesting that corporate social responsibility (CSR) should be taken into account. This means that the definition of sustainability needs go beyond the environmental impact of a building. The same research proposes a new model that guides the decision making process in CRE by firstly mapping out all goals and operations of an organizations. In a second step, it shows the connectivity between the RE and the corporate strategy in regards to social aspects, the environmental and economic development. This means that implementing the CSR in the CRE portfolio will consequently bring changes to an organization as a whole and not only to the shell it operates in (Vieira de Castro et al., 2020).

Making buildings in a CRE more sustainable will affect its stakeholders acting in corporate practices depending on the industry of the organization (Masalskyte et al., 2014). The reason for these differences can be that changing a RE portfolio inevitably affects the organizations processes and operations (Vieira de Castro et al., 2020). However, these changes to an organization can also bring a competitive advantage as has been illustrated for international companies (Khanna et al., 2013). Another study of different organizations in the United Stated has shown that firms with a polluting core business feel higher “institutional pressure” to make sustainability a priority in their rented space. Additionally, firms working in the financial or legal industry have found sustainable office space to be beneficial to attract and retain skilled employees (Eichholtz et al., 2016). These different practices and motivations show that sustainable RE is often used to seek opportunities on top of current practices instead of minimizing risks (Masalskyte et al., 2014). The same study found that dialogue with stakeholders about their behaviour in buildings is one of the more sophisticated current CREM practices but proves to be very impactful if done correctly. Similarly, a study by Seyler & Mult (2019) shows that once occupants rent or own a sustainable building, their behaviour in it is crucial for the energy performance. Additionally, occupants have been observed to behave more environmentally friendly at home than at the office. To change this, a combination of education about environmental behaviour, training on mindfulness and monetary stimuli have proven to be the most effective measure (Seyler & Mutl, 2019). This argument is supported by research highlighting the need for better communication between tenants and land lords in sustainable buildings to maximise their energy performance (Livingstone & Ferm, 2017). These arguments all come down to the need for CRE managers to understand the users they work for in order to further align the RE to the corporate strategy (Seyler & Mutl, 2019).

In summary, the mismatch between supply and demand in the office market has also been identified for sustainable office buildings. Organizations see the benefits of renting sustainable office space but the way they include and weigh sustainability criteria in their decision-making process of CRE remains unclear. Decision-making based on stakeholder preference and especially PAS could provide a solution to this problem.

### 2.1.3. Decision-making using Preference Measurement

Preference measurement has been used in several studies on decision making in the built environment. In this section, Preference Function Modelling, Preference-Based Design, Multi-Stakeholder Design Optimization Methodology, Preference Based Portfolio Design and the Preference-based Accommodation Strategy are explained. Figure 11 illustrates how these five studies are linked to each other and to this research.

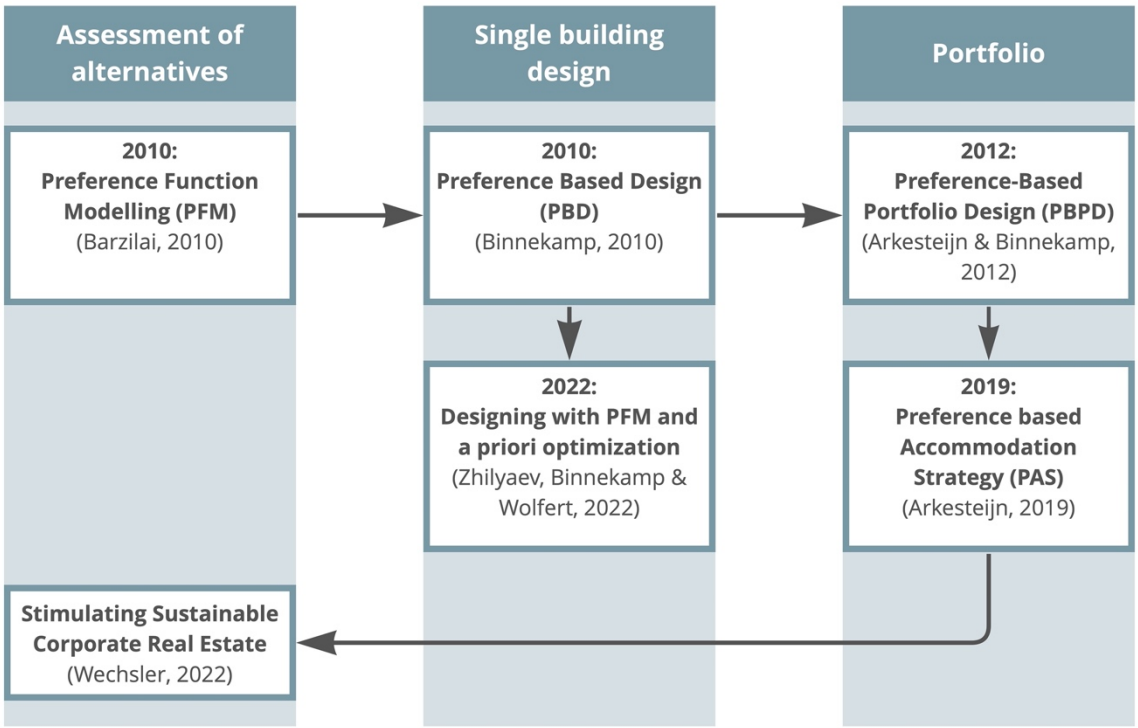



Figure 11 - Illustration of research on preference in decision-making (own illustration)

#### Preference Function Modelling

In his research about the mathematical groundwork behind decision theory, Barzilai (2010) re-shaped the theory behind Preference Function Modelling (PFM). According to his study, the foundations of previous research on decision theory were mathematically incorrect and were therefore adjusted. With this adjustment, t The main use of PFM is that it measures the subjective desirability of different options. “Preference, or value or utility, is not a physical property of the object being valued, that is, preference is a subjective, i.e. psychological, property.”(Barzilai, 2010, p. 58). According to his research, preference needs to be mathematically measurable with the main reason that “To enable the application of mathematical operations, the empirical objects are mapped to the mathematical object on which these operations are performed.” (Barzilai, 2010, p. 59). Figure 12 illustrates this mathematical correlation between empirical and mathematical objects. In the case of PFM, the empirical object is preference which is scaled by PFM and thus corresponds to the mathematical object which is the preference measurement score. This allows for different alternatives to be evaluated mathematically based on stakeholder preference and select the most suitable alternative (Barzilai, 2010).

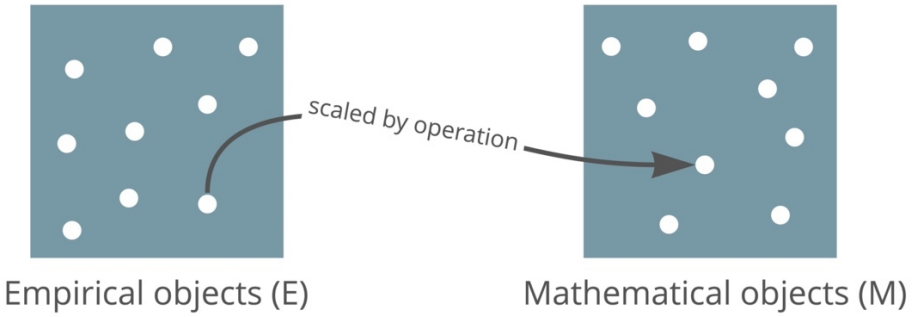



Figure 12 - Correlation between empirical objects (E) and mathematical objects (M) (own illustration based on (Arkesteijn & Binnekamp, 2022, p. 48))

### Preference-Based Design

Based on PFM, Binnekamp (2010) conducted research that links PFM to decision making in architecture by developing the PBD methodology. The main difference in the continuation from PFM to PBD is that in PBD, alternatives are not yet present but different choices in the design evolve during the design process. “The concept of PBD is to 1) use constraints for expressing each decision maker’s interests or criteria in terms of allowed decision variables value ranges and relationships between decision variables in order to define all feasible alternatives and 2) use PFM to select from these the alternative with the highest overall preference rating. A design alternative is then a combination of decision variable values and its feasibility is defined by the constraints.” (Binnekamp, 2010, p. 86). This concept of PBD has been tested in cases of architectural problems but still requires testing in real life projects (Arkesteijn, 2019; Zhilyaev et al., 2022).

### Multi-Stakeholder Design Optimization Methodology

The PBD methodology was the basis for further research on design and construction problems in architecture. PBD was linked to optimization using Matlab to program stakeholder preference prior to the finished design with “the main objective of developing a novel methodology for integrated stakeholder-oriented building design optimization that is based on an iterative a priori approach for finding the best-fitting design solution.”(Zhilyaev et al., 2022, p. 4). This study resulted in a “multi-criteria optimization and decision-making tool” (Zhilyaev et al., 2022, p. 15) that finds the optimal design to a design problem using the preference of multiple stakeholders. It enriches the design process because stakeholders can experience the design consequences of their preference directly which enriches group discussions and results in optimal designs (Zhilyaev et al., 2022)

### Preference-Based Portfolio Design (PBPD)

A study by Arkesteijn & Binnekamp (2012) converted the concept of PBD to be applicable on a portfolio level. Therefore, the concept had to result in multiple portfolio design alternatives. Additionally, the Lagrange preference curves were introduced because it’s equation can be based on three preference points . This concept created the basis for the PAS design and decision approach.

### Preference-based Accommodation Strategy (PAS) design and decision

The Preference based Accommodation Strategy (PAS) is a design and decision making method to strategically design CRE portfolios based on stakeholder preference. The goal is thereby to optimally align a CRE portfolio to the operations and strategies of an organization. The preference

of stakeholders is used as a starting point to find which design alternative results in a portfolio that adds the most value to the organization. All preferences to find the optimal portfolio are evaluated in the PAS design and decision room which follows a set of activities, six steps and models (Arkesteijn, 2019). Below, the activities are explained in the six steps and the model is introduced between Step 4 and 5.

Figure 13 illustrates the activities of PAS, the 6 steps that stakeholders go through and shows the models that are made by the facilitator and system engineer. The first four steps are completed in a first series of individual interviews with the stakeholders which provide the data for the first preference model.

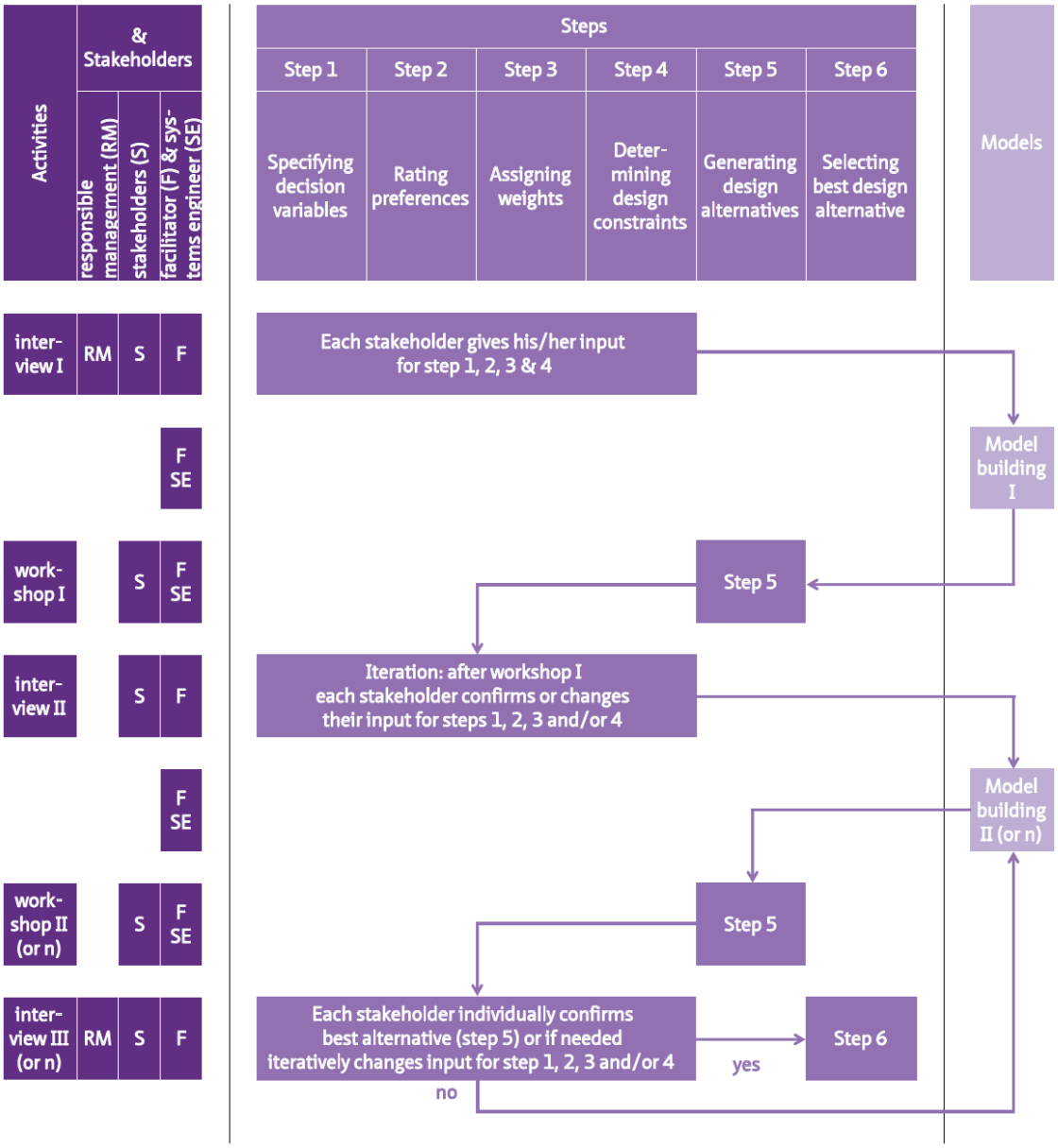



Figure 13 - PAS Flowchart (Arkesteijn 2019, p. 363)

***Step 1 Specifying decision variables:*** The first steps for the stakeholders is to define their decision variables based on their goals and problems with the current CREP. An design variable is defined as a design attribute whose value can be changed by stakeholders or external

influences. For example in regards to sustainability a design variable could be the energy use of a building. The design variable value could then be 100 if it is unit is kWh/m2. The number of decision variables is preferably not limited to allow the stakeholders to define their preference on as many decision variables as needed for an optimal CRE portfolio. Note that the more decision variables a stakeholder specifies, the more detailed the preference of alternatives can be measured but also the more complex the model becomes. Consequently, the time that it takes to complete the design and decision making process is dependent on the number and complexity of the decision variables resulting from step 1.

***Step 2 Rating preferences:*** In the second step, a stakeholder is asked about his or her preference on the set of decision variable values of the defined decision variables in Step 1. The decision variable value that represents the most preferred option is rated with a preference score of 100 (top reference) and the value that is least preferred is rated with a preference score of 0 (bottom reference). Additionally, the stakeholder can rate a value between the most and the least preferred one with a preference score between 0 and 100. Figure 14 shows the calculation which is used to calculate the gradient of the preference curve (Lagrange curve) based on the three defined points by the stakeholder. This results in a preference curve which is shown in Figure 15 based on the example from Step 1. Step 2 is repeated for every decision variable. If the stakeholder decides not to rate an intermediate decision variable value, the preference curve will result in a linear line between the top reference and the bottom reference.

$$P(x) = Min\left(100, Max\left(0, \left(\frac{(x-x_1)(x-x_2)}{(x_0-x_1)(x_0-x_2)}\right)*y_0 + \left(\frac{(x-x_0)(x-x_2)}{(x_1-x_0)(x_1-x_2)}\right)*y_1 + \left(\frac{(x-x_0)(x-x_1)}{(x_2-x_0)(x_2-x_1)}\right)*y_2\right)\right)$$

Figure 14 - Gradient of the preference curve (Lagrange curve) based on three points on the curve (Arkesteijn, 2019, p. 174)

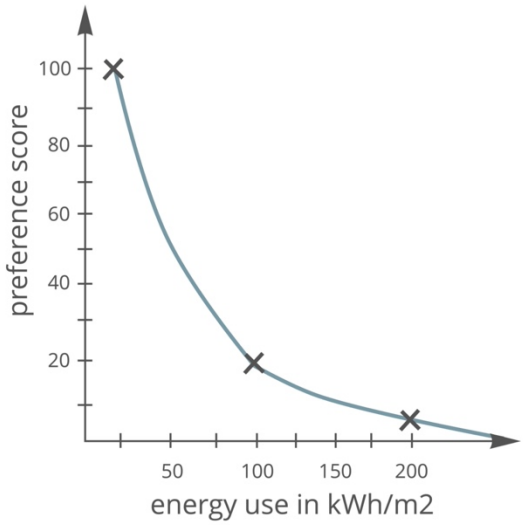



Figure 15 - Example preference curve based on Arkesteijn (2019)

***Step 3 assigning weights:*** In the third steps, weights are assigned to the goals and criteria by the stakeholders. Distributing the weights means that the total weight (100%) is split over the decision variables or stakeholders by means of importance. The weights of the stakeholders in the decision-making process are assigned by the responsible management in the set-up of PAS. These weights decide who has a more important say in the process than others. Alternatively, the stakeholders can transparently discuss about the weights in a plenary meeting or the weights can be attributed equally by default.

***Step 4 determining design constraints:*** The last step of the first set of interviews defines the constraints of the CRE portfolio. These constraints define if a design alternative is feasible or not feasible and can be set by stakeholders. This means that a maximum or a minimum can be attributed to one or more of the defined decision variables. To illustrate this with the previous example of the energy use decision variable, a constraint could be set at 150 kWh/m2 based on governmental sustainability regulations.

***Model building:*** The model is built by the facilitator and the systems engineer. Hereby the input form Step 1-4 and data of the CREP is used to mathematically determine the preference scores of the current CREP and alternatives that will be generated in Step 5.

***Step 5 generating design alternatives:*** The mathematical model is used in Step 5 which takes place during a workshop with the stakeholders. The goal of this workshop is to generate design alternatives which are essentially combinations of decision variable values. The alternatives can either be proposed by the stakeholders or by the systems engineer using for example the multi-criteria optimization and decision-making tool by Zhilyaev et al. (2022). These alternatives are rated with an overall preference score based on the given preferences in Steps 1-4. Based on the results of the first workshop and the resulting design alternative, the stakeholders are asked to revaluate their input from Step 1-4 which will be updated in the model until the stakeholders are content with the result with the highest preference score.

***Step 6 selecting best design alternative:*** Once the iterative process of Step 1-5 is completed, the stakeholders confirm the best design alternative. This result will then be defined as the optimal design for the CRE portfolio based on stakeholder preference (Arkesteijn, 2019).

### 2.1.4. Reference Models in Decision-making

Reference Models in CRE help stakeholders in the alignment of their CRE to their corporate strategies. (Arkesteijn, 2019) After describing the PAS method, Arkesteijn (2019) mentions that in further research, PAS could be supplemented with reference models. For PAS the aim of the reference model is that users in the design and decision-making process can access state of the art advice on a topic and therefore be able to choose decision variables in an informed manner (Figure 16).

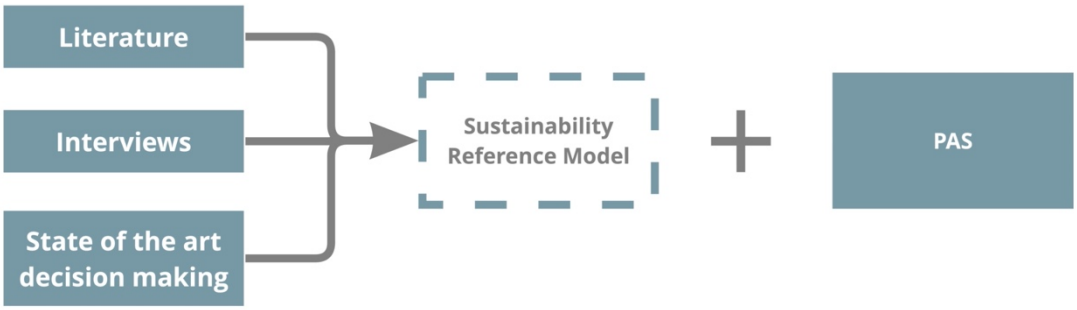



Figure 16 - Input and use of the reference model based on Arkesteijn (2019)I

De Leeuw (2002) finds that reference models are used when diagnosing a situation in a decision making process. Such a diagnosis in management and decision-making entails all activities aimed to reach a clear starting point to change a certain situation and to search for solutions. To formulate a diagnosis, one can use reference models and the diagnosis can be specific or general. For both diagnoses, de Leeuw (2002) describes that there are implicit and explicit reference models. An implicit model is based on the judgment of stakeholders involved in the decision making. These judgements are highly subjective and dependent on the situation which makes an implicit model very goal oriented. An explicit model on the other hand can operationalise a goal or show features that are relevant for reaching a goal. This makes that an explicit reference model could also be called a performance measurement system. Examples of explicit reference models often resemble each other because strategic goals are defined by stakeholders before determining the criteria with witch the performance of the goals is measured (de Leeuw, 2002).

Benchmarking can be seen as a comparative reference model because it compares performance with a reference group of organizations that is aspirational (de Leeuw, 2002). In essence the Green Building Rating Systems and benchmarks relate to this because the goals from the GBRS can be seen as the reference model while benchmarks relate to the score of the GBRS. The benchmark more specifically then relates to the score of best performing buildings measured by a GBRS.

For more complex decisions Bonarini & Maniezzo (1991) describe that Decision – support Systems have been used since the 1960s. “Their aim was to provide management with support enabling them to use a large and wide set of information to take decisions.” (Bonarini & Maniezzo, 1991, p. 172). Management can be confronted with two types of decisions: structured, meaning recurring decisions and unstructured decisions which are new to the management. Both require different support (Gorry & Morton, 1971). A CREP decision would fall under the unstructured decision category which can imply that more support is needed in the decision-making process. This extra support can come in the form of Expert Systems which transfer knowledge from experts to computers and can reach conclusions of complex problems. These Expert Systems can benefit from a connection to Artificial Intelligence (Liao, 2005). Kmiecik (2018) developed an expert tool for multi-criteria decision analysis such as PAS that was based on an expert system for CRE (re)location decisions. She uses state of the art knowledge from literature and inserted the information in an expert system which is a computer program. Expert systems have shown to support group decisions-making by increasing efficiency and quality of group communication (Aiken et al., 1991). The problem of this thesis can be identified as a specific diagnosis (the

environmental sustainability of an organizations CRE) for which an explicit reference model can be used. Within the scope of this research, the problem was solved with a reference model and not a reference system.

One reference model has already been used and tested with PAS which is based on a stakeholder model. The 'Den Heijer Variable Check' is a reference model that was developed in Excel based on the stakeholder model of den Heijer (2011). The reference model consists of three steps in which the stakeholders selected performance criteria, a RE goal and key performance indicators related to the goal (Arkesteijn, 2019). In the methodology of PAS, Arkesteijn describes that "The stakeholders can use a reference model to determine relevant decision variables for the objectives they have. By using such a reference model, they benefit from existing knowledge. However, they are free to choose which reference model to use and which decision variables they find useful for their particular situation and problem." (2019, p. 332).

In this research, state of the art knowledge was used in the reference model which allowed criteria and findings from the knowledge base and the environment to be implemented in real life cases (Arkesteijn, 2019). As recommended by Arkesteijn (2019) and shown in (Figure 17), the model was made for stakeholders to use before they define the decision variables in PAS). The four stakeholders (P, FC, U and TM) used the reference model in Test 3 as a supplement to PAS. This then resulted in the preference curves and preference scores of the three alternative office buildings in the pilot study.

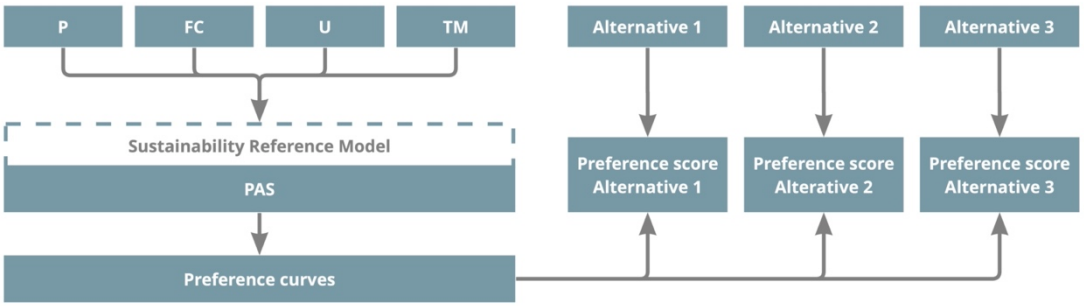



Figure 17 - Use of reference models as suggested by Arkesteijn (2019)

## 2.2. Pilot Study

The SuRMo was developed during a graduation internship at Colliers which is the organization or which a decision-making problem was used for this pilot study. Colliers is an international real estate consultant company operating with 17'000 employees in 62 countries (Colliers, 2021). This study was conducted with the Dutch branch of Colliers, counting 327 employees and four offices in April 2022 (M. ten Hoopen, personal communication, April 7, 2022). In this pilot, several stakeholders were interviewed using the PAS as assessment tool and the SuRMo to study the decision-making process regarding a new office location in Utrecht.

### 2.2.1. Stakeholders

The pilot study included four stakeholders which were selected by the CRE manager of Colliers, who was the thesis supervisor for this research project. The stakeholder selection was made using the four perspectives of Den Heijer (2011) to visually match with previous research such as the development of PAS (Arkesteijn, 2019). These four perspectives are also used in the PAS webtool (Arkesteijn, 2022a). The stakeholders and their qualifications for participating in this study are mentioned in this chapter.


Figure 18 - Stakeholder categorization based on den Heijer (2011)

The four stakeholders as shown in Figure 18 are involved in the selection of the office location in Utrecht and were therefore interviewed for the tests of this pilot study.

- Policy: The Director Corporate Real Estate Solutions of Colliers develops CRE strategies for clients and for Colliers itself (P1, personal communication, February 16, 2022). She was therefore well informed about the CRE strategy for the policy perspective.
- Financial Controller: The Chief Operating Officer (COO) is the board member of Colliers who is responsible for the financial feasibility of the project. As the board member he

takes the final decision which is presented to the board of Colliers Europe, Middle East and Africa (FC1, personal communication, March 22, 2022). For PAS, this function makes him the subject owner (Arkesteijn, 2019).

- User: A Senior Valuer was chosen to represent the perspective of the employees of Colliers. He was the former chairman of the employees council in which he has represented his colleagues in multiple situations such as moving to new office buildings and new pension regulations (U1, personal communication, March 23, 2022).
- Technical Manager: The Director Agency & Business Development Offices of Colliers was selected for his position as director of the Den Bosch office which will move to the new Utrecht office. He was responsible for the search of the new office space in Utrecht and will also lead the move (TM1, personal communication, March 21, 2022).

In the first interview, the Financial Controller was asked to distribute the weights of the stakeholders in the decision-making process of this pilot study. He mentioned that he is responsible for the final decision but that his decision would be influenced by the other stakeholders by 50% (FC1, personal communication, March 22, 2022). Figure 19 illustrates the total weight distribution over the stakeholders.

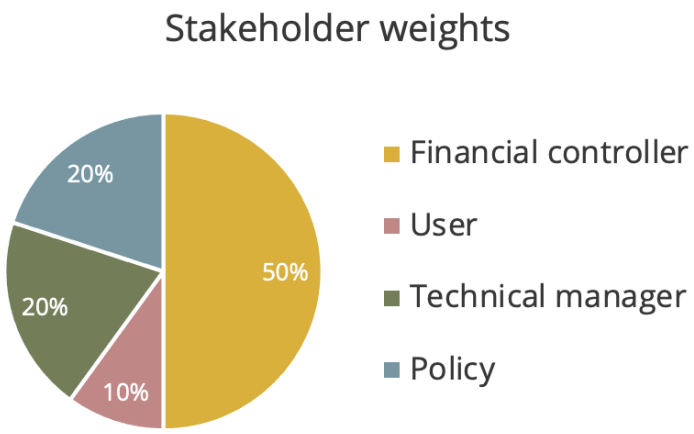
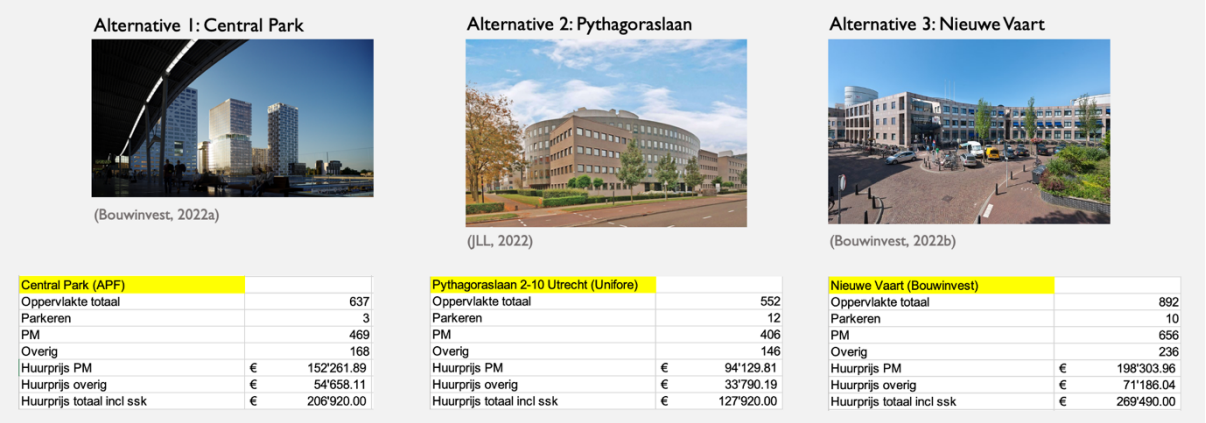



Figure 19 - Stakeholder weights (own illustration)(FC1, personal communication, March 22, 2022)

### 2.2.2. Finding a new office location in Utrecht

The decision that was studied for this research was the selection of the new Colliers office in Utrecht. The context of the decision was studied and the approach taken is illustrated in this sub chapter.

Prior to the pilot study, the new office had already been selected but not yet approved by the EMEA (Europe, Middle East and Africa) board, and the lease agreement was yet to be signed (FC1, personal communication, March 22, 2022). As decided by the Dutch board, the new office will be located in the Central Park building in Utrecht. Figure 20 shows the images and numbers of the three alternatives that were considered. The pilot study was conducted to reevaluate the decision and made it possible to study and compare the current approach to the outcomes with PAS and the SuRMo.




| Central Park (APF) | |
|---|---|
| Oppervlakte totaal | 637 |
| Parkeren | 3 |
| PM | 469 |
| Overig | 168 |
| Huurprijs PM | € 152'261.89 |
| Huurprijs overig | € 54'658.11 |
| Huurprijs totaal incl ssk | € 206'920.00 |

| Pythagoraslaan 2-10 Utrecht (Unifore) | |
|---|---|
| Oppervlakte totaal | 552 |
| Parkeren | 12 |
| PM | 406 |
| Overig | 146 |
| Huurprijs PM | € 94'129.81 |
| Huurprijs overig | € 33'790.19 |
| Huurprijs totaal incl ssk | € 127'920.00 |

| Nieuwe Vaart (Bouwinvest) | |
|---|---|
| Oppervlakte totaal | 892 |
| Parkeren | 10 |
| PM | 656 |
| Overig | 236 |
| Huurprijs PM | € 198'303.96 |
| Huurprijs overig | € 71'186.04 |
| Huurprijs totaal incl ssk | € 269'490.00 |

Figure 20 - The three alternatives for the new Colliers office in Utrecht (Bouwinvest, 2022a, 2022b; JLL, 2022)

In 2021, the availability of office space in the center of Utrecht was low with 6%. However, “Extensive construction activity around the Central Railway Station and in the Utrecht Science Park on the outskirts of the city brought considerable space to the Utrecht market.” (NL Real Estate & Knight Frank, 2021, p. 5).

The aim of the pilot study was to find similarities and differences in the importance of sustainability in the decision-making process. To analyze this, the pilot study was separated in four tests which are again explained below and illustrated in Figure 21.

- **Test 1** studied the current approach of Colliers in selecting the new office space in Utrecht. This was studied during the first round of interviews with the four stakeholders.
- **Test 2** used the PAS webtool by Arkesteijn (2019). This step consisted of the first round of interviews using PAS, followed by calculating the preference scores which were presented to the stakeholders during the presentation of Model 2.0.
- **Test 3** consisted of PAS and the SuRMo 2.0. The SuRMo was presented to the stakeholders to see if they would change their input in the PAS webtool after newly gained information on sustainability.
- **Test 4** compared the outcome of tests one to three to the sustainability goals of the United Nations for 2050.

- **Validation:** To validate and interpret the results from test one to four, two experts were interviewed.

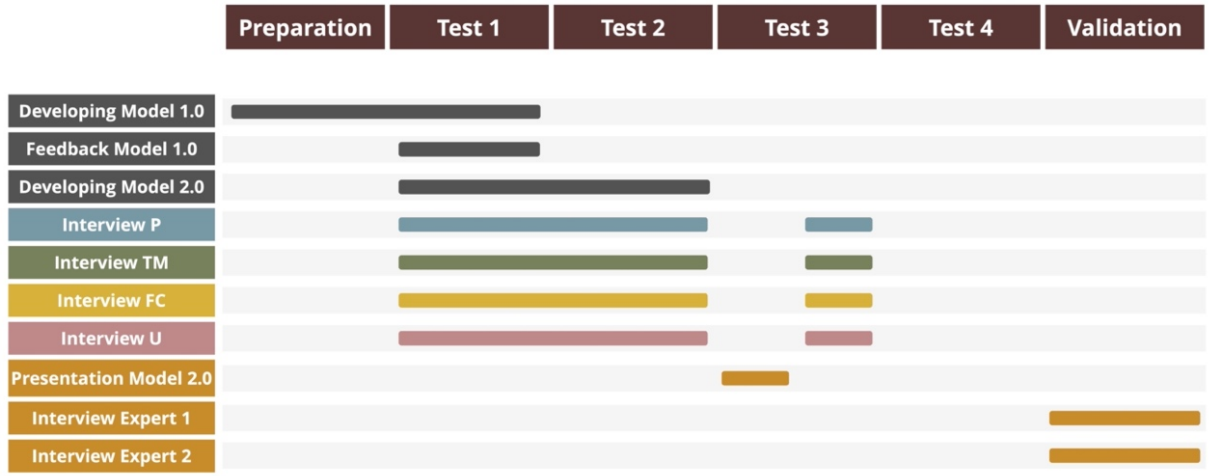



Figure 21 - Illustration of pilot study steps and Tests (own illustration)

Figure 21 shows the interviews that were used for the different tests. During the preparation phase, the first version of the SuRMo was developed. The first interviews were structured by the PAS webtool which provided the input for test two. However, these interviews also provided additional information for test one. Test three consisted of five meetings with the stakeholders. In the presentation of Model 2.0, the outcomes of the stakeholder input from PAS were presented with a focus on their sustainability criteria. The Model 2.0 was then presented to the stakeholders with the invitation to reconsider their input in the PAS webtool. The second round of interviews delivered the remaining data for test three in which the stakeholders evaluated their experience with PAS and the SuRMo. Test number four did not require any interviews with the stakeholders. Lastly, the outcomes of test one to four were discussed with two experts for data validation. Figure 22 shows the sequence of all interviews and presentations as communicated with the stakeholders.

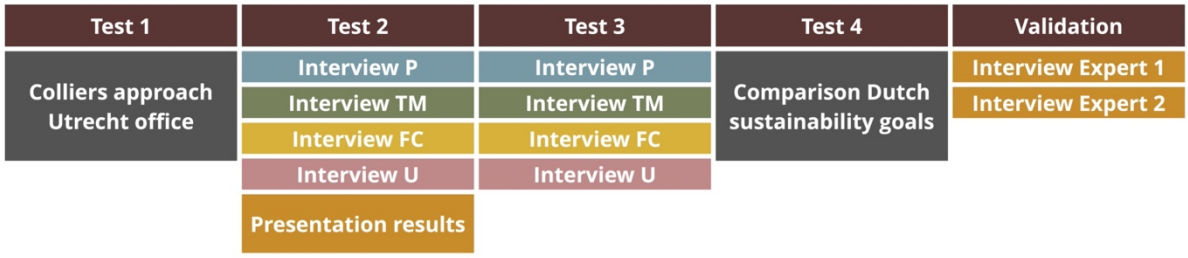



Figure 22 - Sources to conduct the tests and validation (own illustration)

## 2.3. Test 1: Current Approach

In order to study if using PAS and the SuRMo leads to more sustainable decisions in CREPs, the current decision-making approach was evaluated. There was no clear protocol from Colliers which is why information had to be gathered from multiple stakeholders and employees.

***"te huur en niet te duur" – TM***

The quote of the TM partly illustrates the decision making process: "to rent and not too expensive" (TM1, personal communication, March 21, 2022). This quote was referred to in a joking manner but as the FC explained the actual decision-making it appeared that the saying is not very far from the truth. This approach is not uncommon as the following quote shows: "Approaches without an explicit reference model all essentially consist of ways to get stakeholders (shareholders, other stakeholders, problem owners) to make judgments without naming in advance the aspects that are supposed to be judged." (de Leeuw, 2002, p. 305). The selection for possible office buildings in Utrecht was very limited because of the scarce market. Originally it was an idea to work with a flex office provider but needing space for more that 35 permanent employees made this idea disappear. The basis for the decision about the new office was limited to the numbers in the tables of Figure 20. This means that the decision was mainly taken based on the available area and the cost (TM1, personal communication, March 21, 2022). The decision-making process of Colliers was implicit, meaning that many criteria influenced the outcome but these criteria and boundary conditions could not all be explicitly named. For example, Figure 23 shows the data that Colliers collected on the different alternatives but the energy label did also play a role in the decision-making. The remaining data was collected via the real estate agent or the internet and not explicitly added to the list of data.


| Central Park (APF) | |
|---|---|
| Oppervlakte totaal | 637 |
| Parkeren | 3 |
| PM | 469 |
| Overig | 168 |
| Huurprijs PM | € 152'261.89 |
| Huurprijs overig | € 54'658.11 |
| Huurprijs totaal incl ssk | € 206'920.00 |

| Pythagoraslaan 2-10 Utrecht (Unifore) | |
|---|---|
| Oppervlakte totaal | 552 |
| Parkeren | 12 |
| PM | 406 |
| Overig | 146 |
| Huurprijs PM | € 94'129.81 |
| Huurprijs overig | € 33'790.19 |
| Huurprijs totaal incl ssk | € 127'920.00 |

| Nieuwe Vaart (Bouwinvest) | |
|---|---|
| Oppervlakte totaal | 892 |
| Parkeren | 10 |
| PM | 656 |
| Overig | 236 |
| Huurprijs PM | € 198'303.96 |
| Huurprijs overig | € 71'186.04 |
| Huurprijs totaal incl ssk | € 269'490.00 |

Figure 23 - The three alternatives for the new Colliers office in Utrecht (Bouwinvest, 2022a, 2022b; JLL, 2022)

The process of finding a temporary office in den Bosch was described by the FC and followed exclusion criteria in the order from top to bottom (Table 2).

| Requirement or criterion? | Criterion | Consequence for decision |
|---|---|---|
| Boundary condition 1 | Location: Den Bosch | 10 offices available |
| Boundary condition 2 | Required $m^2$ | |

| | | |
|---|---|---|
| *Nice to have* 1 | Proximity to public transport | Not possible with available budget |
| Boundary condition 3 | Financial goals | Little budget means location in outskirts of Den Bosch |
| Nice to have 2 | Energy label A | Label B also acceptable because the office will only be used for two years |

Table 2 - Current approach for Colliers office in Den Bosch

The criteria for the office in Den Bosch resulted in a decision that was made based on the number of square meters for the set price as can be seen in the column consequence for decision of the table above. In terms of sustainability Colliers measures sustainability in their CO2 footprint. Thereby a separation is made between gas use and electricity use (Expert 3, personal communication, December 5, 2022).

# 3

# Setting a base line

# 3. Setting the base line

This chapter studies the decision making with PAS to later compare the use of PAS and SuRMo to.

## 3.1. Test 2: Decision Making with PAS

For Test 2, PAS by Arkesteijn (2019) was used as an assessment tool in the decision-making process of the new office building. The nature of the problem and the limited time of the stakeholders made it more favorable to use PAS to assess the three alternatives than to come up with a CRE strategy using PAS as design and decision room. In the first part of Test 2, the interviews with the four stakeholders were conducted. In the second part, the input of the stakeholders and information on the three alternatives was used to calculate the preference scores of the alternatives. The outcome of the calculations was then presented to the stakeholders in a hybrid session.

### 3.1.1. Interviews

The interviews were conducted with two interviewers and one interviewee at a time using the PAS webtool (Arkesteijn, 2022a). One interviewer (Olivia Wechsler) led the interviews while the second interviewer (Mathilda du Preez) inserted the information from the interview into the PAS webtool. The screen of the second interviewer was shared during the session for the interviewee to confirm the input in the PAS webtool. All inputs from the interviews can be found in appendices I-IV.

The interviewees were first asked about their goals for the new office building in Utrecht. For each goal, they were then asked to define criteria for achieving these goals, a unit and a formula to know how they would measure the criteria. For example, as Figure 27 shows, the Policy stakeholder defined a first criterion: “Accommodation should fit into the 2030 sustainability goals”. This would be measured in the “% of reduction in CO2” of the total footprint of Colliers in 2020 (P1, personal communication, February 16, 2022).

Based on that input, the interviewee was asked to pair preference scores of 0, 100 and a score in between to a decision variable value (Figure 24). The preference score 0 is paired with a value that the stakeholder would be “absolutely not” content with, while a preference score 100 should be paired with a value that the stakeholder would like most. The PAS webtool immediately showed the preference curve of the stakeholder input.

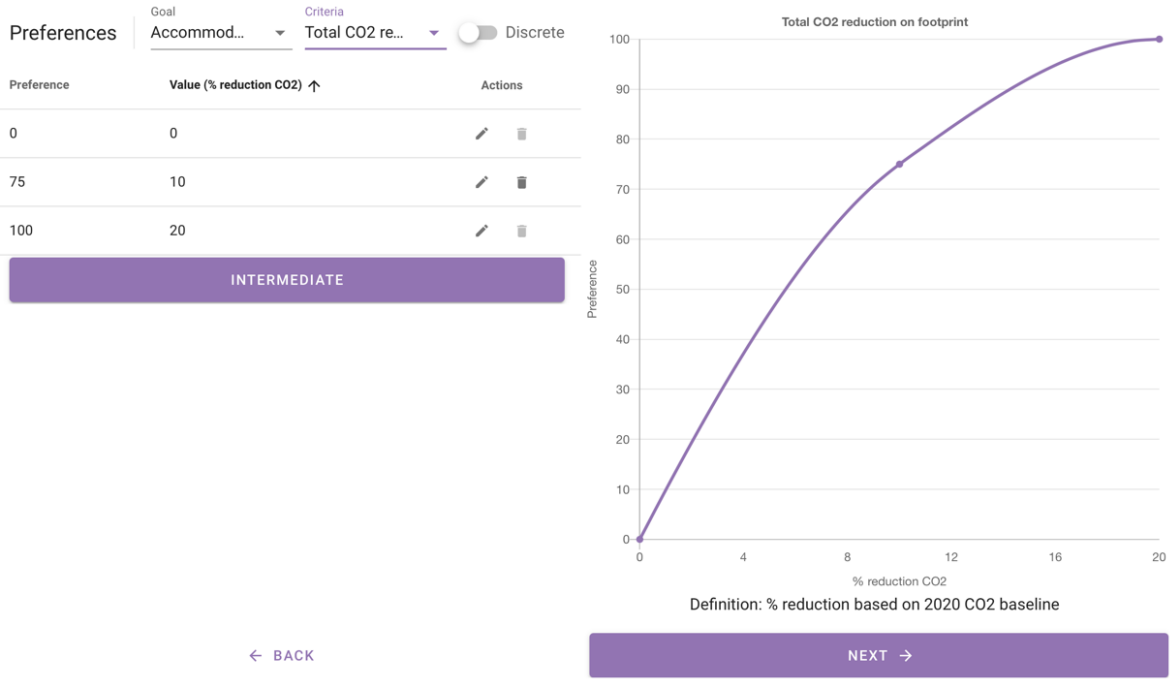



Figure 24 - Preference of criterion 1.1 of P (P1, personal communication, February 16, 2022)

Once the goals and criteria were defined, the stakeholder was asked to distribute the weights over the goals and criteria. For example, the first goal of the policy stakeholder was weighted with 25% and the first criterion within the criteria of goal one was weighted with 40%. This resulted in a relative weight of 10% for criteria 1.1(Figure 25) (P1, personal communication, February 16, 2022)

Weights — Filter OPS

| Goal | Weight per goal | Criteria | Weight per goal per criterion | Relative weight |
|---|---|---|---|---|
| 1. Accommodation should fit into the 2030 sustainability goals | 25% | 1.1 Total CO2 reduction on footprint | 40% | 10% |
| | | 1.2 Energy efficient building | 30% | 8% |
| | | 1.3 WELL score | 30% | 8% |
| 2. Do something different (location and inspirational) | 40% | 2.1 Multifunctionality of the area (Grocery stores/restaurants/meeting space) | 40% | 16% |
| | | 2.2 CBD location/live and work balance | 40% | 16% |
| | | 2.3 Catering/Restaurant space allocation on ground floor | 20% | 8% |
| 3. Permission to erect signage on the building | 5% | 3.1 Permission to erect signage | 100% | 5% |
| 4. Should facilitate co-working and meeting place in both the company and beyond | 30% | 4.1 Transport accessibility by train | 40% | 12% |
| | | 4.2 All square meterage (office) should be on the same floor | 30% | 9% |
| | | 4.3 Transport accessibility by car | 20% | 6% |
| | | 4.4 Transport accessibility (parking within walking distance) | 10% | 3% |
| | 100% | | | 100% |

Figure 25 - Attributed weights by P (P1, personal communication, February 16, 2022)

In the last part of the interview, the stakeholder was asked to define boundary conditions which, in their opinion, would make an alternative unfeasible. Figure 26 shows the three boundary conditions mentioned by the Policy stakeholder. They showed that the office space should not be spread over more than two floors, the building should not stand on a greenfield (see chapter Test 3: Sustainability Reference Model for PAS for the adaptation) and that the other parties in the buildings should not be real estate agents.

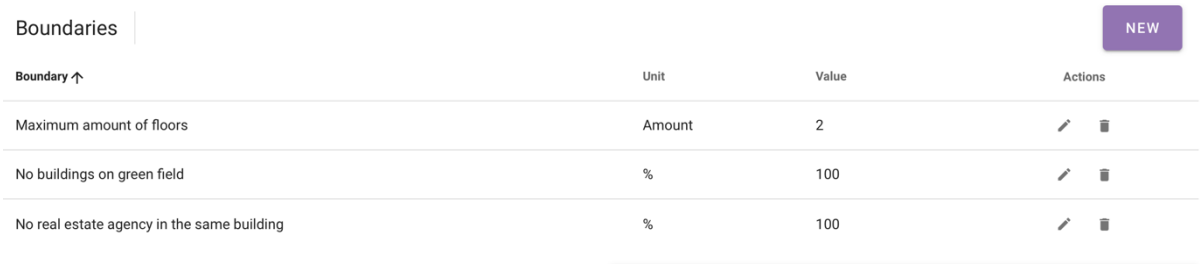



Figure 26 - Boundary conditions defined by P (P1, personal communication, February 16, 2022)

It must be noted that the preference curves in the PAS webtool are PCHIP curves which differ from the Lagrange curve formula used to calculate the preference scores of the three alternatives.

## Calculation of preference scores

The preference scores of the three alternatives were calculated in six steps:

1. **Transfer input PAS webtool to Excel:** To facilitate the calculations, the input from the first four stakeholder interviews was transferred to an excel sheet.
2. **Relative criteria weights overall**: The relative weights per stakeholder were compared to the stakeholder weight and translated to relative overall weight. For example the criterion "Total CO2 reduction on footprint" was attributed a weight of 40% within the overarching goal (P1, personal communication, February 16, 2022). With the stakeholder having a weight of 20%, the relative weight overall resulted in 2% (Figure 27)

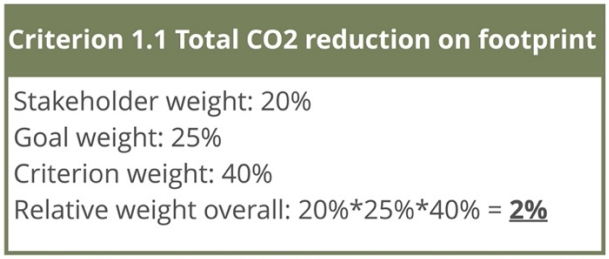



Figure 27 - Example of goal 1, criterion 1 by the policy maker (own illustration)

3. **Decision variable values of alternatives:** For each criterion, the decision variable value of alternative one, two and three were researched. Some of the criterions form the stakeholders were not measurable because data on alternatives was missing. For example, none of the three alternatives has a WELL certification, which the Policy stakeholder mentioned as criterion (P1, personal communication, February 16, 2022). In the cases with lacking information, a preference score 0 was attributed because any building with a WELL score would be preferred over the building without a score.
4. **Calculating preference scores**: In a second Excel sheet the values of the alternatives were mathematically compared to the preference scores that the stakeholders defined. This was done using the Lagrange formula (Equation 1)

$$P(x) = Min\left(100, Max\left(0, \left(\frac{(x-x_1)(x-x_2)}{(x_0-x_1)(x_0-x_2)}\right)*y_0 + \left(\frac{(x-x_0)(x-x_2)}{(x_1-x_0)(x_1-x_2)}\right)*y_1 + \left(\frac{(x-x_0)(x-x_1)}{(x_2-x_0)(x_2-x_1)}\right)*y_2\right)\right)$$

Equation 1 - Formula for a Lagrange curve with values between 0 and 100 (Arkesteijn, 2019, p. 174)

Table 3 shows the calculated preference scores that the four stakeholders have given the three alternatives per category. The table shows that not all stakeholders have defined criteria and therefore preferences for all categories. Only the FC has defined criteria in all categories, which can be explained by the fact that he is the one that has taken the decision for the office building at Colliers and therefore has thought about the office space before.

| | Stakeholder weights | | Score sustainability | Score Location | Score Office space | Score Parking | Score Appearance | Score Financial feasibility | Preference score per stakeholder per alternative |
|---|---|---|---|---|---|---|---|---|---|
| **Ratings P** | 20% | Central Park | 97 | 72 | 69 | 60 | 100 | | 79 |
| | | Pythagoraslaan | 17 | 40 | 37 | 60 | 100 | | 40 |
| | | Nieuwe Vaart | 76 | 61 | 69 | 60 | 0 | | 64 |
| **Ratings TM** | 20% | Central Park | 100 | 58 | 70 | 30 | | 50 | 64 |
| | | Pythagoraslaan | 0 | 11 | 81 | 90 | | 79 | 48 |
| | | Nieuwe Vaart | 75 | 4 | 20 | 80 | | 55 | 36 |
| **Ratings FC** | 50% | Central Park | 100 | 100 | 97 | 21 | 87 | 100 | 74 |
| | | Pythagoraslaan | 30 | 0 | 0 | 100 | 57 | 100 | 43 |
| | | Nieuwe Vaart | 35 | 82 | 0 | 100 | 29 | 0 | 23 |
| **Ratings U** | 10% | Central Park | | | 75 | 1 | | | 64 |
| | | Pythagoraslaan | | | 61 | 21 | | | 55 |
| | | Nieuwe Vaart | | | 75 | 13 | | | 66 |
| | **100%** | | | | | | | | |

Table 3 - Preference scores per stakeholder, category and alternative

5. **Calculating overall preference scores:** All preference scores calculated in step 4 were compared to the relative weight overall of the criteria which resulted in an overall preference score for all three alternatives.

Table 4 presents the overall preference score of Test 2. Alternative 1 has the highest preference score which makes sense when looking at Table 3. This table shows that all stakeholders except one have defined preferences that result in an overall preference for the office space in Central Park. The high score is for big parts related to its sustainability, central location and financial feasibility. It is notable that some stakeholders have not defined preferences for all categories. For example the preference score that results from the PAS input from U is based on the office space and parking criteria.

6. **Feasibility**: The feasibility of the three alternatives was tested by checking if the building meets the boundary conditions set by the stakeholders.

Table 4 shows the overall preference score (OPS) and the feasibility. It shows that the alternative with the highest OPS is not feasible as defined by the boundary conditions of the stakeholders. The boundary conditions and OPS are shown in Figure 28. The only alternative that fulfilled all boundary conditions also had the lowest OPS.

| Alt. | OPS | OPS and feasibility |
|---|---|---|
| Central Park | 72 | not feasible |
| Pythagoraslaan | 44 | not feasible |
| Nieuwe Vaart | 38 | feasible |

Table 4 - Overall Preference Score (OPS) and feasibility of the three alternatives

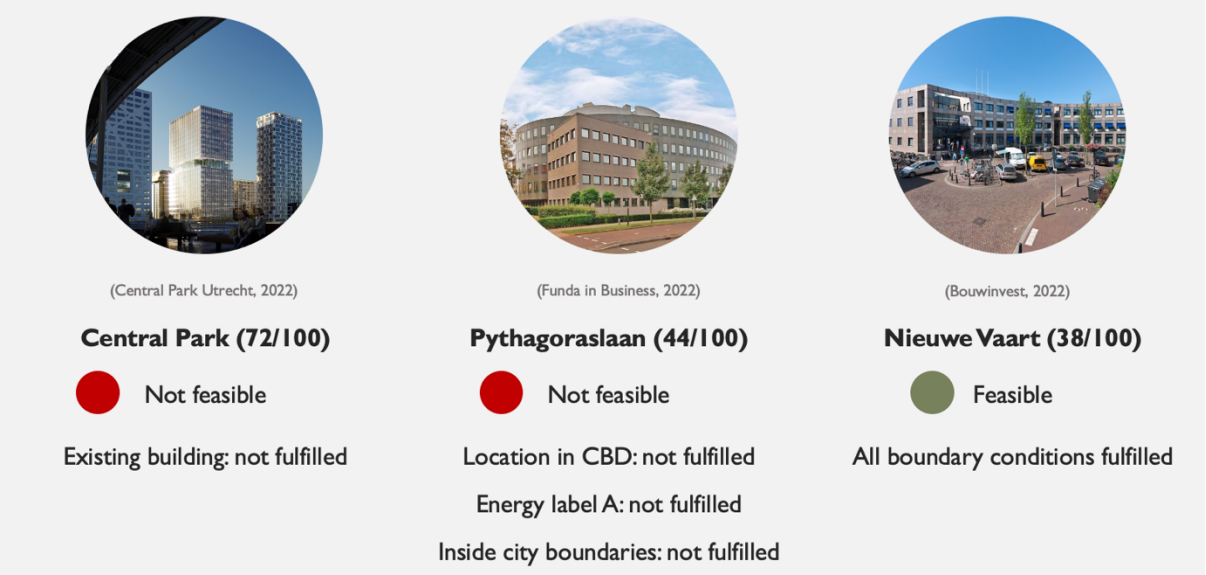



Figure 28 - Feasibility of the three alternatives based on the boundary conditions of the stakeholders

## Outcome

Test 2 resulted in 37 criteria from the four stakeholders. To facilitate the analysis and to present the outcomes, the criteria were assembled in six groups which are shown in Figure 29

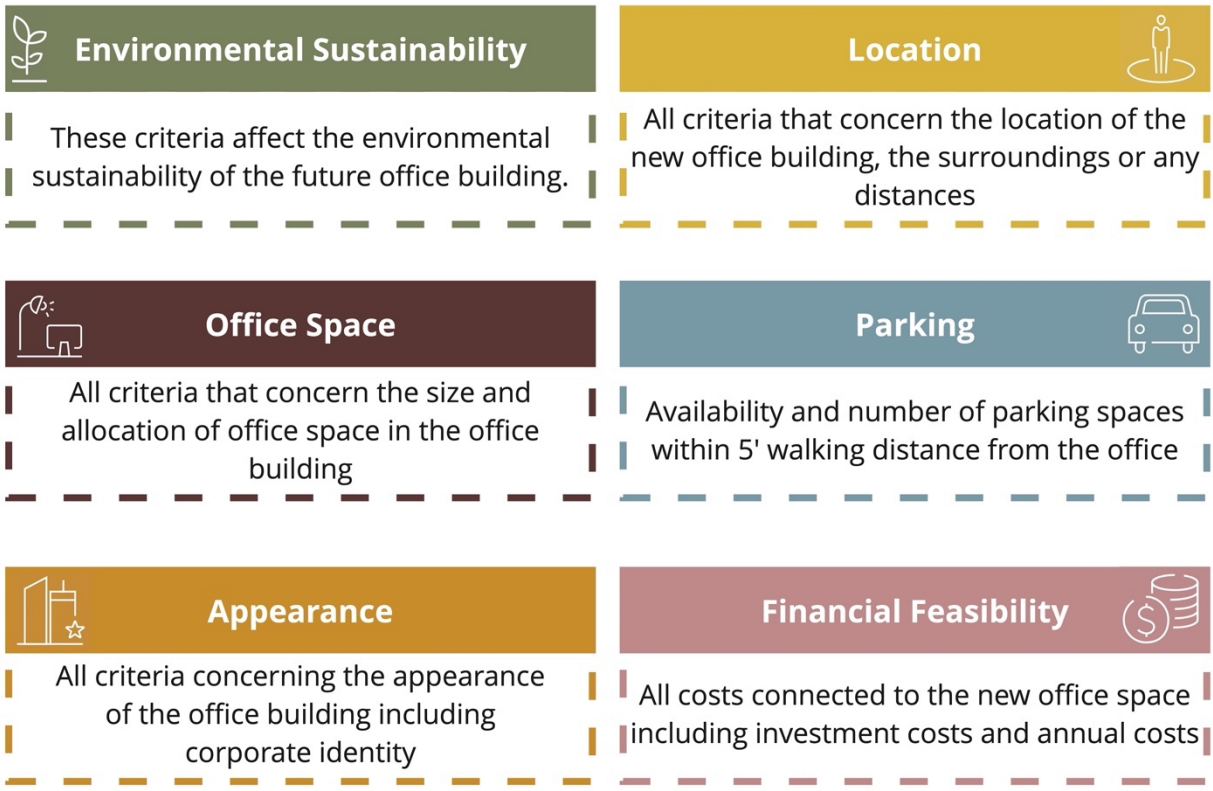



Figure 29 - Six groups of criteria (own illustration)

Figure 30 shows that the group *Office Space* counts the most of criteria, followed by *Location* and *Sustainability.* However, the attributed weights of these criteria groups do not correspond directly with the number of criteria.

| Goals | % | Nr. of criteria |
|---|---|---|
| Environmental Sustainability | 16.50% | 5 |
| Location | 24.60% | 9 |
| Office space | 21.90% | 12 |
| Parking | 3.50% | 4 |
| Appearance | 13.50% | 3 |
| Financial feasibility | 20.00% | 4 |
| **Total** | **100.00%** | **37** |

Figure 30 - Number of criteria and weights per group (own illustration)

The total number of criteria with their attributed weights is illustrated in Figure 31. It shows that a financial criterion is weighted highest (*within budget*), followed by a location criteria (*Access from a central station*) (FC1, personal communication, March 22, 2022).

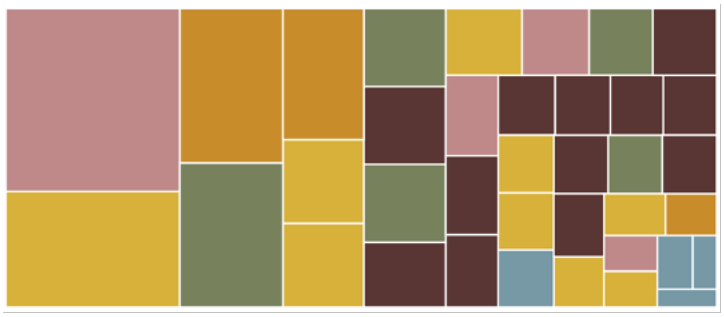


Figure 31 - Illustration of the weighted criteria coloured by group (own illustration)

Figure 32 provides an overview of the weights of the criteria groups. It shows that the criteria concerning *Location* are weighted highest followed by *Office Space, Financial Feasibility, Environmental Sustainability, Appearance* and *Parking.*

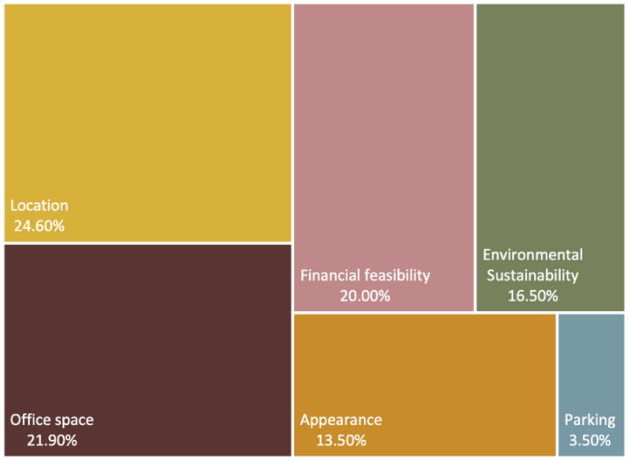



Figure 32 - Overview of the groups and their attributed weights (own illustration)

Figure 32 combines the weights of all groups, but this does not represent an average weight of all criteria. Figure 33 shows that the group *Location* still consists of nine criteria with different weights.

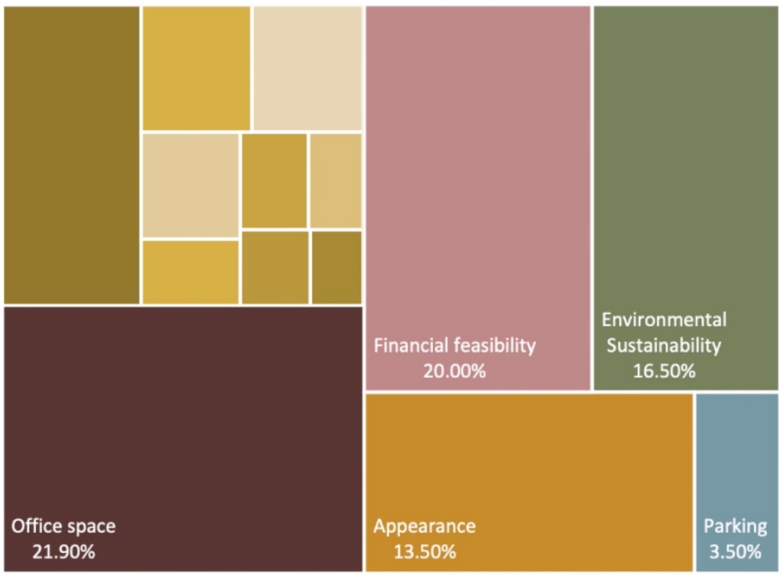
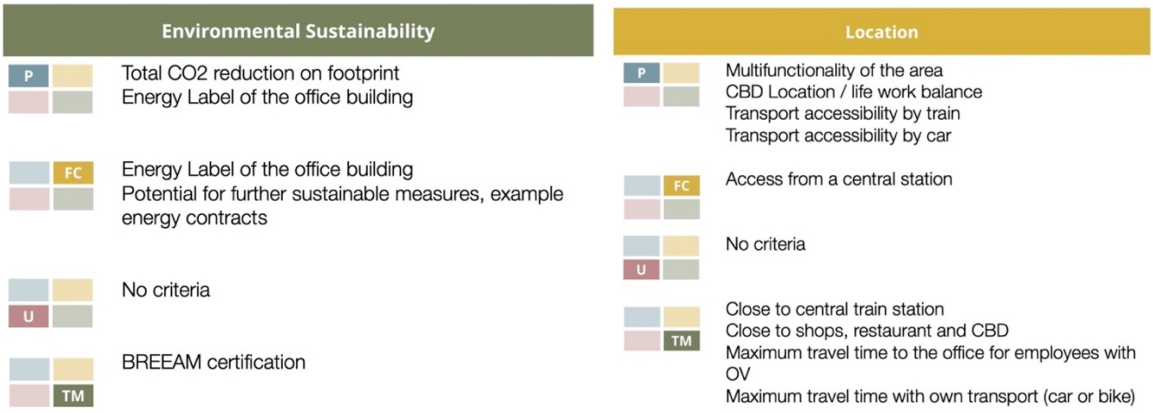



Figure 33 - Illustration of groups made up of weighted criteria (own illustration)

The following figures show lists of criteria per group and the relative weight of criteria within the group. The icons on the left indicate which stakeholder has defined the criteria. Figure 35 shows the weighted criteria which are in the sustainability group. The same illustration of the other groups can be found in the appendix.



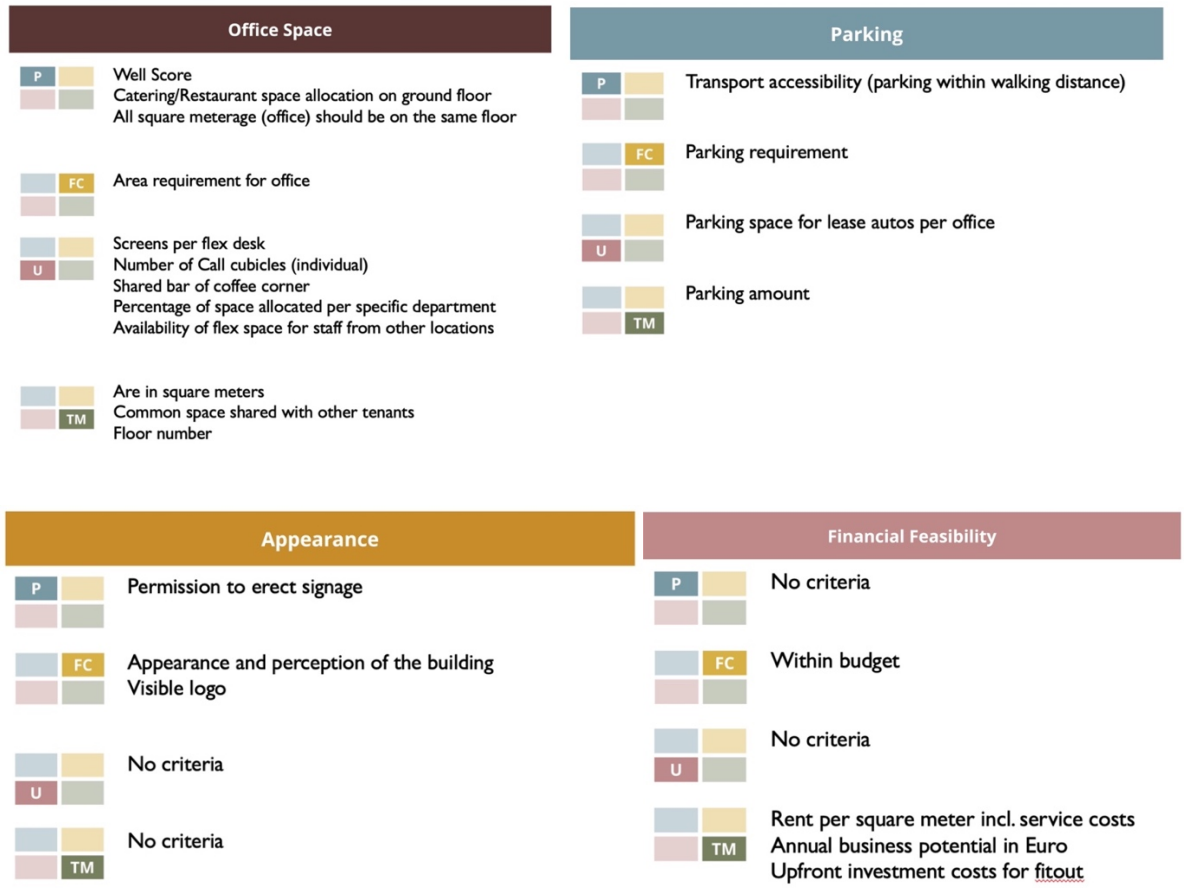



Figure 34 - Complete list of criteria from interviews 1-4 (own illustration)

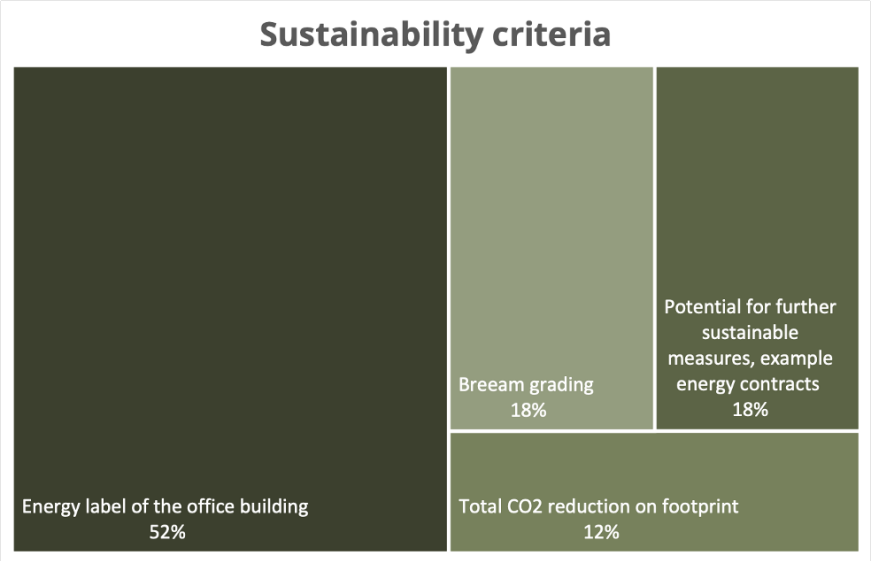



Figure 35 - Example of weighted criteria within the Sustainability group (own illustration)

All stakeholders were asked to formulate boundary conditions, which everyone did except for the Technical Manager. Figure 36 shows a list of the ten boundary conditions (FC1, personal communication, March 22, 2022; P1, personal communication, February 16, 2022; TM1, personal communication, March 21, 2022; U1, personal communication, March 23, 2022).

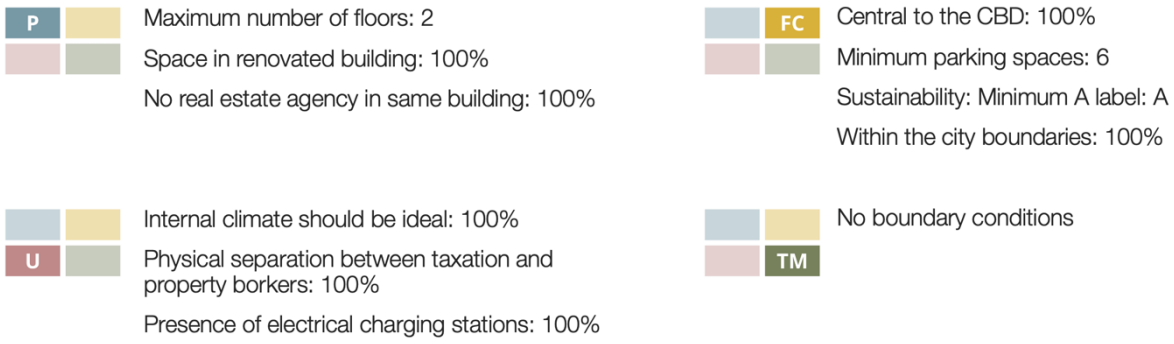



Figure 36 - Boundary conditions defined by the stakeholders (own illustration)

Test one resulted in five sustainability criteria which combined had a weight of 16.5% in the decision-making with PAS. This outcome will be compared to the result of Test 3.

The first test was well perceived by the stakeholders. The Policy manager and the Technical Manager agreed that PAS provided them with useful insights that can enrich the discussion about CRE. All stakeholders like the freedom to formulate criteria without boundaries but they did express concerns that important criteria might be forgotten with the lack of guidance (Presentation, personal communication, April 20, 2022).

# 4

# Making the Model

# &

# Testing and evaluating the Model

# 4. Making, Testing and Evaluating the Sustainability Reference Model

The findings from Reference Models started the design cycle of the SuRMo (A. Hevner et al., 2004). The SuRMo was made using an iterative process bases on Hevner et al. (2004) and the five steps of operation research (Ackoff & Sasieni, 1968). The model was developed using the design cycle but was based on information from the knowledge base and was tested in the research environment which was the pilot study in this research (A. Hevner et al., 2004). The goal of the reference model is to help decision makers select a set of goals, criteria, measurements, preferences and weights about environmental sustainability for PAS (Arkesteijn, 2019).

Using an iterative process resulted in developing multiple versions of the SuRMo. Table 5 shows the different steps of developing the SuRMo and the goal of these steps. After developing Model 1.0, it was presented to the CRE services (CRES) team of Colliers for feedback. This feedback was implemented in Model 2.0 which was presented to the four stakeholders of the pilot study. The learnings form Model 2.0 were also discussed in the evaluation interviews with the stakeholders. These learnings are used in the current development of Model 3.0.The following chapters will elaborate on the steps that have been taken in the development of the SuRMo.

The 'Den Heijer Variable Check' is a reference model that was developed in Excel based on the stakeholder model of den Heijer. The reference model consists of three steps in which the stakeholders selected performance criteria, a RE goal and key performance indicators related to the goal (Arkesteijn, 2019). In essence, the SuRMo was meant to serve the same purpose as the Den Heijer Variable Check but aimed at sustainability in CRE.

| Model | Step | Goal | Interview | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | P | U | FC | TM | |
| Model 1.0 | Set up of model headers | Match with input format in PAS | | | | | (Arkesteijn, 2019) |
| | Defining attitudes | Making values relatable | ■ | ■ | ■ | ■ | |
| | Including regulations | Fulfill obligated measurements | ■ | | ■ | | (RVO, 2021; van Eijk & Lebouille, 2022) |
| | Including building certification | Finding measurable and complete set of criteria for overall environmental sustainability of buildings | | | | ■ | (Vieira de Castro et al., 2020) |
| Model 2.0 | Model in Miro | Userfriendliness | | | | | Feedback CRES team Colliers |
| | BREEAM categorisation | Link to widely known and used building certification and completeness of model content | ■ | | | ■ | (Vieira de Castro et al., 2020; Ferrari et al. 2022; Nguyen & Alten, 2011; van Eeckhoven, 2021; Cole & Jose Valdebenito, 2013) |
| | Increase similarity to PAS and suggested preference | Userfriendliness | ■ | ■ | ■ | ■ | |
| Model 3.0 | Link to SDG's | Decrease nr. of criteria and make model less technical | ■ | | ■ | | (BRE Global Limited, 2018) |
| | Option of having facilitator use the model | Translation between ambition stakeholders and technical sustainability criteria | ■ | ■ | ■ | ■ | |

Table 5 - Steps of developing the SuRMo (own illustration)

## 4.1. Sustainability Reference Model 1.0

The first model was developed based on information from regulations and rating bodies. This subchapter shows the development of the first SuRMo and learning from discussing it with the CRES team at Colliers.

### 4.1.1. Sustainability Reference Model 1.0 Input

The first model combined Dutch government regulations for environmental sustainability in buildings and rating bodies (Figure 37). The input consists of the different regulations and one building certification.

The regulations for the environmental sustainability of office buildings are communicated and checked by the Netherlands Enterprise Agency, short RVO (NL: Rijksdienst voor Ondernemend Nederland) (RVO, 2021). For Model 1.0, the regulations entail the rules for Almost Energy Neutral Buildings, short BENG (NL *Bijna Energie Neutrale Gebouwen*), the Dutch national goal for a circular building economy by 2050 and the energy label (Circularie Bouweconomie, n.d.; RVO, 2017, 2018b).


Figure 37 - Input model 1.0 (own illustration)

The Dutch Green Building Council (DCBG) was selected as the most important rating body for the SuRMo because it gives out the BREEAM certificates in the Netherlands (DGBC, n.d.). BREEAM is the most used rating system in the Netherlands and knows a local version of the certificate (Cole & Jose Valdebenito, 2013; DGBC, n.d.; van Eeckhoven, 2021). BREEAM was also known among the stakeholders and was defined as a criterium in PAS by the Technical Manager (TM1, personal communication, March 21, 2022) These regulations and rating bodies were used to make the expert system because they have been developed for a long time and therefore show a very complete picture of sustainability in RE. It was not found necessary to reinvent the thorough content of existing rating systems and regulations.

Four steps were taken to develop the SuRMo 1.0 (Figure 38):

| Model | Step | Goal | Interview | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | P | U | FC | TM | |
| Model 1.0 | 1 Set up of model headers | Match with input format in PAS | | | | | (Arkesteijn, 2019) |
| | 2 Defining attitudes | Making values relatable | ■ | ■ | ■ | ■ | |
| | 3 Including regulations | Fulfill obligated measurements | ■ | | ■ | | (RVO, 2021; van Eijk & Lebouille, 2022) |
| | 4 Including building certification | Finding measurable and complete set of criteria for overall environmental sustainability of buildings | | | | ■ | (Vieira de Castro et al., 2020) |

Figure 38 - Model 1.0 steps (own illustration)


Figure 39 - Step 1 and 2 of making Model 1.0 (own illustration)

**Step 1** was to build the model similarly to the input format in PAS (Arkesteijn, 2019). With a similar format, the goal was to make it easy for the stakeholder to use the information and insert it in PAS (Figure 39).

In **Step 2**, attitudes were selected for stakeholders to define how important they find the different goals and criteria. The goal of using attitudes was to make the values of the model relatable for the stakeholders. They could choose between three attitudes: *Minimalist, Mainstream rower* or *Frontrunner* (Figure 39).

**Step 3** connected the attitudes to the regulations and goals of the RVO (Figure 40). Selecting *Minimalist* means that the chosen decision variable value complies with regulations for 2023. The attitude of the *Mainstream rower* matches the announced regulations for 2030 and the Frontrunner is prepared to comply with the goals of $CO_2$ neutrality in 2050 (RVO, 2018b). In the model these regulations translated into criteria for BENG, circularity and energy labels (Circularie Bouweconomie, n.d.; RVO, 2017, 2018b; van Eijk & Lebouille, 2022) (Figure 41).

| Attitude | Compliance NL regulations | Source |
|---|---|---|
| Frontrunner | 2050 (95% CO2 reduction compared to 2015) | (RVO, 2020)<br>(van Eijk & Lebouille, 2022)<br>(Nieman Raadgevende Ingenieurs, n.d.) |
| Mainstream rower | 2030 (49% CO2 reduction compared to 2015) | |
| Minimalist | 2023 (1,5% energy reduction/year) | (RVO, 2020)<br>(van Eijk & Lebouille, 2022) |

Figure 40 - Attitudes based on Dutch goals on CO2 reduction (own illustration)

**Step 4** of included a criterium for BREEAM certification. This criterium that goes beyond the regulations on energy use was included because it includes criteria that enrich the ecosystem and criteria that test the protection of natural resources (Vieira de Castro et al., 2020). (BREEAM-NL, n.d.-a) (Figure 41).

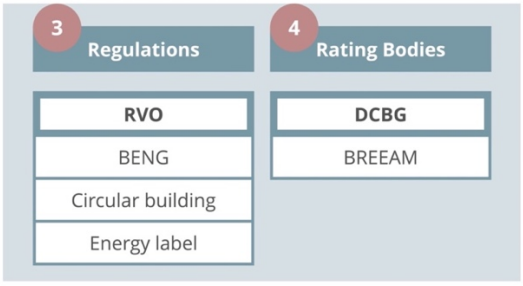



Figure 41 - Step 3 and 4 of making Model 1.0 (own illustration)

### 4.1.2. Sustainability Reference Model 1.0

Figure 42 shows the complete SuRMo 1.0. It was presented to the CRES team of Colliers which is the department where this research was conducted. In total it proposes six goals, and seven criteria that can be used to as input in PAS.

| Goal | Criteria | Unit/formula | Values | Attitude | Source |
|---|---|---|---|---|---|
| BREEAM certification | BREEAM | BREEAM Score | Very good, excellent or outstanding | Frontrunner | based on BREEAM-NL (n.d.) |
| | | | Pass or good | Mainstream rower | |
| | | | No rating | Minimalist | |
| | | | | | |
| Energy label | Energy Label | Energy Label | A+-A++++ | Frontrunner | RVO (2018) |
| | | | A | Mainstream rower | |
| | | | B-G | Minimalist | |
| | | | | | |
| BENG 3 | Renewable energy use | % of total energy use | 100% | Frontrunner | based on RVO (2019) |
| | | | >50% | Mainstream rower | |
| | | | >30% | Minimalist | |
| | | | | | |
| BENG 2 | Fossil energy use | kWh/m2/year | <240 | Frontrunner | based on van Eijk & Lebouille (2022) |
| | | kWh/m2/year | 241-315 | Mainstream rower | |
| | | kWh/m2/year | >316 | Minimalist | |
| | | | | | |
| BENG 1 | Energy use for heating and cooling | kWh/m2/year | < 90 kWh/m2/year(Als/Ag <1.8) | Minimalist | based on RVO (2019) |
| | | kWh/m2/year | ≤ 90 + 30 * (Als/Ag -1,8) kWh/m2/jaar (Als/Ag > 1,8) | Minimalist | |
| | | | | | |
| Circularity | state of the building | New building | | Minimalist | based on Vos et al. (2020) |
| | | Re-purpose | | Mainstream rower | |
| | | Re-use | | Frontrunner | |
| | Use of material pasport | Yes/No | Yes | Frontrunner | Based on RVO (2018) |
| | | | No | Minimalist | |

Figure 42 - Complete Model 1.0 in Excel (own illustration)

The second goal of the model is presented in Figure 43 to exemplify the use of the model. If a stakeholder choses the energy label as a goal for the future CREP, he or she can refer to the attitude and choose which one matches with the organizations sustainability ambitions. Once the attitude is selected, the stakeholder is advised to use the value on the left of the attitude as boundary condition in PAS or give it the preference score 100. If the value is used to define a

preference curve, it is open for the stakeholder to define the middle value and the preference score 0. However, it is advisable to give values close to the *Frontrunner* attitude a higher preference score than to the values close to the *Minimalist* attitude (Arkesteijn, 2019; RVO, 2018b). (RVO, 2019) (van Eijk & Lebouille, 2022) (Vos et al., 2020)(RVO, 2018a)

| Goal | Criteria | Unit/formula | Value | Attitude | Source |
|---|---|---|---|---|---|
| Energy label (energy efficient office building) | Energy label | Energy label | A+ - A++++ | Frontrunner | (RVO, 2018) |
| | | | A | Mainstream rower | |
| | | | B-G | Minimalist | |

Figure 43 - Example of the Energy label goal in Model 1.0 (own illustration)

### 4.1.3. Learnings from SuRMo 1.0

The first version of the SuRMo was presented to the CRES team of Colliers to receive feedback to develop a second version of the model. Figure 44 summarizes the main feedback to the SuRMo 1.0. The separation of the values in three different attitudes was well perceived because it gave the users of the model a sense of what values are considered more environmentally sustainable then others. The team found that the link to the PAS webtool could be stronger to make the model more user-friendly. Some commented that the model is very focused on energy use although biodiversity, location to discourage the use of cars and criteria linked to wellbeing also make a building more sustainable (CRES Colliers, personal communication, April 8, 2022). This feedback led to the development of SuRMo 2.0 which dissects BREEAM, the most used sustainability certification in Europe (Cole & Jose Valdebenito, 2013; van Eeckhoven, 2021).

| | |
|---|---|
| **To keep** | Separation in “Frontrunner”, “Mainstream rower” or “Minimalist” |
| **To improve** | Stronger link to PAS for easy input in the webtool |
| | Clear categorization and organization of criteria |
| | Link to widely used sustainability measurement in buildings |
| | Userfriendliness |

Figure 44 - Evaluation of Model 1.0 (own illustration)

## 4.2. Sustainability Reference Model 2.0

The second version of the SuRMo implemented the findings from the evaluation of SuRMo 1.0 and expanded the model to more detail of the BREEAM categories. Developing SuRMo 2.0 consisted of three steps which would make the SuRMo more user-friendly and show a more complete set of criteria for environmental sustainability in buildings (Table 6).

| Model | Step | Goal | Interview | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | P | U | FC | TM | |
| Model 2.0 | 1 Model in Miro | Userfriendliness | | | | | Feedback CRES team Colliers |
| | 2 BREEAM categorisation | Link to widely known and used building certification and completeness of model content | | | | | (Vieira de Castro et al., 2020; Ferrari et al. 2022; Nguyen & Altan, 2011; van Eeckhoven, 2021; Cole & Jose Valdebenito, 2013) |
| | 3 Increase similarity to PAS and suggested preference | Userfriendliness | | | | | |

Table 6 – Model 2.0 steps (own illustration)

The SuRMo 2.0 was presented to the stakeholders of the pilot study for Test 3.

### 3.2.1. Sustainability Reference Model 2.0 Input

The second version of the SuRMo was made in the whiteboard tool Miro to improve the user-friendliness. The content was mainly based on the categories of BREEAM to include a more complete set of criteria for environmentally sustainable buildings ((Bernardi et al., 2017).

To create a stronger link to PAS, an introduction slide was included in Miro to guide the user. It includes an explanation of how to make a personal selection of criteria and how to insert the selection in the PAS webtool (Arkesteijn, 2022a).

The model 2.0 was based on the categories and criteria from BREEAM International *New Construction* to expand the applicability to international CRE (BRE Global, 2021a). This version on *New Construction* was selected because it includes criteria that rate to the construction site of buildings. The local version of BREEAM-NL *In-Use* is separated in three parts: *Asset, Management* and *Use.* The first part Asset is comparable to BREEAM-NL *New Construction and Renovation* but the other two parts concern the use of a building (BREEAM-NL, n.d.-b). The scope of this research does not go beyond the building itself, which is why BREEAM International *New Construction* was selected. BREEAM-NL has published a new version of *BREEAM-NL In-Use Sustainable CRE and Business Operations* (DGBC, 2021). Although this version was developed for the use of buildings, the categories were taken into account in SuRMo 2.0 to allow for the organization of the CRE to get a *BREEAM-NL In-Use Sustainable CRE and Business Operations* certificate in the future.

| BREEAM International New Construction | BREEAM-NL *In-Use Sustainable CRE and Business Operations* |
|---|---|
| Management | Management |
| Health and wellbeing | Health and wellbeing |
| Energy | Energy |
| Transport | Transport |
| Water | Water |
| Materials | Materials |
| Waste | - |
| Land use and ecology | Land use and ecology |
| Pollution | Pollution |
| Innovation | - |

Table 7 - Comparison BREEAM categories (BRE Global, 2021a; BREEAM-NL, 2021)

Table 7 shows that eight categories overlap between BREEAM International *New Construction* and *BREEAM-NL In-Use Sustainable CRE and Business Operations* (BRE Global, 2021a; BREEAM-NL, 2021) These eight categories of BREEAM International *New Construction* were used in the SuRMo 2.0. From the eight categories, the criteria were checked for their relevance to office buildings and significant impact on the greenhouse gas emissions. The selection of criteria is shown in Table 8 and Table 9.

| | | | | | Exclusion criteria | | |
|---|---|---|---|---|---|---|---|
| Category | Number | Issue | Credits | In SERMo | Other function than office | Significant impact on the environment | Elaboration/Analysis |
| Management | Man 01 | Project brief and design | 4 | Yes | | | Essential for correct measurement of BREEAM performance |
| Management | Man 02 | Life cycle cost and service life plannig | 4 | Yes | | | Longer life cycle reduces unnecessary need for new materials |
| Management | Man 03 | Responsible construction practices | 6 | Yes | | | Important for minimal use of energy and natural resourses during construction |
| Management | Man 04 | Commissioning and handover | 4 | Yes | | | Important for correct and sustainable use of the buiding |
| Management | Man 05 | Aftercare | 3 | Yes | | | Important for sustainable occupancy and maintenance |
| Health and wellbeing | Hea 01 | Visual comfort | <=6 | No | | | About user comfort and little impact on the environment |
| Health and wellbeing | Hea 02 | Indoor air quality | 5 | Yes | | | minimizes air pollution |
| Health and wellbeing | Hea 03 | Safe containment in laboratories | 2 | No | | | Laboratories not part of office space scope |
| Health and wellbeing | Hea 04 | Thermal comfort | 3 | Yes | | | flexibility to reduce heating according to need due to climate change |
| Health and wellbeing | Hea 05 | Acoustic performance | <=4 | No | | | About user comfort and little impact on the environment |
| Health and wellbeing | Hea 06 | Accessibility | 2 | No | | | About safety and security in the building |
| Health and wellbeing | Hea 07 | Hazards | 1 | Yes | | | Resilient buildings important to survive for a long time (see definition sustainbility) |
| Health and wellbeing | Hea 08 | Private space | 1 | No | | | About wellbeing of user, little to no impact on environmental performance |
| Health and wellbeing | Hea 09 | Water quality | 1 | Yes | | | minimizes water pollution |
| Energy | Ene 01 | Reduction of energy use and carbon emissions | 13 | Yes | | | reduction of emissions |
| Energy | Ene 02 | Energy monitoring | 2 | Yes | | | measurement of energy use allows for reduction measurements |
| Energy | Ene 03 | External lighting | 1 | Yes | | | optimizes energy use during the day and reduced energy use of light sources |
| Energy | Ene 04 | Low carbon design | 3 | Yes | | | lower emissions by design |
| Energy | Ene 05 | Energy efficient cold storage | 3 | Yes | | | minimizes emissions of refrigeration systems |
| Energy | Ene 06 | Energy efficient transport systems | 3 | Yes | | | minimize environmental impact of transportation inside the building |
| Energy | Ene 07 | Energy efficient laboratory systems | 5 | No | | | Laboratories not part of office space scope |
| Energy | Ene 08 | Energy efficient equipment | 2 | Yes | | | minimize environmental impact of equipment |
| Energy | Ene 09 | Drying space | N/A | No | | | Not assessed in BREEAM International New Construction |
| Energy | Ene 10 | Flexible demand side response | 1 | Yes | | | Allows for energy with less environmental impact if available, demand confrimed by interview Daan Potjer |
| Transport | Tra 01 | Public transport accessibility | 5 | Yes | | | Reduces environmental impact by individual car commutes |
| Transport | Tra 02 | Proximity to amenities | 2 | Yes | | | Reduces environmental impact by individual car commutes |
| Transport | Tra 03 | Alternative modes of transport | 2 | Yes | | | Reduces environmental impact by individual car commutes |
| Transport | Tra 04 | Maximum car parking capacity | 2 | Yes | | | Reduces environmental impact by individual car commutes |
| Transport | Tra 05 | Travel plan | 1 | Yes | | | Maximises use of environmenally friendly transportation |
| Transport | Tra 06 | Home office | 1 | Yes | | | Allows for smaller office spaces and reduced emissions from employee travel |

Table 8 - Criteria selection for the SuRMo (BRE Global, 2021a)

| | | | | | Exclusion criteria | | |
|---|---|---|---|---|---|---|---|
| Category | Number | Issue | Credits | In SERMo | Other function than office | Significant impact on the environment | Elaboration/Analysis |
| Water | Wat 01 | Water consumption | 5 | Yes | | | Using less water reduces negative impact on the environment |
| Water | Wat 02 | Water monitoring | 1 | Yes | | | Monitoring allows to take measures for reduces water consumption |
| Water | Wat 03 | Water leak detection and prevention | 3 | Yes | | | Reduces amount of waste water |
| Water | Wat 04 | Water efficient equipment | 1 | Yes | | | Using less water reduces negative impact on the environment |
| Materials | Mat 01 | Life cycle impacts | 6 | Yes | | | Maximising the time materials can be used in buildings |
| Materials | Mat 02 | Hard landscaping and boundary protection | N/A | No | | | Included in Mat 01 |
| Materials | Mat 03 | Responsible sourcing of construction products | 4 | Yes | | | Minimizes the use of materials that use a lot of natural resources |
| Materials | Mat 04 | Insulation | N/A | Yes | | | Included in Mat 01 and Mat 03 |
| Materials | Mat 05 | Designing for durability and resilience | 1 | No | | | Only little impact on the environment |
| Materials | Mat 06 | Material efficiency | 1 | No | | | Vague criteria, only little impact on the environment |
| Land use and ecology | LE 01 | Site selection | 3 | Yes | | | Not touching greenfields allows for carbon absorbing vegetation |
| Land use and ecology | LE 02 | Ecological value of site and protection of ecological features | 2 | Yes | | | Non disturbance keeps carbon absorbing vegetation alive |
| Land use and ecology | LE 03 | Minimising impact on existing site ecology | N/A | No | | | Not assessed in BREEAM International New Construction |
| Land use and ecology | LE 04 | Enhancing site ecology | 3 | Yes | | | Allows for carbon absorbing vegetation around building |
| Land use and ecology | LE 05 | Long term impact on biodiversity | 2 | Yes | | | Allows for carbon absorbing vegetation around building |
| Pollution | Pol 01 | Impact of refrigerants | 4 | Yes | | | minimizes emissions of refrigeration systems |
| Pollution | Pol 02 | NOx Emissions | 2 | Yes | | | Minimzes environmental impact by heating systems |
| Pollution | Pol 03 | Surface water run-off | 5 | Yes | | | Flood prevention allows for longer use of the building |
| Pollution | Pol 04 | Reduction of night time light pollution | 1 | No | | | No effect on emissions |
| Pollution | Pol 05 | Reduction of noise pollution | 1 | No | | | No effect on emissions |

Table 9 - Criteria selection for the SuRMo (own illustration based on BRE Global, 2021a)

Based on this selection, the criteria were arranged in the SuRMo 2.0 in their categories from left to right by weight for the BREEAM certification (BRE Global, 2021a).

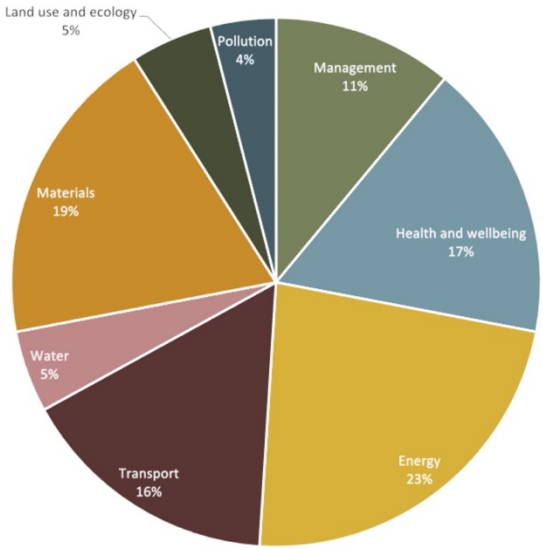



Figure 45 - Weights of BREEAM categories (own illustration based on BRE Global, 2021)

To improve the connection to the input dashboard of the PAS webtool, the SuRMo 2.0 shows the BREEAM category, the related criteria, formula, unit and suggested preference score (Arkesteijn, 2022a; BRE Global, 2021a).

- **Formula:** The formula is based on the aim of the BREEAM criteria. For example, for category *8 Land use and Ecology*, criteria *01 Site selection* the aim is "To encourage the use of previously occupied or contaminated land and avoid land which has not been previously disturbed" (BRE Global, 2021b). This was turned into the formula *Reused land.*
- **Unit:** The unit was based on the unit described in the BREEAM International *New Construction* Manual which is the "Percentage of proposed development's footprint on previously developed land" (BRE Global, 2021b). For the model this was rephrased to *% of previously occupied land*.
- **Suggested Preference:** Similarly to SuRMo 1.0, three different attitudes were used (Frontrunner, Mainstream rower and Minimalist) to help the user of the model relate to the proposed values. The values were linked to the distribution of credits in BREEAM International *New Construction.* For example for the criteria 01 Site selection, two credits are given if 95% of the land was preoccupied and one credit is given if 75% of the land was preoccupied (BRE Global, 2021b). Based on the credit distribution, the SuRMo 2.0 suggests to set preference 100 at 95% of previously occupied land, preference 50 at 75% of previously occupied land and preference 0 at 0% previously occupied land.

The same logic was applied to all criteria of the SuRMo 2.0 as shown in the next subchapter.

### 4.2.2. Sustainability Reference Model 2.0

The SuRMo 2.0 is shown in Figure 46. It is composed of two main parts. The first part is the introduction on top of the model which explains how the model can be used. The second part is the selection of criteria from the previous subchapter where users of the model can select criteria relevant to their decision making process. The following figures will zoom in on the two parts of the SuRMo 2.0.

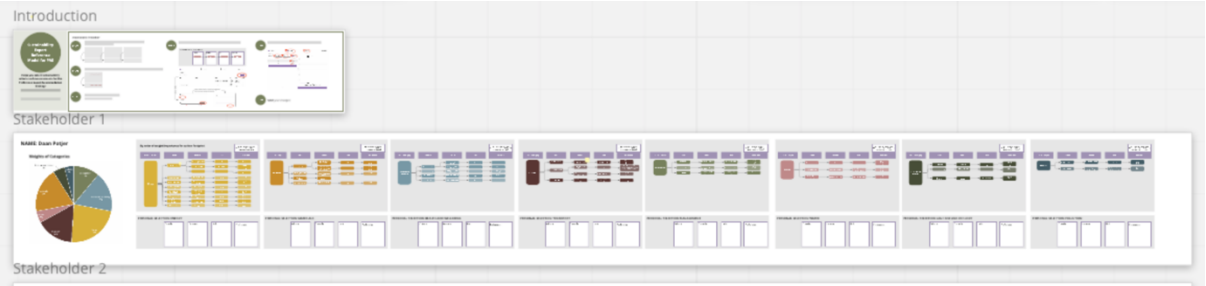



Figure 46 - SuRMo 2.0 (own illustration)

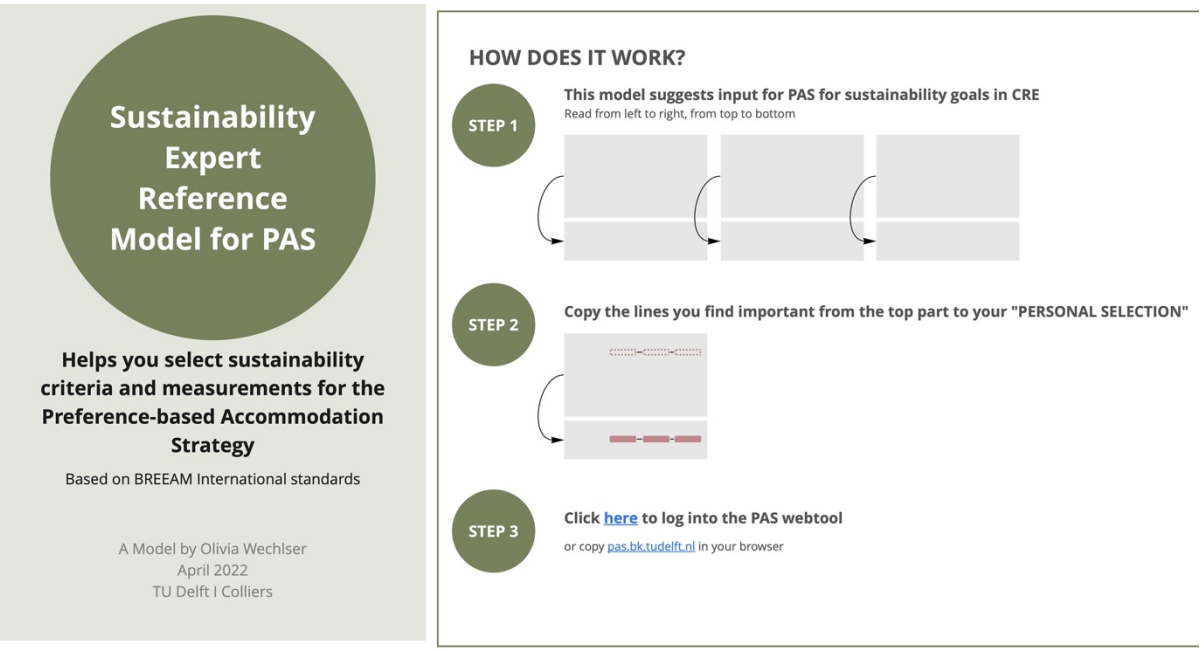



Figure 47 - Introduction to SuRMo 2.0 (own illustration)

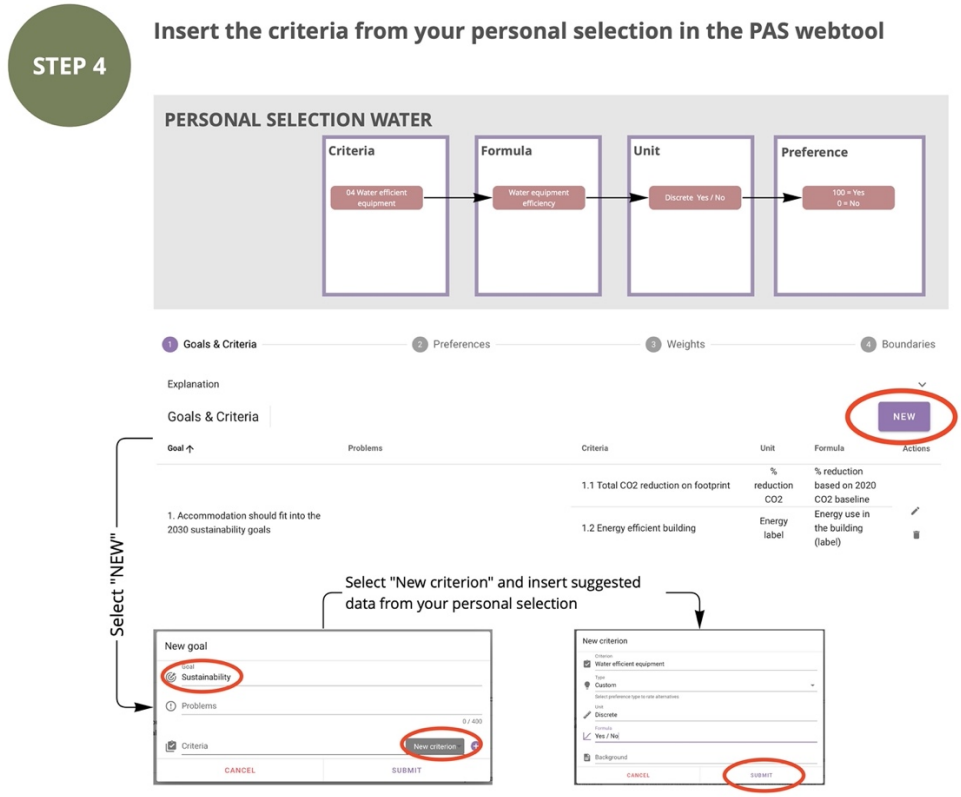



Figure 48 - Introduction to SuRMo 2.0 with screenshots of the PAS webtool (Arkesteijn, 2022a)





Figure 49 - Introduction to SuRMo 2.0 with screenshots of the PAS webtool (Arkesteijn, 2022a))

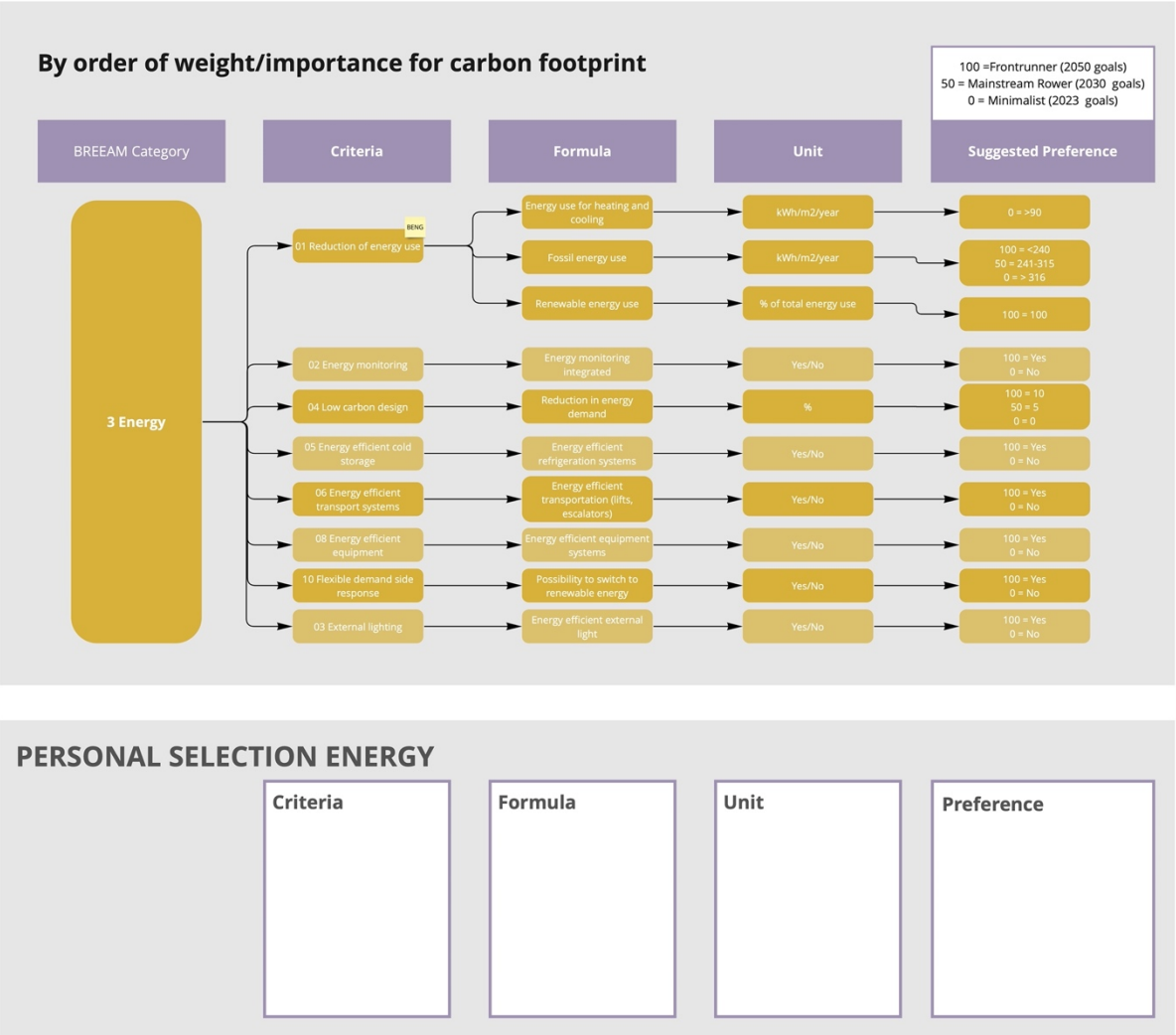



Figure 50 - Criteria of category 3 Energy with space for personal selection (Arkesteijn, 2022a; BRE Global, 2021a)

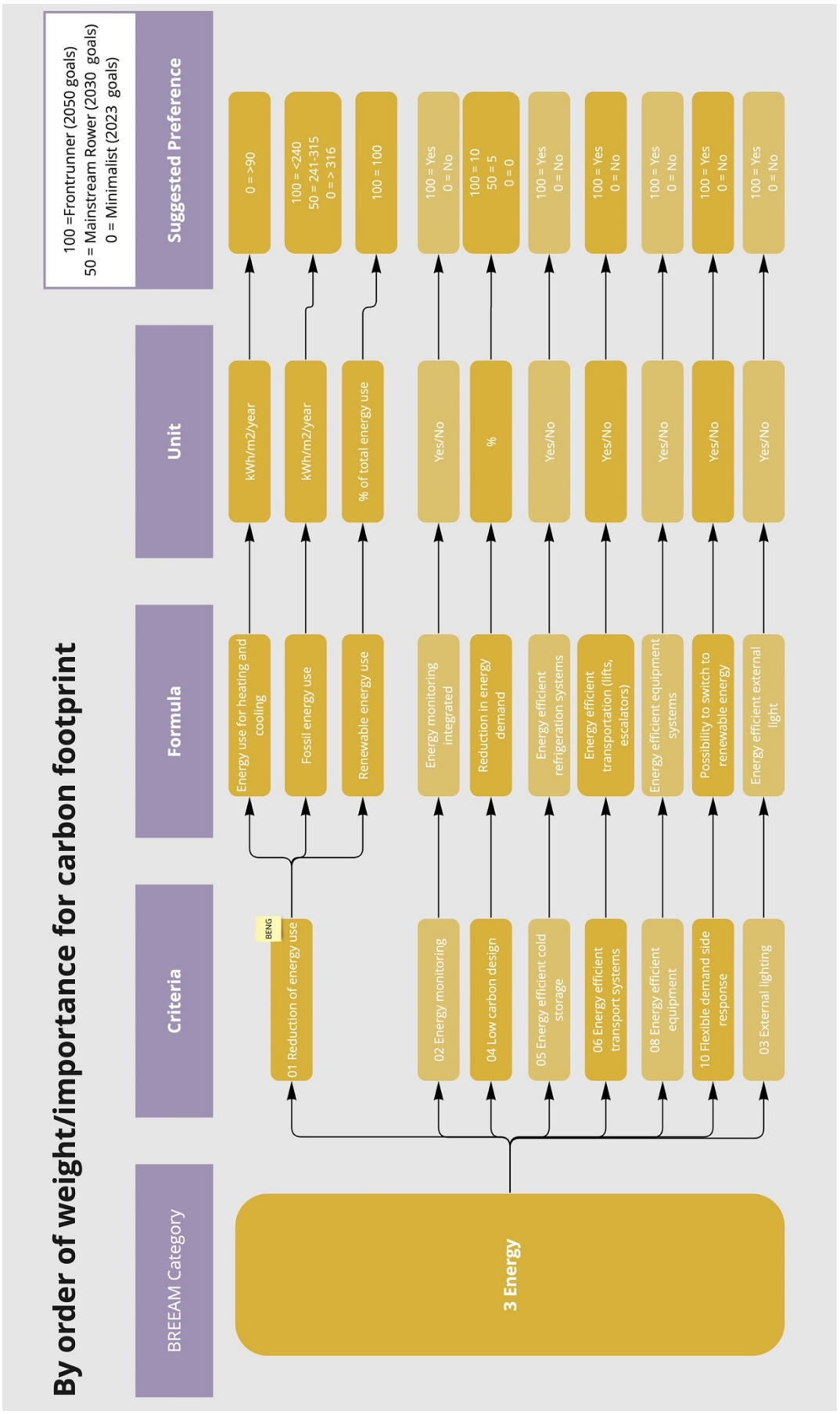



Figure 51 - SuRMo category 3 Energy (own illustration)

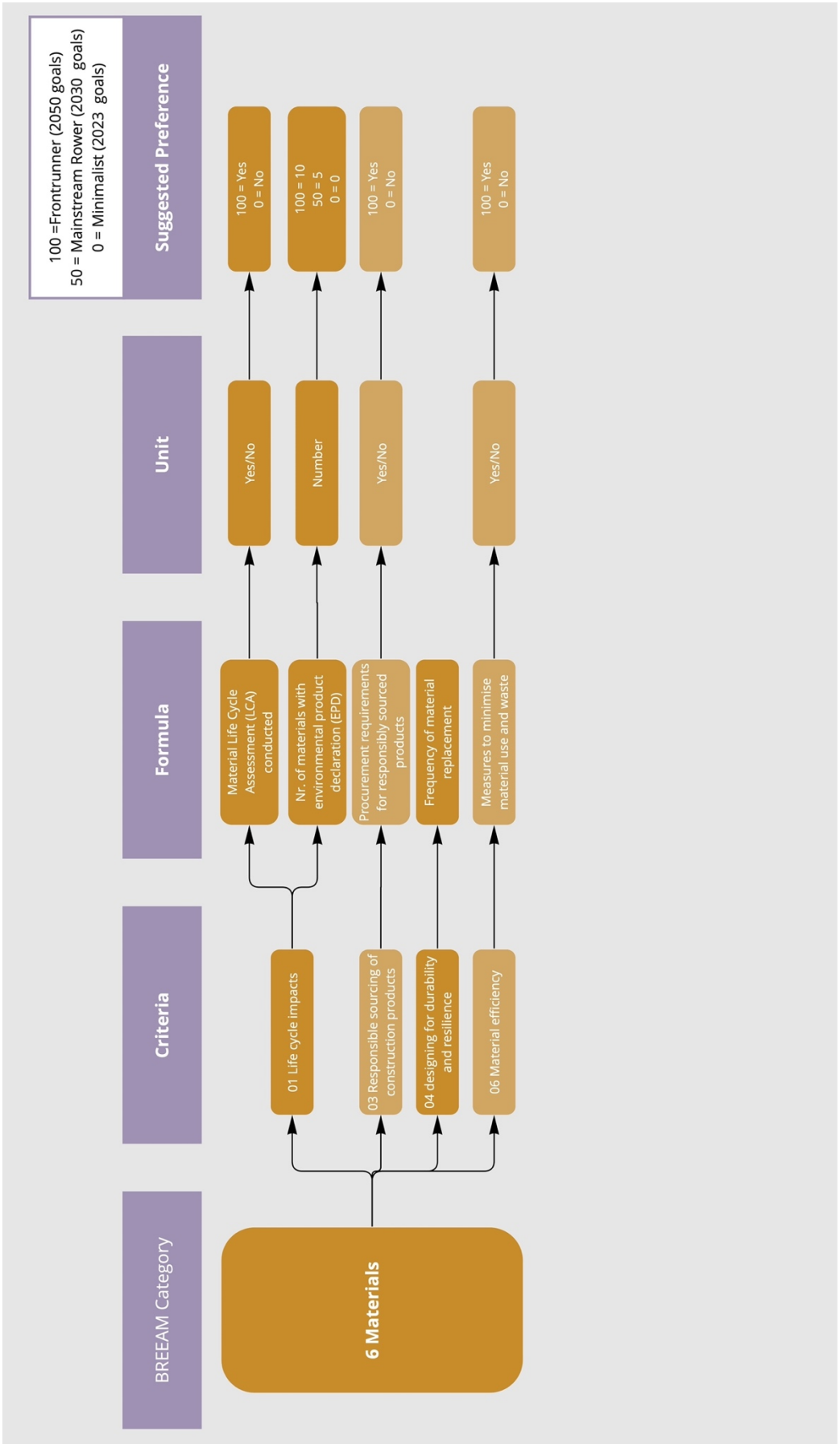



Figure 52 - SuRMo category 6 Materials (own illustration)

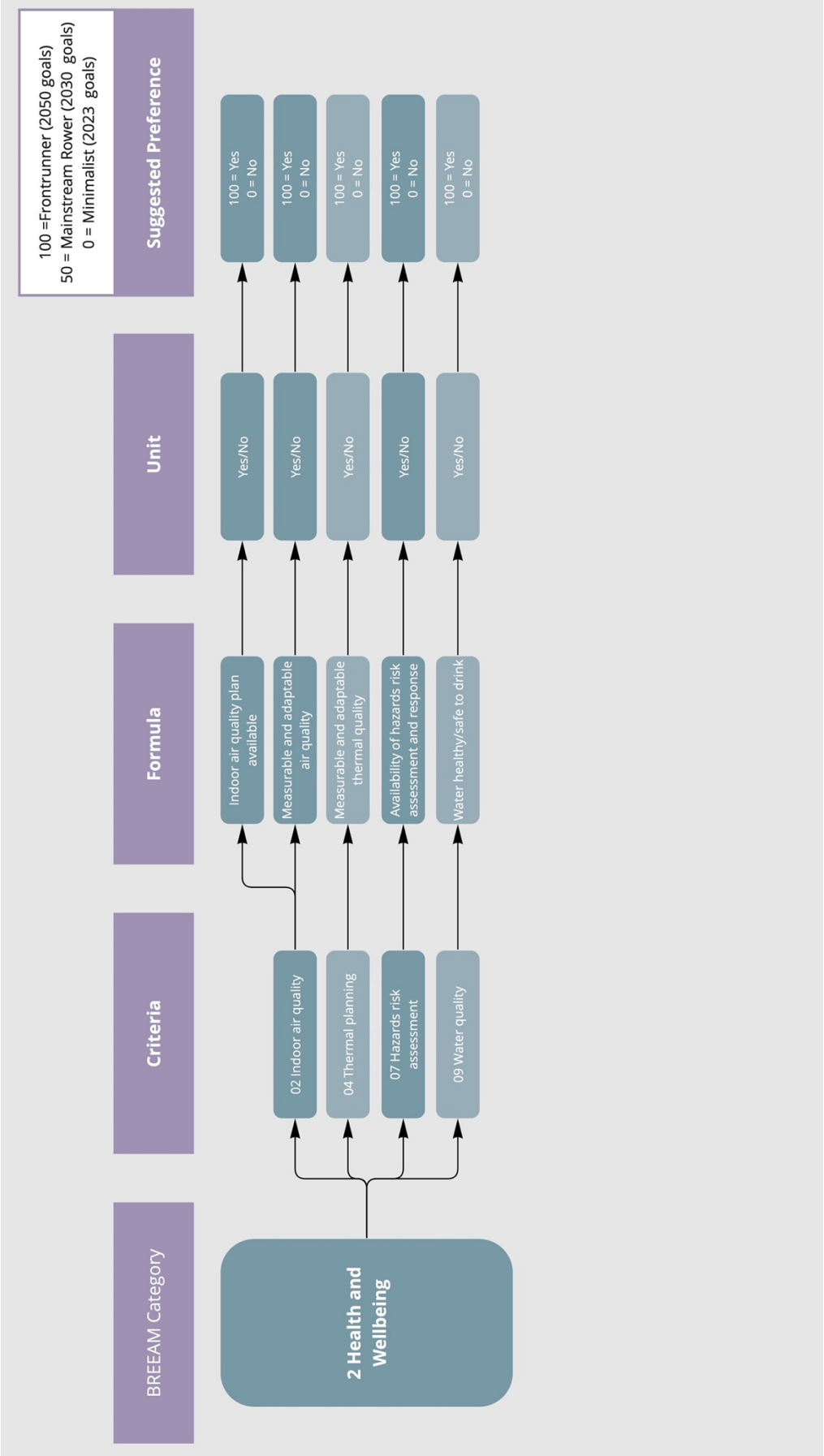



Figure 53 - SuRMo category 2 Health and Wellbeing (own illustration)

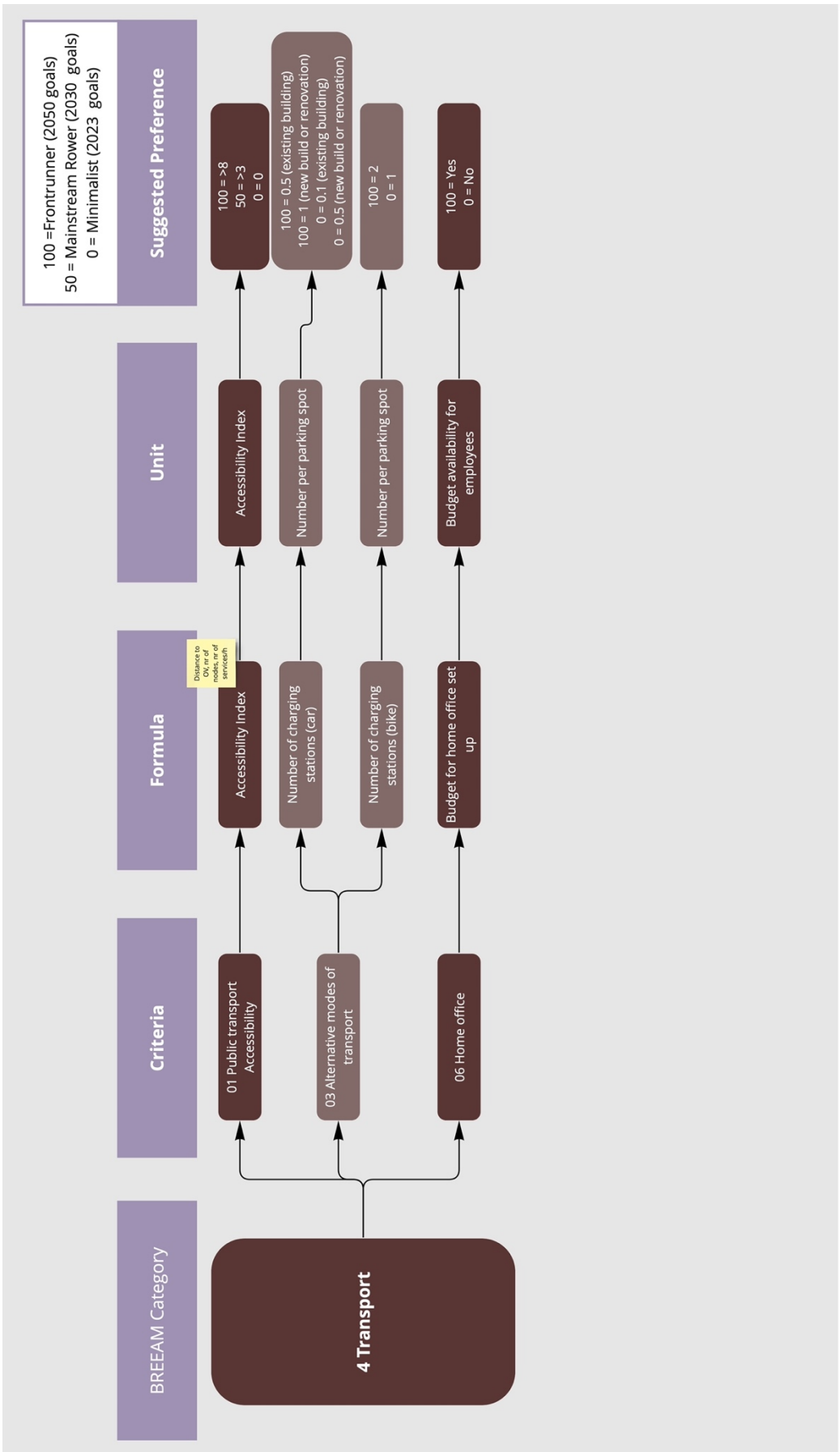



Figure 54 - SuRMo category 4 Transport (own illustration)

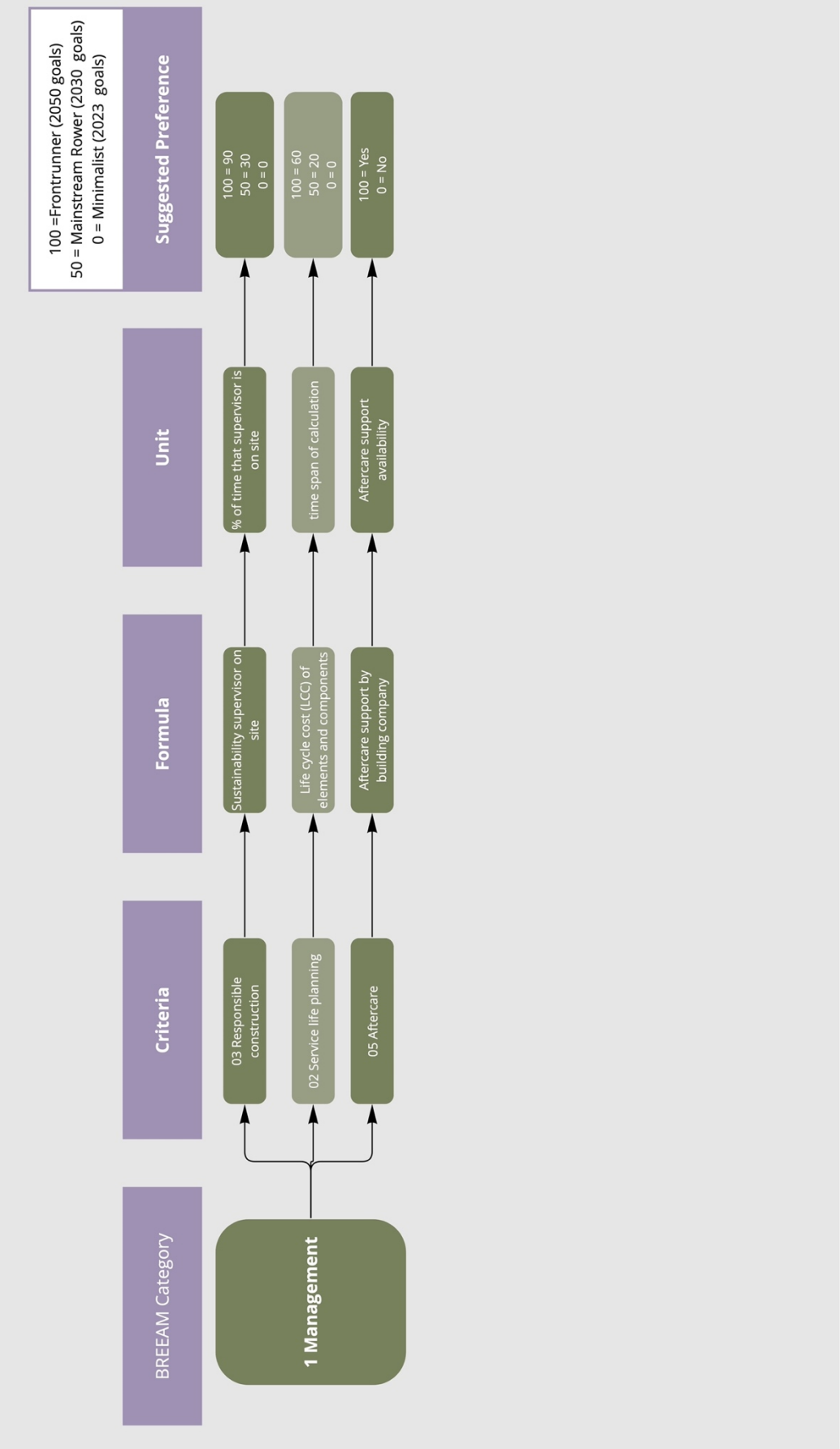



Figure 55 - SuRMo category 1 Management (own illustration)

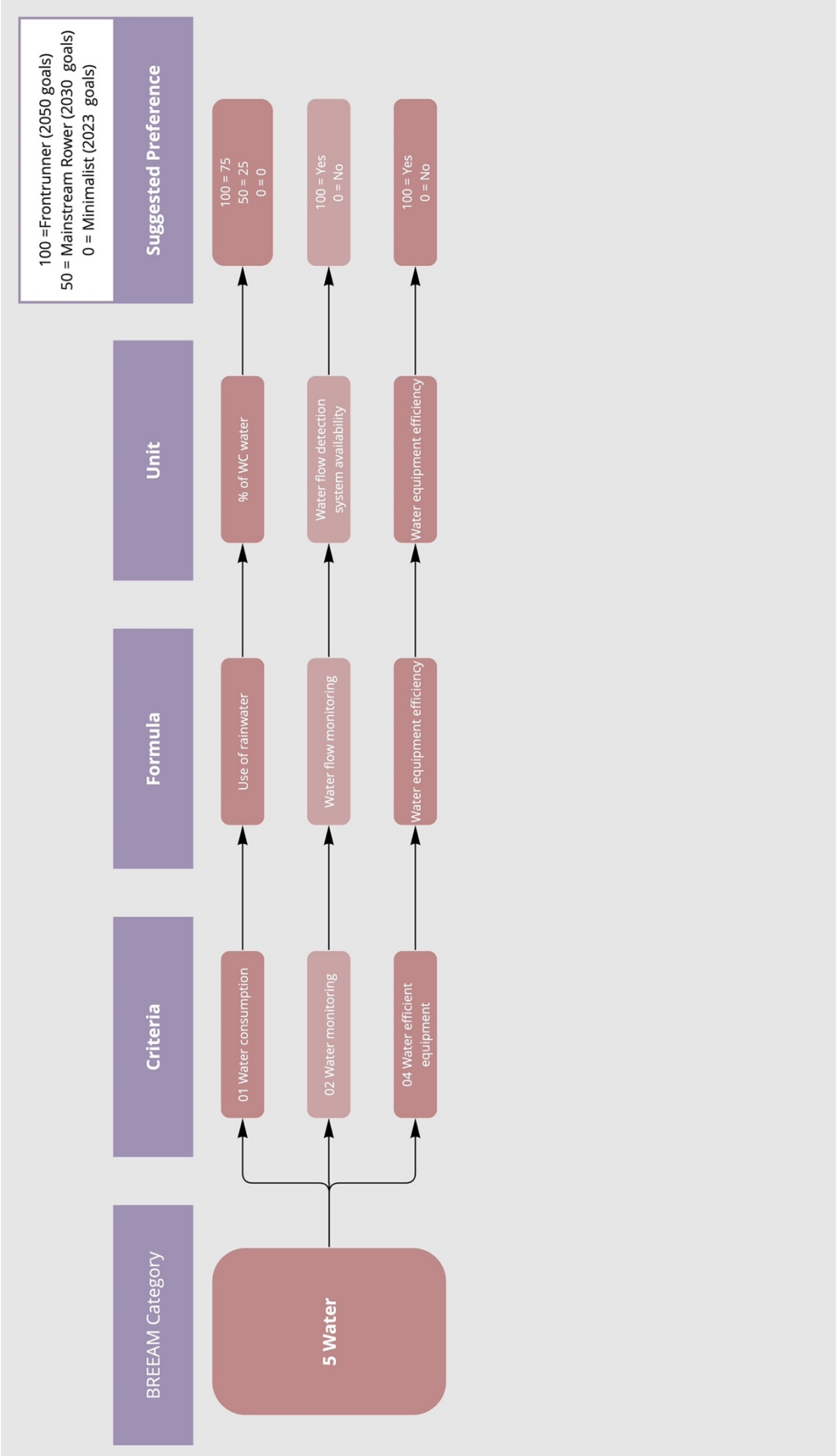



Figure 56 - SuRMo category 5 Water (own illustration)

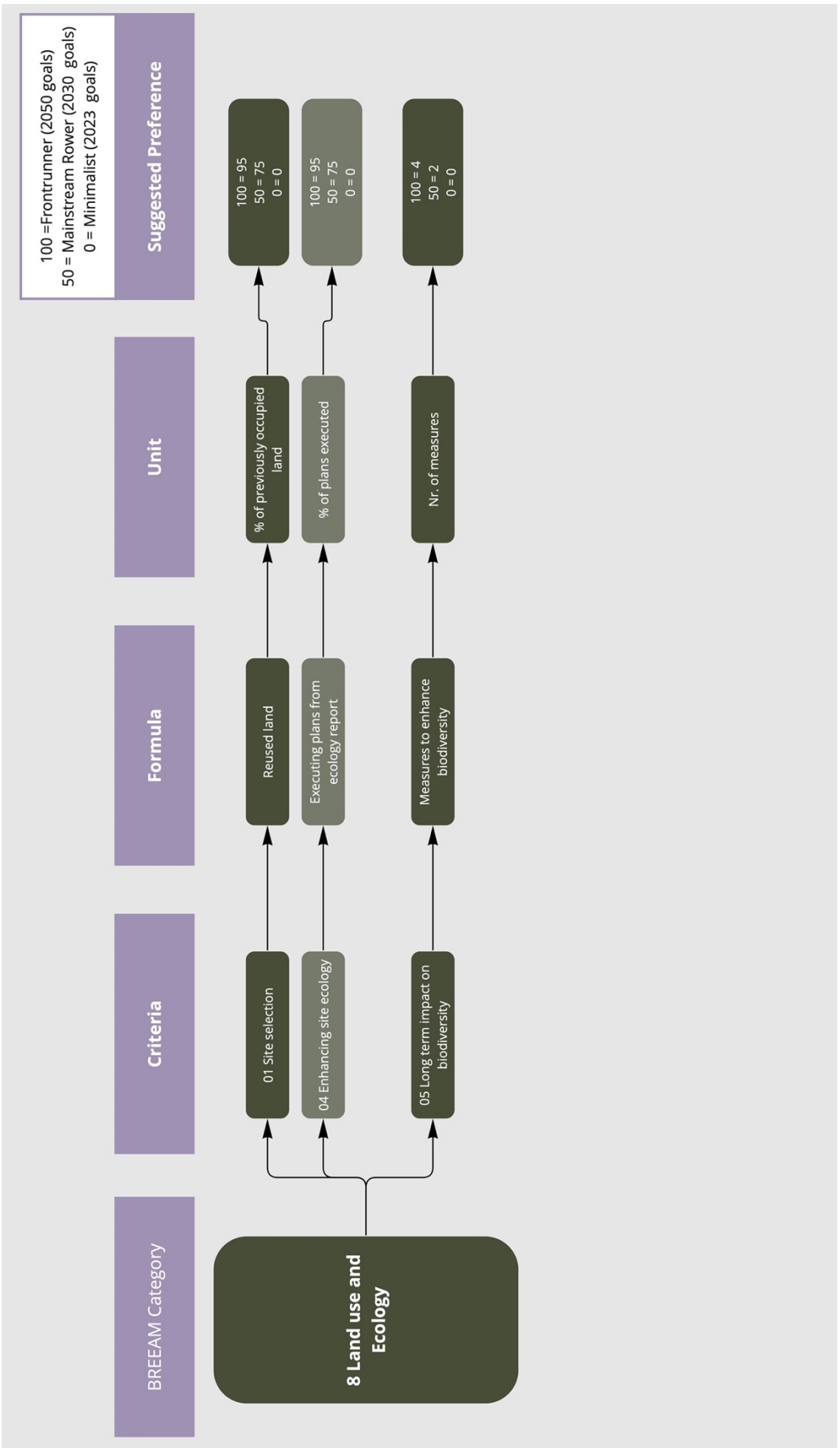



Figure 57 - SuRMo category 8 Land use and Ecology (own illustration)

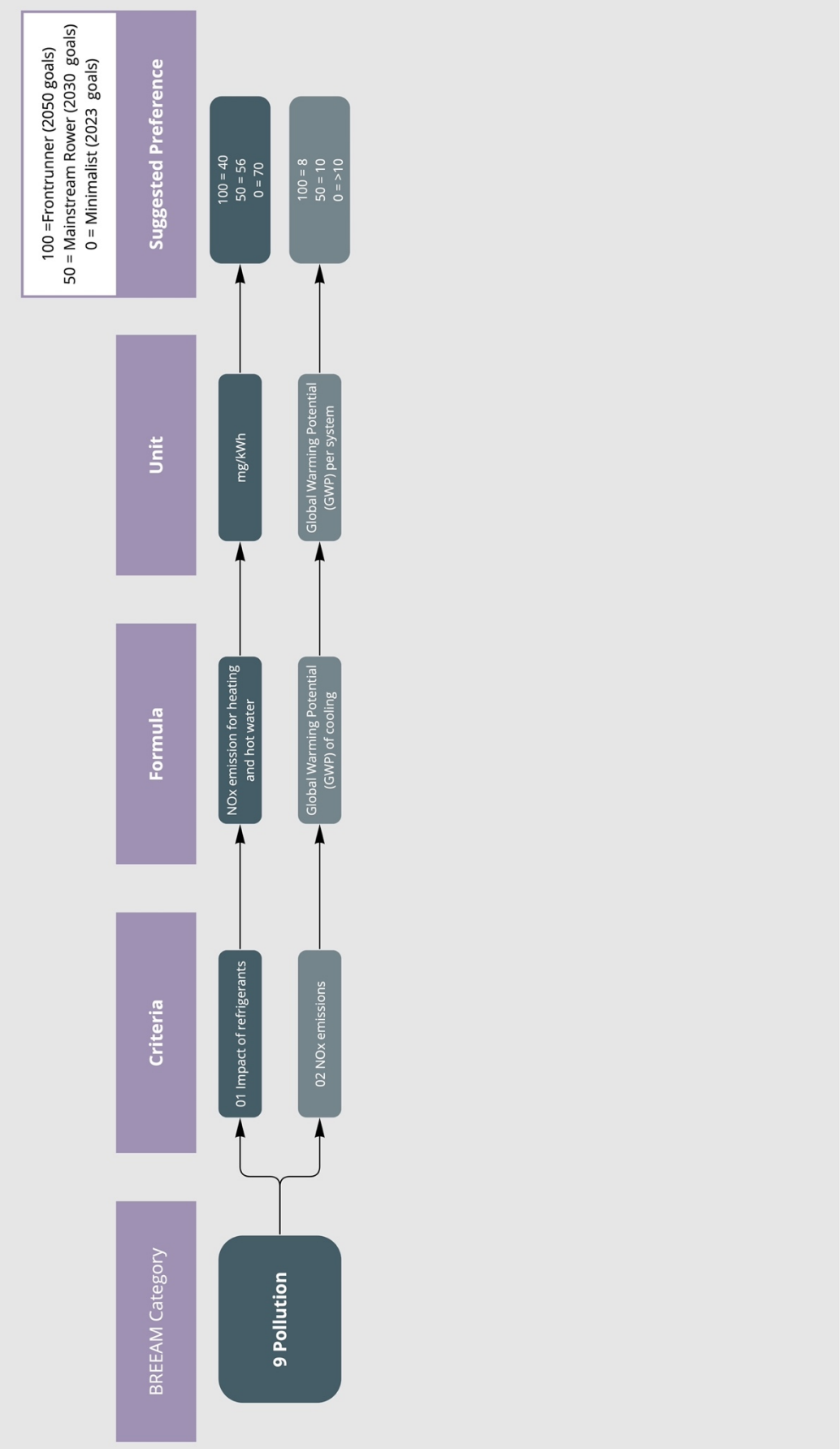



Figure 58 - SuRMo category 9 Pollution (own illustration)

## 4.3. Test 3: Sustainability Reference Model for PAS

The third test consisted of the hybrid presentation of the SuRMo 2.0 to the stakeholders and four individual evaluation interviews.

The SuRMo was presented in the whiteboard tool Miro. All four stakeholders had received a link and password to access the model prior to the presentation. The goal of this test was to identify whether the stakeholders would be stimulated to choose other criteria after being confronted with the model, and whether the chosen criteria in the group *Sustainability* are attributed a higher weight than in Test 2.

The presentation showed the chosen sustainability criteria by the stakeholders next to the categories of BREEAM to depict that more aspects go into environmental sustainability than $CO_2$ reduction, energy label of the office building and potential for further sustainability measures. The goal of the SuRMo was to stimulate the stakeholders in choosing their sustainability criteria for PAS based on BREEAM categories.

After the presentation no changes were made to the criteria in PAS. The SuRMo was considered too complicated to use by the stakeholders.

### 4.3.1. Learnings from Test 3 for SuRMo 2.0

The SuRMo 2.0 was shown to the stakeholders of the pilot study in a presentation in which they were asked to give feedback on the model. Based on their feedback, the model was evaluated as shown in Figure 59 (Presentation, personal communication, April 20, 2022).

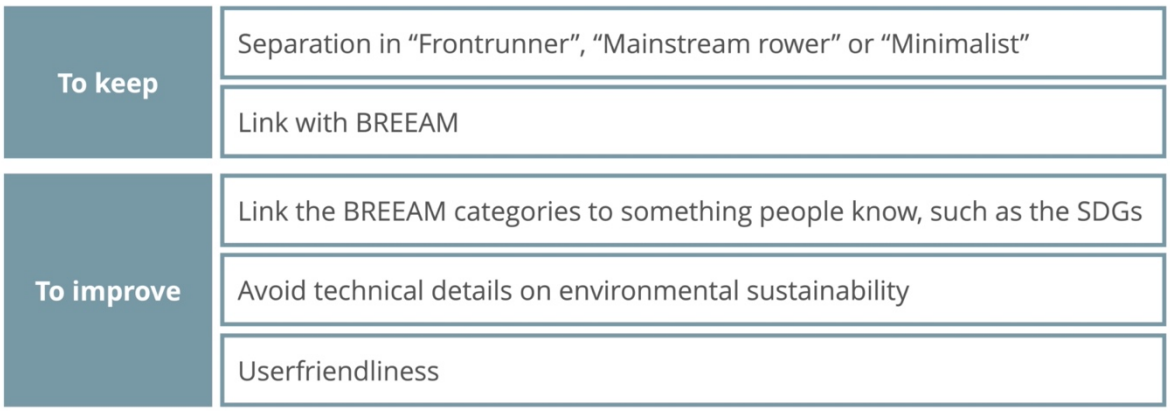



Figure 59 - Evaluation of SuRMo 2.0 (own illustration)

The stakeholders liked that they could refer to an attitude to define how serious they are about sustainability. BREEAM is a well-known GBRS which the stakeholders liked to see back in the SuRMo. However, going into the categories of BREEAM went too far for the knowledge that the stakeholders claimed to have. They proposed that the model would profit from being less technical and if it were to link with strategic goals such as the Sustainable Development Goals (SDG). Lastly, the user-friendliness of the model should be improved and tested with another program than Miro (Presentation, personal communication, April 20, 2022).

## Input for Model 3.0

Based on the learnings of SuRMo 2.0 some first steps were made in the development of SuRMo 3.0. The third model concentrates on linking BREEAM with the SDGs and making the model less detailed and less technical.

BREEAM is a good method to use because it treats sustainability very broadly and the certification method consists of categories that are linked to the SDGs. Organizations tend to work with the SDGs on a corporate level so using the same goals for the CRE strategy seems like a good idea. The SDGs could be ranked SDGs depending on their impact on the environmental sustainability of buildings to create a good overview for organizations (Expert 3, personal communication, December 5, 2022).


Figure 60 - Selection of SDGs with significant relation to BREEAM based on BREEAM (2018)

Based on a study by BREEAM (2018) the SDGs were selected that BREEAM certifications can contribute to significantly (Figure 60). Based on the same document, the BREEAM categories were linked to the selected SDGs (Figure 61).

| SDG | Contribution of BREEAM | Translation to the SERMo |
|---|---|---|
|   | "Encourages the provision of comfortable, healthy and safe internal and external environments for asset users and others within the vicinity" (BREEAM, 2018) | BREEAM Category 2: Health and wellbeing |
|   | "Encourages the provision of water efficient solutions, systems and equipment that minimise water consumption, whilst maintaining a clean and reliable supply" (BREEAM, 2018) | BREEAM Category 5: Water |
|   | "Encourages the provision of energy efficient solutions, systems and equipment that minimise energy consumption and carbon dioxide emissions, whilst maintaining a reliable supply" (BREEAM, 2018) | BREEAM Category 3: Energy |
|   | "Promotes the delivery of sustainable and **resilient** buildings and infrastructure, and encourages and recognises innovations that improve the sustainability performance of assets and provides learning opportunities for wider dissemination" (BREEAM, 2018) | BREEAM Category 10: Innovation |
|   | "Promotes the development of sustainable communities and encourages access to sustainable transport, delivery of affordable and safe homes, implementation of flood **resilience** measures, minimisation of air pollution, and access to public and green space" (BREEAM, 2018) | BREEAM Category 4: Transport |
|   | "Encourages the sustainable **procurement** and use of construction materials by recognising materials that are reused or recycled, are used in an efficient manner, have a low environmental impact, are sourced in a responsible way, and are durable and resilient" (BREEAM, 2018) | BREEAM Category 6: Materials |
|   | "Encourages the sustainable use of energy, minimisation of greenhouse gas emissions, and implementation of **climate change adaptation** and flood resilience measures in one of the biggest contributing sectors globally" (BREEAM, 2018) | BREEAM Category 3: Energy<br>BREEAM Category 7: Waste |
|   | "Encourages sustainable land use, protection and creation of ecological features, and improvement of long term biodiversity for asset sites and surrounding land" (BREEAM, 2018) | BREEAM Category 8: Land use and ecology |

Figure 61 - Linking SDGs to BREEAM categories based on BREEAM (2018)

## 4.4. Test 4: Strict Constraints

Test 4 compares if the outcome of Test 1-3 comply with the sustainability goals of the Dutch government to reduce greenhouse gas emissions to zero kg.

The alternative that has been selected is the newly built office tower Central Part in Utrecht next to Utrecht central station. It follows high standards in sustainability which and has the following characteristics:

- BREEAM Excellent certificate
- Energy saving installations
- Solar panels
- Thermal energy storage in -50m
- Energy label A++++
- Smart facade for interior light and heat regulation
- Charging stations for electrical cars and bikes

Although there is no data on the actual energy use of the building yet, the building is expected to reach the goals for energy neutrality of 2050 (APF International & GroupA, 2021).

Next to goals about greenhouse gas emissions, the Dutch government has also set a goal for circularity. In the year 2050 the whole construction sector should be circular to stop the overuse of scarce resources (Ministerie van Infrastructuur en Waterstaat, 2022). The analysis of the BREEAM certificate of Central Park shows that from the nine categories, the building has the lowest score in the category “Materials” with 58.82% out of 100% (Boerma, 2021). The exact breakdown of the certificate is not shown but it can be assumed that with a score under 100%, the building is not 100% circular.

## 4.5. Comparing the Test Outcomes

Test 1 to 3 were conducted using different methods but resulted in the same decision outcome which was the most environmentally sustainable office building based on the energy label and BREEAM certification (Bouwinvest et al., n.d.). The decision making process that led to these outcomes differed and brought interesting insights about criteria, boundary conditions and decision making approach. In the following paragraphs, these differences and similarities between Test 1 (current approach), Test 2 (PAS) and Test 3 (PAS + SuRMo) are presented.

Table 10 shows the outcome of the decision making processes that were conducted with the pilot study. It shows that with the current decision making process, Colliers decided that Alternative 1: Central Park was the best option for the new office building in Utrecht. In the decision of Test 1, the criterion "Energy label A" was one criterion out of two that related to environmental sustainability. Out of the three boundary conditions, none was related to sustainability. The evaluation of the three alternative offices was done in an implicit way. This means that the FC took the decision for alternative 1 based on the advice of colleagues, the TM, the P stakeholder and the employee representatives (U) without directly expressing their say in the decision (FC1, personal communication, March 22, 2022).

| | Test 1 | Test 2 | | Test 3 | |
|---|---|---|---|---|---|
| **Result** | Alternative 1: Central Park | Alternative 1: Central Park | | Alternative 1: Central Park | |
| **Number of sustainability criteria** | 1 | 5 | | 5 | |
| **Sustainability criteria** | Energy label A | | Stakeholder | | Relative |
| | | Total CO2 reduction on footprint | P | | 2.00% |
| | | Energy label of the office building | P | | 1.50% |
| | | Energy label of the office building | FC | | 7.00% |
| | | Potential for further sustainable measures, example energy contracts | FC | | 3.00% |
| | | Breeam grading | TM | | 3.00% |
| | | | | Total: | 16.50% |
| **Total criteria** | 2 | 37 | | 37 | |
| **Boundary conditions sustainability** | 0 | Space in renovated building | P | No building on greenfield | P |
| | | Presence of electrical charging stations | U | Presence of electrical charging stations | U |
| | | Energy label A | FC | Energy label A | FC |
| **Total boundary conditions** | 3 | 10 | | 10 | |
| **Evaluation** | implicit | explicit | | explicit | |
| **Weights decision makers** | FC: 100% | P: 20%, FC: 50%, U: 10%, TM: 20% | | | |

Table 10 - Outcome of Test 1 to 3

Test 2 and 3 share many similarities in the decision-making process which used PAS (Test 2) and PAS with the SuRMo (Test 3). Using the PAS as a decision-making method in Test 2, the stakeholders defined five criteria out of 37 that were categorized as sustainability criteria. From these five criteria, the “Energy label of the building” was mentioned by the Policy stakeholder and the financial controller, meaning that there were four different criteria out of the five. After being confronted with the SuRMo in Test 3, the stakeholders did not wish to change their criteria or relatives weights to the criteria. Therefore in Test 2 and 3 the sustainability criteria weighted 16.50% out of 100% in the decision-making about the new office space.

In Test 2 three boundary conditions were defined concerning sustainability, namely “Space in renovated building” mentioned by P, “Presence of electrical charging stations” by U and “ Energy label A” by FC. The technical manager did not mention any boundary conditions after naming the criteria. In Test 3, the stakeholders were shown the SuRMo and asked if based on the model or other reasons they would like to change any of their input for PAS. P was the only stakeholder to change the boundary condition “Space in renovated building” because it did not match with the office that had been chosen in Test 1. She mentioned that after thinking about it, the boundary condition should be changed to “No building on greenfield” (P2, personal communication, April 21, 2022). When using PAS in Test 2, the number of criteria increased from 2 to 37 and the number of boundary conditions increased by seven. Between Test 2 and 3, only one boundary condition changed. The reason for this might lie in the fact that the evaluation in Test 1 happened implicitly while in Test 2 and 3, the stakeholders were asked to formulate all their goals for the office building in Utrecht explicitly. Additionally, in Test 2 and 3 the weights of the stakeholders were distributed clearly showing that the FC had a weight of 50% in the decision-making process but let himself be influenced by the other stakeholders for the remaining 50%.

The following chapter will go into the discussion on the meaning of these results.

# 5

# Implementing and Maintaining the Solution

# 5. Implementing and Maintaining the Solution

In this chapter the results are discussed, limitations are mentioned, the research questions are answered in the conclusion and recommendations are formulated for further research.

## 5.1. Added value of PAS and SuRMo

In this section, the added value of PAS and SuRMo is discussed for the implementation of environmental sustainability in the decision-making process about CRE. It covers issues of accountability, the use of PAS as an assessment tool, added value and the use of PAS and SuRMo in real life cases of Colliers.

### Added Value of PAS

The added value of PAS for environmental sustainability in decision-making was shown in the difference between Test 1 and Test 2.

The biggest change between the two decision-making processes was that the evaluation went from implicit to explicit. This means that in Test 1, the decision was made based on little information about the three alternative office spaces and that the criteria were not clearly expressed. With PAS, the decision-making process was explicit, meaning that the stakeholders were asked to clearly formulate goals, criteria, preference and boundary conditions for the new office building. It showed the building characteristics that were valued by the four stakeholders and therefore PAS modeled stakeholder preference explicitly. For the criteria about environmental sustainability, this meant that the energy label was the criterion for the office building according to the FC. When using PAS, the stakeholders measured sustainability not only by the energy label but also by three other criteria and three boundary conditions. This resulted in a set of criteria and boundary conditions that take more aspects of environmental sustainability into account that the energy label does alone.

Measuring the exact added value in terms of environmental sustainability was out of the scope of this research. However, the increase in explicit criteria and boundary conditions on the environmental sustainability of the office building in Test 2 can mean two things. Either, the stakeholders had already taken all those criteria into account in Test 1 but were not able to express them in the implicit decision-making process, or the stakeholders were motivated by the PAS method in Test 2 to expand their set of criteria concerning environmental sustainability. After conducting this research and interviewing the stakeholders, it is most likely that the answer is a combination of the two. Even though the energy label was the only sustainability criteria in Test 1, the same office building came out as in Test 2 which leads to believe that the first statement is true. This outcome could also come from the fact that this research was introduced as a research that studies environmental sustainability in CRE decision-making.

Based on the increased number and variety of criteria and boundary conditions Test 2, it can be assumed that using PAS can stimulate stakeholders to make more sustainable decisions in CRE.

### Added Value of PAS with SuRMo

The added value of the SuRMo for environmental sustainability in decision-making was shown in the difference between Test 2 and Test 3. The stakeholders had already used PAS in Test 2 and were presented the SuRMo in Test 3. After the presentation, the stakeholders had the possibility to change the input of Test 2 if they had the wish to do so.

The SuRMo did not lead to any changes by the stakeholders in Test 3. This can mean that the stakeholders were already satisfied with their own input in PAS (Test 2) and did not see any added value in the SuRMo. The evaluation interviews confirmed that the stakeholders did see an added value in the idea of the SuRMo but that it would have to be further developed to be used with PAS. The SuRMo was based on the BREEAM rating system which the stakeholders had already mentioned as criteria in Test 2. This could mean that the stakeholders did not feel the need to go into the categories of BREEAM if they already defined the overall BREEAM rating as a criterion. The TM was the only stakeholder that had set "BREEAM grading" as a criterion. This criterion was listed in the presentation of the Test 2 results which might have signaled to the other stakeholders that BREEAM was therefore already included in the decision-making process and did not have to be added by them.

These arguments lead to the assumption that the added value of the SuRMo was lower than the added value of PAS for the inclusion of environmental sustainability in the decision-making process.

### Accountability

This subchapter questions the accountability of the stakeholders using PAS and the SuRMo. PAS is structured in a way that allows the decision-making process to be transparent and therefore stakeholders can be held accountable for their goals, criteria, preference and boundary conditions. This necessitates that stakeholders have to define goals, criteria, measurements, preferences and attribute weights themselves (Arkesteijn, 2019).

The SuRMo supplies the stakeholders with knowledge on sustainability leading to accountability of stakeholders that can be discussed at two levels. The first is that with PAS, the stakeholders can be held accountable for any input they define because of the transparent nature of PAS. If PAS is done openly, stakeholders can question each other's input and the reasons or morals behind it in a discussion. The second is that when the stakeholders have seen the SuRMo, they can be held accountable for not implementing the newly gained knowledge from the SuRMo. They would have to explain their reasons for not defining sustainability criteria and therefore taking clear consequences into account. This accountability is directed towards the other stakeholders and possibly to other actors that are involved in or affected by the decision-making.

Nevertheless, when it comes to defining criteria about environmental sustainability, the stakeholders in the pilot study have expressed the need for more guidance from an expert instead of the presented SuRMo. As the Financial Controller explained in the evaluation interview: "Sustainability is a container term for me. I give it a high weight but I do not have the knowledge to go deeper into that topic." (FC2, personal communication, April 21, 2022). The SuRMo was not clear and concise enough to compensate the lack of knowledge: "[A sustainability consultant] would have to provide a menu of choices. And also that menu of choices would be dependent on each individual building" (FC2, personal communication, April 21, 2022). The Policy stakeholder who works as CRE consultant agreed that a sustainability expert should be involved at some point in the decision-making process. From her experience, clients do not know much about sustainability and often think that sustainability is important, but that cannot name it in more detail. (P2, personal communication, April 21, 2022). The reason for this might be twofold. Firstly, the SuRMo might not have been user friendly for the stakeholders to see it as a replacement for a sustainability expert Secondly, the stakeholders were all consultants used to

getting filtered advice from a person instead of looking for the information themselves which they would have needed to do in the SuRMo.

A possible solution would be to include a sustainability expert as stakeholder when using PAS for decision-making or mentioning that an expert was involved in developing the SuRMo. The expert would ideally be an internal expert that knows about the sustainability goals of the organization and that the stakeholders trust. The accountability of stakeholders would be safeguarded, and the sustainability criteria would possibly be relevant to the CREP goals of the organization.

### PAS as assessment method

The decision in the pilot study was about the choice between three possible office buildings for the expansion of the CRE portfolio of Colliers. PAS was used as a decision-making method for evaluating alternatives but it is also usable as a design and decision-making approach on a portfolio level which was not studied in this research (Arkesteijn, 2019). P would use PAS again in her work of developing CRE strategies for clients (P2, personal communication, April 21, 2022).

### The use of the SuRMo in real life cases

According to an interviewed sustainability consultant, clients find it very difficult to define technical sustainability criteria. The energy use of a building is on the limit of what clients find tangible about environmental sustainability. For criteria that are more technical more generic goals need to be presented that organizations can use. At Colliers they try to do exactly that in their consulting practices. They try to make sustainability more tangible for clients and to implement sustainability in more projects. To rate the sustainability of a building, a large set of building characteristics is needed which are not always available. This means that consultants and clients always depend on the available data of buildings. If the SuRMo were to be used on a strategic level, an organization could include sustainability in their demands when searching for new buildings to rent. The people searching for available office space can then use those requirements when selecting the right building for the organization. Therefore PAS can be used on a strategic level and as assessment tool. If the model is used on a strategic level, an organization could include sustainability in their demands when searching for new buildings to rent. The people searching for available office space could then use those requirements when selecting the right building for the organization (Expert 3, personal communication, December 5, 2022).

## 5.2. Limitations

This research has a set of limitations that need to be considered. The limitations concern the pilot study, the use of PAS and testing the SuRMo.

### Stakeholder choice

In PAS, "The responsible manager in the organization, sometimes in conjunction with the responsible real estate manager, selects the different types stakeholders who will be involved in the project." (Arkesteijn, 2019, p. 167). In the pilot study of this thesis, the real estate manager (Policy stakeholder) took the initiative to use PAS and therefore made the stakeholder selection. In the evaluation interview the Financial Controller, who is responsible for the CRE decision in the board of Colliers, was asked if he approved of the stakeholder selection. In response, he mentioned that when choosing an office building "At any company, the board ultimately makes the decision" (FC2, personal communication, April 21, 2022).

### Pilot study is RE consultant

The second limitation is that Colliers operates as an RE consultant. This means that the stakeholders might have more knowledge on buildings than stakeholders of other organizations. Additionally, their business model is based on advising other organizations, which might make them look at PAS as a tool to consult their clients.

### Lagrange instead of PCHIP

The preference scores of the pilot study were calculated using the Lagrange curve instead of the PCHIP curve. The problem of preference scores below 0 or higher than 100 using the Lagrange curve had been predicted by Arkesteijn & Binnekamp (2012). The Lagrange curve was still used in Excel because the PCHIP curve requires using a program called Matlab which was out of the scope of this research. The calculations resulted in a few preference scores outside the range of 0-100. All the results were checked and the results that were incorrectly calculated were visually determined in the PAS webtool where the PCHIP calculation is integrated. The effect of this on the preference scores is neglectable.

### Limit of time

In the pilot study, PAS was used as assessment tool and did not include the design and decision room (Arkesteijn, 2019). The outcomes of the first round of interviews were presented in a presentation and not as intended by Arkesteijn (2019) in form of a workshop. The User in the pilot study mentioned that he would have liked to have interacted and discussed more with the other stakeholders about their input (U2, personal communication, April 25, 2022).

### Integrity of stakeholder input

The integrity of the stakeholder input might be compromised in Test 2 and similarly in Test 3 because of two reasons. Firstly, the pilot study was only used after the decision for the office building had already been taken by the Dutch board of Colliers. This means that the outcome of the study would not have influenced the actual decision of Colliers and the input in PAS was partly made with the outcome of the decision-making already in mind. "The preferences were ultimately the reason for us choosing Central Park so I would be surprised if it resulted in a different outcome" (TM1, personal communication, March 21, 2022)

Secondly, the User expressed his concerns due to existing power positions: "What you have to take into account with this kind of situation is that there are also different power relationships. For example, [the FC] is obviously the boss of everyone else in the meeting." (U2, personal communication, April 25, 2022)

### Test 3

The third test where PAS was tested with the addition of the SuRMo 2.0 did not bring the expected results. The stakeholders quickly found the model too detailed and technical which led to them not using the model. Therefore the feedback on SuRMo 2.0 was limited.

## 5.3. Conclusion

This section presents the conclusions that are drawn from the research by answering the main research question and the research sub questions. Figure 62 is presented again to show the connection between the research questions and the research method. The research sub questions will be answered first as they lead to the answer of the main research question which was the following: How can environmental sustainability be integrated in the decision-making of Corporate Real Estate Portfolios when using the Preference-based Accommodation Strategy?

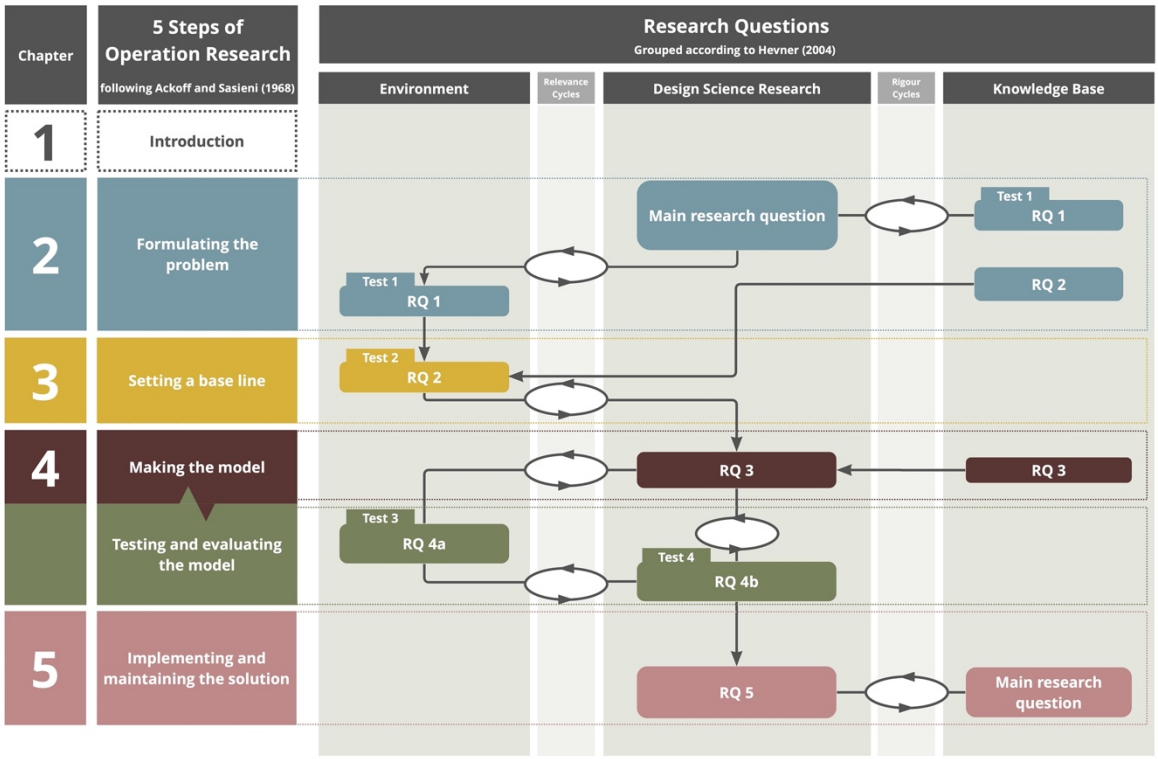



Figure 62 - Connection of research questions to the research method (own illustration)

1. Formulating the problem
    a. What is the state of the art in decision-making about environmentally sustainable CRE?

This question requires an answer based on the outcomes of the literature study and Test 1 from the pilot study. The literature study found that many decisions on sustainable CRE are based on financial criteria but that criteria on sustainability become increasingly important (Khanna et al., 2013). However, the mismatch between supply and demand often means that sustainable buildings are scarce on the market and that organizations risk that their goals on sustainability are not met (Keeping & Cadman, 2000). These findings from literature were confirmed by the interviews with the stakeholders of the pilot study. In the current approach of Colliers described by the FC, criteria on financial feasibility, location and availability of the required office area weigh heavier than sustainability criteria.

2. Setting a base line
    a. How do decision makers include environmental sustainability in the CREP when using PAS?

The outcome of Test 2: Decision-making with PAS provides the answer to this research question. The second test showed that the stakeholders defined significantly more (and different) criteria and boundary conditions when PAS required them to explicitly describe what they value in the new office building. This was also true for the sustainability criteria. With PAS, the stakeholders had to define a weight to the criteria which they did not do with their current approach. The criteria related to environmental sustainability made up 16.5% of the preference scores of the alternatives. The alternative that received the highest preference score in Test 2 was the same office building that the Colliers board had approved in Test 1.

3. Making the model
    a. How can a reference model for PAS stimulate decisionmakers to choose criteria that lead to environmentally sustainably CREP?

The answer to this research question results from developing the SuRMos and testing SuRMo 2.0 in Test 3 are relevant. The idea of providing the stakeholders with a SuRMo was well perceived but many issues remain to be solved. The feedback from the stakeholders was mainly that the presented model was too detailed and required too much technical knowledge on environmental sustainability. Stakeholders would profit from a model that is integrated in the PAS webtool and that is based on goals and criteria that they can relate to such as the SDGs.

4. Testing and evaluating the model
    a. How does the reference model change the decision outcome about CREPs?

This research sub question was answered in the comparison between the test outcomes. The three tests resulted in choosing alternative I: Central Park Utrecht. This office building was already chosen prior to this research and scored highest on sustainability criteria set by the stakeholders. The developed SuRMo in this thesis did stimulate the stakeholders to change their input in PAS compared to Test 2.

    a. Do the decisions of the decision makers meet the sustainability goals of the Dutch government for 2050?

Test 4 has shown that the building that the stakeholders have chosen in Test 1-3 does meet the goal to reduce the greenhouse gas emissions to zero by the year 2050. However, the building was not built following circular building goals and therefore does not meet the sustainability goals for 2050 fully.

5. Implementing and maintaining the solution
    a. How can PAS and the reference model be implemented in future decision-making processes?

The discussion section of this research provides the answer to the two parts of the last research sub question.

The discussion has shown positive outcomes by changing the decision-making process from the currently implicit approach to an explicit approach with PAS. In terms of sustainability, the outcome was equally positive because the stakeholders in the pilot study included clear criteria and boundary conditions for the environmental sustainability of the new office building in Utrecht. Using PAS and the webtool worked smoothly and was well perceived by the four stakeholders

which is promising for future use of the same method in a professional setting. PAS could be used in future decision-making processes by CRE consultants to advise clients on their CREP.

The idea and concept of the SuRMo was well perceived by the four stakeholders of the pilot study but further development is needed to test it's added value for PAS. The interviews shoed that many aspects of environmental sustainability in buildings are too technical and intangible for people of other expertise to understand. This is why the need or decision support for sustainability goals was confirmed by the stakeholders of the pilot study.

Further research is required with different pilot studies to test whether using PAS suffices to stimulate stakeholders to include environmental sustainability or that an improved SuRMo achieves a more stimulating effect in decision-making about CRE.

***Main research question: How can environmental sustainability be integrated in the decision-making of Corporate Real Estate Portfolios when using the Preference-based Accommodation Strategy?***

PAS has shown to be a useful and valued way to make the implicit decision making explicit. The PAS webtool that was shared on a screen was useful during the interviews because the stakeholders could directly see the impact of their choices in PAS. It also helped to create an overview of the input and puzzle with the weight distribution for the stakeholders to be confident that their input reflected their preference. The PAS webtool could certainly be used in practice to professionalize decision-making in CREP.

From developing the SuRMo it became evident that environmental sustainability in buildings entails more than just $CO_2$ emissions. Governments use $CO_2$ emissions to set main objectives to their goal to become greenhouse gas neutral at a certain point in the future. However, for the preservation of a livable planet, aspects such as biodiversity, resource scarcity and circularity play a major role. These aspects are covered by GBRS such as BREEAM which is why the SuRMo should be based on them instead of on the emission of greenhouse gasses. The stakeholders from the pilot study did formulate sustainability goals but felt the need for decision support in that category. For future pilot studies and use of PAS in practice it is important to have a further developed SuRMo to stimulate stakeholders to implement sustainability in their decision-making.

In conclusion, PAS proved to be a helpful tool for explicit decision-making in CRE and the development and use of a SuRMo is encouraged for CRE consultants working with clients. The applicability of the SuRMo will depend on the knowledge clients have about environmental sustainability in RE. Clients with basic knowledge could use the SuRMo as a checklist for the completeness of their sustainability goals, criteria and boundary conditions. Clients with little knowledge could use the SuRMo to learn about sustainability in RE, how it links to their corporate values and goals and use it to formulate their input for PAS.

## 5.4. Three recommendations for practice

The three main findings are highlighted in Figure 63.

Apart from the answers to the research questions, this research found three main recommendations for practice which are listed in Figure 63.

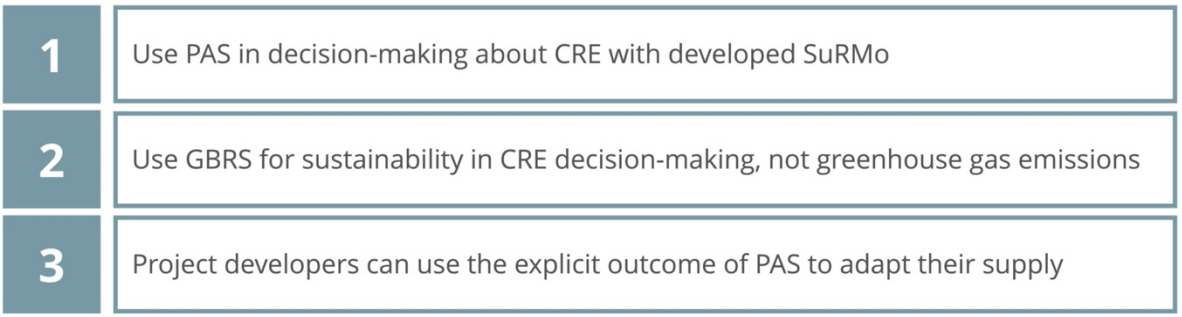



Figure 63 - The three main conclusions of this research (own illustration)

Firstly, the pilot study showed that PAS was a useful tool for explicit decision-making and that it would profit from a further developed SuRMo. The stakeholders in the pilot study defined sustainability goals without the SuRMo but mentioned they were whether their sustainability goals were the most beneficial for a sustainable office building. In the case of Colliers, an improved model would be used to check if the input matches the literature on sustainability in buildings. In other organizations that do not work in the field of sustainability or RE, the model could be used to introduce the topic of sustainability to the stakeholders and to guide them in defining sustainability goals in PAS. In any case, using a SuRMo for PAS has not resulted in any negative effects and could teach, guide or confirm stakeholders in the decision-making about their CRE.

Secondly, the Dutch government has set sustainability goals in maximums of greenhouse gas emissions that can be emitted. However, the Dutch Green Building Council (DGBC) continuously updates the BREEAM rating system that rates buildings on various aspects of environmental sustainability. Aspects such as biodiversity, natural building materials and circularity have many benefits are part of working against climate change and should therefore also be included in the CRE decision-making process. By developing the SuRMo in close collaboration with the DGBC and existing GBRS, stakeholders are stimulated to look at sustainability goals that go beyond $CO_2$ reduction.

Lastly, when organizations start to use PAS and SuRMo in their decision-making about CRE, they might start to formulate explicit demands for sustainable CRE. For investors and project developers this means that they might need to adapt the supply on the market. Current rules and regulations about new buildings already have high sustainability requirements. A more significant adaptation might be required to increase the renovation of existing RE to adapt it to the demand on the market. For the project developer of the pilot study, the outcome of this research confirms that they have built a building that matches the criteria and requirements of organizations.

## 5.5. Recommendation for Further Research

In further research, the following points could be studied to validate and continue this research:

- Integrate the learnings form SuRMo 2.0 to develop and test SuRMo 3.0 in the same or different pilot study.
- Include all aspects of Environmental Social and Governance (ESG) in the SuRMo 3.0 (Expert 1, personal communication, April 15, 2022; FC2, personal communication, April 21, 2022; P2, personal communication, April 21, 2022)
- Test the SuRMo 3.0 with other organizations working in different sectors
- Test the SuRMo 3.0 in a pilot study with a strategic decision-making problem about a CREP and use the PAS design and decision room approach (Arkesteijn, 2019)
- Test the SuRMo 3.0 when PAS is used in full transparency about the criteria and (stakeholder-) weights (Arkesteijn, 2019)
- Include a sustainability stakeholder in a pilot study to test the different outcomes with and without the SuRMo 3.0. This would lead to a new limitation because not every organization has an employee that could be the sustainability stakeholder.
- Test SuRMo 3.0 and develop it further to improved versions of the SuRMo and keep it up to date with regulations and updates in the knowledge base.

# Reflection

The last subchapter of this thesis is a reflection that covers the topic, the method, the findings and the conclusions. I will also reflect on the potential to use the results of this thesis in practice and discuss ethical issues.

This thesis "Stimulating Sustainable Corporate Real Estate" has a tight connection to the master program Management in the Built Environment. As a lecturer introduced in one of the first lectures: "Management is a set of activities, resulting in the deployment of means, directed at an area of attention to achieve a desired objective within a given context." (Vande Putte, 2020, p. 15). In this thesis I studied the management or decision-making of organizations for their CRE and found ways to make the outcomes more environmentally sustainable. In a sense in my research was linked to the definition of management.

- Interviewing stakeholders an testing PAS and the SuRMo with the stakeholders was a set of activities;
- that resulted in the definition of goals, criteria, boundary conditions and weights in the PAS webtool and with the SuRMo which were means to make the decision-making process explicit;
- at a real estate consultancy organization which was the area of attention;
- focussing on an objective which was searching for a decision-making process that would lead to a sustainable office building;
- within the context of this master thesis and a graduation internship.

For the research I worked with my thesis mentor Monique Arkesteijn to further research the Preference-based Accommodation Strategy and study it's applicability for organizations to find more sustainable CRE. This was especially relevant considering that the PAS webtool could be tested and that the topic of sustainability matches the theme of this year's Lustrum of TU Delft: Speeding up the energy transition. Early literature that I found on the topic of sustainability in CRE mentioned many reasons why organizations would benefit from having or renting more sustainable RE. However, in recent years regulations are being introduced which do not leave organizations with other options than to make their CREP more sustainable. Still the decision-making process to get to sustainable buildings was not clear for me yet and has shown to be top down (Test 1). With the development of the SuRMo, more organizations could be confronted with the need and feasibility of making their CRE more sustainable.

The method that I used in this research was the operation research method by Ackoff and Sasieni (1968) linked with the design science cycles by Hevner (2004). This allowed me to develop a sustainability reference model with an iterative design approach that I was already familiar with from architecture projects. It was a new way to look at the design approach by actively knowing that the design cycle linked to the environment of the knowledge base. The research method itself was also made in an iterative approach because new developments of the research made the method more clear step by step. The strong point of the chosen methodology was the adaptability and openness for multiple iterative cycles in the development of the SuRMo. The PAS was also a big part of the research method which was followed according to the research of Arkesteijn (2019). The PAS method was very well thought through but was initially complex to understand. Having a webtool to support researchers and consultants in practice use PAS is a great development which is still under construction and will hopefully soon be able to also replace

the preference score calculations in MS Excel. A weak point of this research method was that it was quite time consuming for stakeholders to participate. In the beginning the plan was to do the whole PAS design and decision making approach with the CREP of Colliers. However this would have taken between six to eight hours from stakeholders which they did not have. It is to be researched if this time is also considered too long for a real life consultancy mandate. In this research this has been overcome by focussing the research on the new office building in Utrecht instead of on the whole CREP of Colliers.

This research was conducted during a graduation internship at Colliers who are interested in using PAS for their CRE consultancy work. For this reason, researching this topic has shown how the CRE Strategy team could use PAS and which steps, opportunities and difficulties it brings. The SuRMo has highlighted the difficulty of making sustainability tangible for people to understand and form an opinion about. However, it has also shown that there is a need to inform stakeholders about sustainability before they can define input for PAS in an educated manner. The influence of PAS and SuRMo on the sustainability of the decision was difficult to measure. It was out of the scope of this research to identify if the decisions resulted in a very sustainable building because PAS modelled the implicit decision-making process or if PAS stimulated the stakeholders to define more sustainability goals. The fact that the outcome was the most sustainable alternative could have a positive effect on the clients of Colliers if the clients see the offices of Colliers as best practice and would like to follow.

Laslty, the ethical issues and dilemmas are discussed. The SuRMo of this research challenges the responsibility of decision makers to make sustainable choices. As mentioned in the discussion about accountability, the decision makers are making choices that have an impact on their employees but also on the environment. The FC has the professional responsibility to rent office space that follows the rules and regulations for office spaces but also the role responsibility of leading by example for the clients of Colliers. A moral dilemma that has been identified is the transparency of and the hierarchy in the decision-making process. By conducting this research, stakeholders such as the User were involved in the decision making process that were not involved in the current decision-making. Additionally, the distribution of the weights per stakeholder were not shown transparently as requested by the problem owner.

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