A support system for strategic decision making in a Sea Rescue Institute

By applying a Multi-criteria Decision Making model and theory

W.M. van der Hilst Karrewij

In cooperation with the Koninklijke Nederlandse Reddingmaatschappij

TU Delft

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by

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KNRM TU Delft Koninklijke Marine

Preface

A Masters thesis is quite an investment in time, effort and commitment. Indeed, an investment with many returns, learning opportunities, contacts, insights and many more. So, from the start, I have been looking for an opportunity to do a research project with a practical use and a positive impact. During the study, we did a project with the Koninklijke Nederlandse Reddingmaatschappij (KNRM). The cooperation was great and the project was a great success. Therefore, it would be great to do a project for this charity once more. Although a research question wasn't immediately obvious, the KNRM was found to be open to the idea. And in an initial brainstorm session possible subjects immediately started to emerge.

One of these topics was the implementation of sustainability within the organisation. Although the organisation expressed the need to address this as an important topic for the future and even assigning it as a strategic theme, initially no implementation of the theme existed. The organisation struggled to break with some paradigms existing within the organisation. The question was raised what role sustainability played in the decision making on strategic innovation decisions. This proved to present an angle for a research. How could the decision making structure deal with ever increasing complexity of decision making, incorporating ever more criteria, of which the integration of sustainability was only symptomatic. This topic had the potential to provide the KNRM with a solution that could offer a solution for the time to come.

This topic grabbed me from the start, both as a volunteer crew member on the local lifeboat and strategic decision making on innovation topics having intrigued me both during my studies and in my professional life. The research topic thus suited me perfectly and I am glad I got the opportunity to pursue it. Therefore, I would like to thank the KNRM for their openness and support embracing this study, supporting me and bearing with me, even as the time path changed numerous times. It was an honour and a pleasure to do a research study knowing it may benefit such a beautiful organisation and support its aims of saving lives at sea.

This research couldn't have succeeded without the help of many. First of all, I would like to thank the founder and his team mate from Next Generation Machinery. They helped me in particular with the validation case and their critical engineering skills. I would also like to thank my peer and fellow student Marina van Oord, who helped me by critically reviewing my work and providing valuable feedback.

The study provided me with many opportunities to get to know the organisation and the people working for it. It was great to get to know the participants and learn from them. Talking to you always gave me extra energy to continue working and I felt supported both in underlining the research aim as well as the way in which I implemented and executed the research. I would like to thank in particular Hans van der Molen, who helped me setting up the research and keep my feet on the ground. I would also thank Gert-Jan Wijker for his support in this process, reviewing my work, participate in the supervisory committee and providing advise and support throughout.

One of the most telling moments showing the commitment of the KNRM to make this study a success, was when I received a phone call on a Sunday evening, as the CEO was busy providing input for the research in his free time. This was a fantastic mental booster and support.

This research project lasted for a significant period of time, in which many life-changing events took place in my personal life. This asked for the flexibility and indulgence of both the KNRM and the supervisory committee on numerous occasions. The thesis period coincided with the COVID-19 period, from the first national lockdown until receiving my vaccination and eventually being able to defend my thesis physically at the University. The COVID period impacted the research as it hindered personal contact and necessitated executing many interviews and conversations via telephone or through online virtual means. It really showed the richness of non-verbal communication and the many things the online means as of now cannot replicate or compensate. Not having them felt impersonal and made it more

difficult to truly connect with the interviewees.

The supervisory committee supported me a lot as well. A call for support or discussion with the second supervisor, ass. professor Jafar Rezaei never went unanswered and his expert knowledge on the subject of Multi-criteria Decision Making (MCDM) helped me significantly to improve the implementation on a technical level.

In particular the meetings with the first supervisor, ass. professor Roland Ortt, were a great stimulant throughout and helped me on many accounts. Our conversations easily switched from dealing with scientific matters, technical matters as well as on a personal level. His huge experience both in guiding theses, doing research and dealing with the major changes in life helped me overcome many obstacles along the way and providing me inspiration to keep going and absorb all challenges along the way. For this, I owe much gratitude to the entire supervisory committee and to Roland Ortt in particular. Although a meeting with the supervisory team always resulted in additional work, it also made me grow.

One of the life-changing events that took place at the start of this research was the birth of my daughter, making me a father for the second time. And my oldest child has started an educational career of his own. Also, I started working as a policy advisor for the Netherlands Coastguard. This allows me to continue working in the field of sea rescue and support the safety of seafarers in the Netherlands waters. All in all, the research period has been emotionally challenging and a lot of important matters fought for my time and attention. This made it very hard at times to give the research the attention it needed, while maintaining the right balance with other things going on simultaneously. But I gave it my best and I am proud of the end product. With the help of the aforementioned people, but also with the support of my family.

W.M. van der Hilst Karrewij
Harlingen, June 28th 2021

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Introduction

Rescue at sea is an activity that is full of contradiction. When your life is in danger whilst at sea, you want to be rescued as soon as possible. You want a rescue vessel shown in figure 1 to have an engine as big as possible, to be at your location the soonest. You don't mind any noise or exhaust fumes, as long as it is fast and have the right equipment to take you ashore, back to safety. On the other hand, when you are not in an emergency, sailing along the shore on a beautiful sunny afternoon, a rescue vessel passing you by at full speed aggravates. They make large waves, rocking your boat. They make a hell of a noise. And when they have passed you still smell their exhaust. This contradiction is illustrative for the problems the Koninklijke Nederlandse Reddingmaatschappij (KNRM) has to deal with. And these decisions become ever more complicated in the light of the increase in traffic on the waterways and pleasure crafts crowding the limited available space, in particular in the tidal streams of the Netherlands. This, amongst others, leads to a more informed, opinionated and demanding general public. And the relation of the KNRM with the general public is a complicated one, as the KNRM is not only responsible for providing safety, it also depends on the general public for donations. The general public grows more diverse in their demands, no longer taking the KNRM for granted. As an organisation therefore, the KNRM needs to seek an ever more complicated balance, involving ever more and diverse criteria towards its performance. Providing safety is by far not the only criteria relevant for mission success!

Presenting the case

This research aims to counter this increasing burden by providing a tool that may assist in seeking the balance amongst all criteria. And, ultimately, aid the KNRM in finding the balance. This research is based on the principle that one can only support an outcome if it reflects ones beliefs (and values). Within the KNRM, there is a trend towards incorporating many aspects of the values that gain traction in the world around the organisation, such as sustainability and environmental awareness. Therefore, the research will take the organisations preferences as a starting point when judging decision problems. Then again, achieving these aims in an optimal and balanced manner, is a daunting task. This holds in particular for a small organisation like the KNRM, employing only around 30 people. This research thus aims to introduce a tool assisting in decision making, whilst not enforcing an outcome upon the decision makers.

Nowadays, there is a trend amongst corporations and for products to become more and more sustainable. This is one of the criteria that is supported by a steadily increasing part of the general public, receiving ever more attention nowadays. Yet, the meaning of the words 'sustainable' or 'sustainability' are ambiguous and almost as diverse as are the companies and products that label themselves under these terms. Whilst labels and certificates for screening under 'universal'[1] standards emerge everywhere around us, also here a wide range of definitions is used for the terms. Furthermore, some of them originate from a collaboration of companies in a given sector while only some are truly independent.

Although these times demand from many companies to either participate in the trend (According to (Nambiar, 2010), pursuing sustainability contributes to better product quality, increased market share and higher profits) or jeopardise a significant amount of market share. This may be even more of a struggle for a Non-Governmental Organisation (NGO). This holds because investing in sustainability tends to be in line with their objectives, yet seldom their main objective. This may raise the question, whether it is legitimate to invest in sustainability, if this doesn't contribute (directly) to the main objective, in this case being the saving of lives at sea. In this case, it is hard for such a NGO to free up already limited means to invest in sustainable projects, as these means were originally labelled for the main objective of the NGO.

[1] These standards tend to be applicable for certain groups of products only, rather than being truly universal.

Figure 1: The lifeboat of Scheveningen, the Netherlands.

NGOs are thus likely to struggle with the implementation of sustainability within their organisation. Which holds in particular when few options are available combining the benefits with regards to sustainability goals with benefits related to the primary goal. And even if these benefits can co-exist, it may very well be that these options or projects are less efficient when it comes to achieving the main objective of the organisation. Those projects and investments which truly benefit both objectives without compromises tend to be rare. Even if these options exist, there may also be other decision criteria that may weigh in on the final decision. Furthermore, prior research has shown that these decisions often determine long-time success or failure of organisations (Moody, Doyle, Middleton & Sussman, 2018).

One of the phenomena that plays a role in many organisations is mixing ambition with strategy (Rumelt, 2017, pp. 5). Being sustainable should counter a problem for it to be eligible as a strategy. Or, if not being sustainable is a problem for the organisation, the organisation needs to assign means to address the problem. Instead, it is more likely for organisations to have a sustainable ambition, making sustainability part of a framework of arguments to make decisions. In the end, strategy is about identifying critical factors and challenges the organisation faces and then devise a plan of action and address effort and resources towards addressing these challenges (Rumelt, 2017).

Being a NGO, he KNRM also struggles with the aforementioned challenges. This struggle forms the basis for this research. Their prime concern is the rescue of people and animals that require assistance on the Dutch seas. Since they operate lifeboats that should be capable of a multitude of tasks in a multitude of extreme weather conditions[2], the safety of the crews is amongst the top priorities when it comes to spending money that was entrusted the organisation for their main aim. The research aims to chart existing methods to assist in the decision making process, and to chart the organisation itself, aimed at discerning its decision making values and preferences. By doing so, the research aims to support practitioners both within the KNRM as well as the wider community of sea rescue organisations worldwide.

[2]Although gales tend to be the first that jumps into mind, cold and icing or extreme heat present total different set of demands and performance characteristics.

As any technology company, the KNRM faces many investment decisions. For instance, there are three new classes of lifeboat that have to be developed in the forthcoming years[3] And, as Cheng, Liou and Chiu (2017) puts it, in today's rapidly changing economy, technology companies have to make decisions on Research and Develpoment (R&D) project investments on a routine basis. And, as such decisions are fundamental for the future course of the company, they have a direct impact on that company's profitability, sustainability and future growth. This further stipulates the importance of these decisions. Although it would be presumptuous to claim that this research would contribute to 'better' decisions (which would then also invoke the discussion on what defines a 'good' decision), this research does aim to assist in achieving decisions that are in line with the companies preferences and vision. Multi-criteria Decision Making (MCDM), then, is a generic term for methods that assists a Decision Maker (DM) in making decisions according to their own preferences in cases where more than one conflicting criterion exists ((Chen, Kilgour & Hipel, 2008), as quoted by (Camargo Pérez, Carrillo & Montoya-Torres, 2014)). While doing so, this method should achieve transparency and accountability for the decisions taken.

In recent years the KNRM has revisited its strategy for the period 2018-2024. In this strategy it has defined sustainability as an ambition to solicit increased income from donations. Yet, just stating the ambition of being sustainable, would qualify as the aforementioned pitfall described by Rumelt (2017). Therefore, this ambition has to be supported by a concrete strategy, plan of action and the allocation of resources in order to be successful in realising this ambition. This research therefore aims to play a role in the development of that strategy.

When considering these investment decisions or project decisions, sustainability and safety are thus amongst the key focal criteria in this research. Yet, in reality, there will be many other criteria playing a role in the decision making as a holistic perspective is required to find the optimal outcome in all situations. Adding sustainability to this already complex set of criteria only further complicates the overall decision making process. This process tends to become so complex that it reaches the limit of what the human brain can cope with. Therefore, decision making in practise may be lead by emotions, individual understanding of the problem at hand, the interaction of characters amongst the group of deciders or the emergence of a narrative.

All these scenario's are prone to introduce biases into the decision making process. This would then argue for a structured approach to aid the decision making and guarantee the deliberate and transparent evaluation of all options and arguments. MCDM-methods provide such kind of formal and rigorous methods, aimed at dealing with complex situations and conflicting criteria, thus enabling consistent project assessment (Gal, Stewart & Hanne, 1999).

But even more fundamental to choice making is, that to even have an actual choice, alternatives are required. This goes further than deciding on a mere *yes* or *no* in respect to a decision at hand. A good decision requires alternatives to choose from in order to be an actual choice. And most organisations take this task lightly, which results in an often unnecessarily narrow range of alternatives for a given Decision Making Situation (DMS) (Keeney, 1994).

Keeney (1996) found that decision makers focus traditionally on the alternatives first and on the criteria later. He refers to this approach as *alternative-focused thinking*. However, he concludes this way of thinking is limited to think through decision situations. It is reactive rather than proactive. Instead, in order to be the master of your decision making, it makes sense to have more control over the decision situations one faces. This may be achieved to start from the values important to you or your organisation and extract decision criteria from these values. Keeney refers to this method as *value-focused thinking*, of which MCDM is an practical application. Research by Finnerty et al. (2017) shows that these methods are effective of assessment against corporate energy policy and -strategy as well.

On the other hand, experienced decision makers tend to bring a significant and valuable amount of tacit knowledge and experience to the table. This may lead them to find the best option even without using extensive toolsets. One of the challenges then lies in how a tool can still reap benefit from

[3]This refers to the projects NH-1816-2, 7,6m RHIB and the replacement for the Nikolaas-class. The van Wijk-class is about to be built and orders have been issued to the wharfs. Therefore, the investment decisions in this project have already been made and therefore, the outcomes of this research will be too late to be of value for this project.

this tacit knowledge for instance through aiding the decision maker in capturing his preferences and substantiating his gut feeling and showing it using the toolset.

Research shows (f.i. Macmillan (2000)) that these decision support tools actually lead to better decision making, even under risky circumstances, in this particular research in the upstream oil and gas industry. This research further showed that the effectiveness further increased when multiple methods were used.

The KNRM is a sea rescue organisation with a strong dependence on power and speed to achieve its primary objective. At first glance, this is contradictory to sustainability. As such, the KNRM struggles to holistically integrate its sustainable ambitions into the organisation. It is posed that, in order to achieve this objective, sustainability criteria should be integrated in the decision making process of the KNRM. This may be combined with the introduction of a MCDM-based Decision Support System (DSS) as this is shown to contribute to a deliberate, structured, transparent and better decisions (Macmillan, 2000).

Having set the scene for decision making issues in a sea rescue organisation like the KNRM, the next section will go over the research problem central in this research in more detail.

Problem classification and methodologies

First of all, the decision that is to be made, will be made by people that are part of the same company and ultimately strive to achieve the same goal, even although they may represent different departments or have different responsibilities within the organisation. This sets the case apart from f.i. political decision making, in which interests, goals and objectives are fundamentally different amongst stakeholders.

In the case involving investment decisions or innovation project selection, the decision maker doesn't have to convince others in the process about the objective or goal, which is already aligned. Instead, decision makers can focus on the actual properties of the options themselves and discussions are limited to evaluating these options only. Thus, solely the decision is evaluated, which requires the use of a method that has the same focus.

Furthermore, when assessing investment options or innovation projects, many criteria of evaluation are involved. This often includes comparison between both quantitative and qualitative metrics. And, as Cheng et al. (2017) put it, companies seeking profitable opportunities for investment and project selection must consider many factors such as resource limitations and differences in assessment, with consideration of both qualitative and quantitative criteria. Often, differences in perception by the various stakeholders hinder the attainment of a consensus of opinion and coordination efforts.

Therefore, a method is required that allows both types of criteria and the input of multiple stakeholders. In this case, as detailed earlier, its not the stakeholders to be implemented, but different key figures that have a say in the decision making and altogether, make up the KNRM as a decision making entity.

Another set of methods that could be applied, are the lexicographic methods. These methods achieve reaching consensus on an option through comparing variants according to a predominant criterion. Then, the method proceeds comparing remaining variants on the next important criterion, and so on until only a single variant remains. An example of such a method is the Delphi-method, which has its foundations in psychological and sociological studies (Linstone & Turoff, 2002). In this method, a procedure is used to steer the group process for group decision making. However, this process still relies on human judgement of a balance of all relevant criteria. As detailed before, the nature of the problem shows an ever increasing number of criteria that play a role in the decision. The number of criteria is of such size, that the human brain is incapable of dealing with the data and maintain a good balance. It's simply too much to cope with. In such cases, research by Kahneman and Klein (2009) shows that the human nature makes that humans will look for shortcuts or narratives to substantiate a preference for any variant, most likely resulting from type 1 thinking. To avoid such 'shortcuts', one requires the discipline to use a method or an exercise that commits one to justly compare criteria and variants. MCDM provides methodologies to do just that.

All in all, MCDM methods should be used in this case, as these methods are designed to incorporate both at the same time, while still allowing careful and weighted evaluation of all characteristics of the

options involved. Furthermore, MCDM-methods are also recommended for combining multiple criteria aimed at making sustainable decisions ((Ashbolt, Livingston, Peters, Lai & Lundie, 2006; Halog & Manik, 2011), as cited by Godskesen, Hauschild, Albrechtsen and Rygaard (2018)).

Research problem

Having detailed the core elements of the research, being the case and the core group of methodologies to be used to assist in the matter, the core research question to be answered in this study is the following:

How can a structured decision making method aid a sea rescue institute in evaluating the sustainability of a set of multiple investment options and selecting the option best aligning with corporate values and preferences?

This study aims to develop a method that may be used by similar organisations facing similar difficulties. In order to start this process, upon recommendation of the KNRM the outcome is to be shared amongst the international community of sea rescue institutes, the International Maritime Rescue Federation (IMRF).

The first chapter will split this research question into a number of sub-questions and will detail the research done to derive the answer on these questions. The second chapter will go deeper into the case, describing the current decision making process. The third chapter will discuss viable MCDM-methods and select the model that is to be used in this study. The fourth chapter will detail accumulating the data that is required to operate the model and the final chapter will seek to validate the model using a test case. The report will end with conclusions, a discussion and recommendations.

1

Methodology

As shown in the introduction, the Koninklijke Nederlandse Reddingmaatschappij (KNRM) would benefit from a tool to assist in balancing criteria in order to reach an optimal decision. Such a tool needs to be implemented within the decision making process or flow that is present within the organisation. As will be shown in chapter 2, the current decision making process is yet to be formalised and the Board of Executives (BOE) intends to do so. This offers a valuable opportunity to introduce and implement a Decision Support System (DSS). So, the main research question taps into this integration question, and is formulated as follows:

How can a structured decision making method aid a sea rescue institute in evaluating the sustainability of a set of multiple investment options and selecting the option best aligning with corporate values and preferences?

This chapter aims to introduce an overview of the research and the steps taken to achieve the aim. This overview is visualised in figure 1.1.

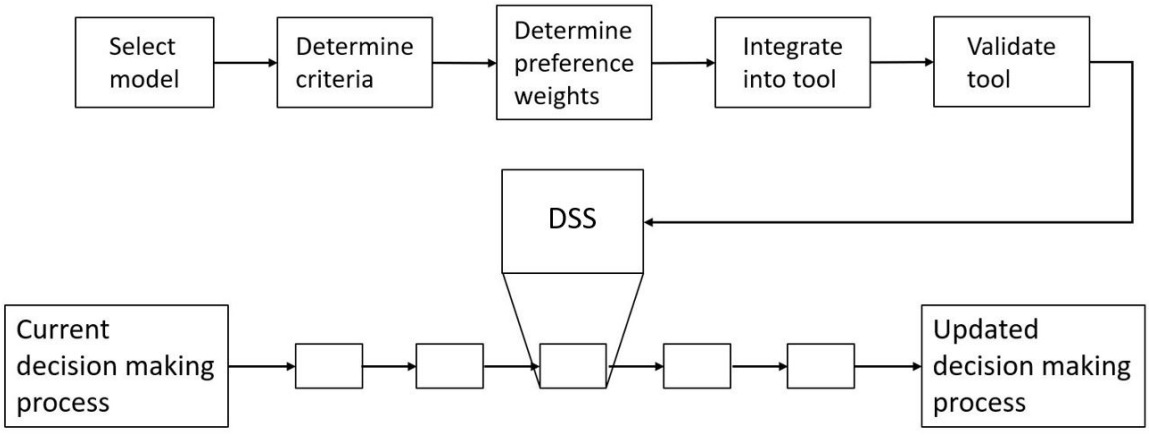


Figure 1.1: Overview of the steps involved in this research.

In order to meet the envisioned end state, which is delivering a proven and working DSS tailored to the envisioned or updated decision making process, a number of questions remain to be answered (which will be referred to as the sub-questions):

1. What method and underlying model best fits the Maritime Search and Rescue (SAR) environment?
2. What does the current decision making process look like when investments in sustainable innovations are evaluated? How do key decision makers in this process envision this process and how

will it change in the near future[1]? Which step of the process would benefit most from the usage of a DSS?
3. What factors or criteria play a role in the aforementioned step in the decision making process, according to the decision makers and other relevant key stakeholders in the process?
4. How are the aforementioned criteria weighted by the different key players in the decision making process?
5. How does the model that results from sub-questions 3 and 4 reflect on the apparent conflict between safety and sustainability?
6. To what extend does the model resemble specific individuals and group opinions? Does this reflect the organisation in a satisfactory manner?
7. Does the new process achieve the aims in a case study?
8. How is the usage of such a model valued by the potential users?
9. What are the implications with respect to the implementation of the model of choice as a DSS?

As this study aims to research these questions, the following sections will detail with the research methods used for answering these sub-questions.

In order to integrate the DSS in a meaningful way, both the current process of decision making and the envisioned future process need to be understood, as the DSS should be integrated in the latter in a meaningful way. The first section of this chapter will show how both the current and the envisioned decision making process are charted. It also aims to identify how key members of the BOE reflect upon the usage of a DSS. This would also answer sub-question 2 and 8.

The second section will review how an appropriate model is selected from the wide range of Multi-criteria Decision Making (MCDM)-models available, thus answering sub-question 1. The third section will show how the data that fills the model is being collected. An analysis of this data should allow answering sub-questions 3, 4, 5 and 6. The fourth section will detail how the validation of the model is being set up. This should result in being able to answer sub-question 7. The chapter will finish by presenting an overview of the sub-questions and the research methods that are envisioned to answer them.

1.1. The current process of decision making

As detailed before, in order to identify how a DSS will fit into the envisioned decision making process, it is necessary to understand the current decision making process and its envisioned changes. These fundamental questions have resulted in the inclusion of sub-question 2. This question thus requires a deeper understanding of the decision making process on a qualitative level. This knowledge is best obtained using the access provided by the KNRM to interview their key decision makers and those having influence on how the process is shaped. Therefore, in order to answer these questions, qualitative interviews will be used. In total three interviews were held. An exploratory interview was held[2] with a senior technological inspector that has contributed to numerous innovation projects for the KNRM. From that perspective he can provide details on how the current process is embedded and what has been learned in the past. Second of all, two new BOE-members were interviewed. First of all, the Chief Executive Officer (CEO) was interviewed[3]. Second of all, the Chief Technology Officer (CTO) was interviewed[4].

These latter two interviews were held in a semi-structured manner. The interviews were split in two parts, first of all addressing sustainability and its relation to the strategy of the KNRM. In the second part of the interview the participants were asked to reflect on the current decision making process and procedures used in this process.

The main aim of the interviews was to get a better understanding of the decision making process, in order to distil requirements, desirabilities and preferences in respect to the 'technical' working of the MCDM-model. In this phase of the research, these requirements are formulated in an operational and

[1] From a practical perspective, some key players have been transferred internally or newly hired. This may have an impact on the decision making process that can be taken into account by evaluating their reflection upon the process and by investigate how the process is likely to change in the near future.
[2] This interview took place on Friday June 5^{th}.
[3] This interview was held on the 1^{st} of July.
[4] This interview was held on the 23^{rd} of July.

practical way. They are to be translated into 'technical' requirements in a later stage.

1.2. Selection of the MCDM

This part of the research should identify an appropriate model for the case, from the wide range of MCDM-models. In order to do so, the research takes two approaches. First of all, a literature research is conducted to chart the models and identify categories and their specifications. The literature research focusses on the integration of sustainability criteria in investment decisions, as this is the core of the Decision Making Situation (DMS). The literature research is detailed in chapter 3, section 3.3. It aims to achieve the following:

- Present an overview of existing methods, divided into categories.
- Detail the usage of different categories in similar cases by other scholars. Similar cases then refers to innovation investment decisions in which (the evaluation of) sustainability criteria play a central role in the decision taken.
- Identify argumentations why certain methods have been chosen and, if possible, match them with the case at hand.
- If possible, present pro's and con's of each method in relation to the case.

So, first of all, this part of the research also identifies how similar cases have been handled by other scholars and potentially what lessons can be learned from them. Second of all, the requirements posed by the KNRM are translated into technological requirements, which are then compared to the characteristics of the model categories developed earlier. In this way, a relevant category is to be selected, and an appropriate model is then to be identified from this category. Thereby, this part of the research aims to answer sub-question 1.

1.3. Establishing the model input

After having established the model that is to be used, this model needs to be filled with relevant data such as the set of organisational preferences, as shown in the second and third building block of the upper level of figure 1.1.

The criteria will be established in an open and explorative interview, seeking to have as many criteria mentioned by the interviewee him- or herself and the context in which (s)he sees them. This will eventually be cross referenced with a prior prepared list in order to eliminate any topics that were not covered, having the interviewee decide if (s)he deems them relevant.

The criteria mentioned by all interviewees are to be aggregated before moving on to the next phase. This would entail gathering a set of weights. Yet weighting requires clarity on the criteria that are to be weighted, which thus have to be aggregated beforehand.

Having determined criteria and weights, they can be evaluated to relate them to viewpoints that were shared or mentioned during qualitative interviews, in order to establish if the numerical outcome reflects information that has been shared during these interviews. Furthermore, in a similar manner, the numerical outcome is compared to the organisational preferences as they were presented by the key players during qualitative interviews.

This evaluation should also provide insight in how key players in the decision making reflect on the balance between safety and sustainability. It also allows evaluation in respect to the influence of individual input on the overall outcomes. This analysis is detailed in chapter 5.

If the numerical values are found to be in line with prior findings, the values can be integrated into the model. This should result in an operational yet untested and unproven DSS.

Establishing the weights will be part of the second interview. Depending on the method, this will likely require a quantitative interview to establish. It will be a part of the second interview, although the order in which topics will be discussed during the interview is yet to be determined (but will be elaborated upon in this section).

1.4. Validate the model

This part of the research aims to put the model to the test by applying it to a fictional investment decision. This is achieved in an interactive (interview) session integrated with gathering the weights.

The interview itself will consist of two parts. Initially, interviewees are asked to state their preference and build a case for their decision (without using the model). Then, the interviewee is asked to conduct the scoring of criteria in the way required by the chosen model.

In this part of the interview, two questions form the foundation of the evaluation:

1. Does the outcome of the DSS resemble your personal view on what the outcome should be? Why so or why not?
2. How do you evaluate working with a DSS? Do you think its usage provides benefits to the organisation?

As such, these interviews will therefore be both quantitative and qualitative in nature. Identifying a preferred investment option or filling out the data that is needed for calculations by the DSS is quantitative by nature, while the personal evaluations are qualitative of nature. The quantitative part, along with the first question of the qualitative part, will provide answers to sub-question 7, as this goes into the technical working of the model. In the end, the model should generate outcomes that resemble the organisational preferences and therefore the outcomes should be appreciated to do so.

The second question of the qualitative interview on the contrary, evaluates whether people enjoy working with the model, if they understand and appreciate its added value and if they envision working with it in the future. This part thus focuses on the human as key part of the decision making process.

Having concluded the interviews, the integration of the outcomes forms the basis for a further analysis, detailed in chapter 6. This analysis should provide the data for an evaluation of working with such a tool and should allow evaluating if it has added value in this case.

1.5. Implementation of the model

Having established the model and evaluated its effectiveness, the model and its usage needs to be implemented in the decision making process of the KNRM. As such, to answer sub-question 9, the answers of sub-question 2 need to be revisited and the knowledge gained during the research should lead to insights as to how to moderate the current decision making process to implement the model and gain the most added value from it.

In order to answer this question, knowledge gained during the remainder of the research is being used, as well as insights provided during the final qualitative part of the interviews used for the validation of the model.

During these interviews, the interviewees are asked to evaluate the process of using the DSS and their considerations for using it in their daily practises. These insights are combined into a set of recommendations on the usage of the model and implement using a DSS during the decision making process.

1.6. Conclusions

Answering the main research question detailed in section 1 has been divided in five stages, to each of which a chapter has been devoted (chapters 2 to 6). These steps are also visualised in figure 1.1. The first step is devoted to charting the current decision making process, the envisioned future decision making process and the role a DSS may play therein. This part of the research thus aims to answer sub-questions two and eight. As detailed in table 1.1, these questions are to be answered using qualitative interviews.

The first step results in a set of requirements in respect to the model. The second step is to translate these operational requirements into technical requirements and thus to a set of criteria a model has to meet in order to be relevant for this case. Chapter 3 then details this process, resulting in the choice

	SQ 1	SQ 2	SQ 3	SQ 4	SQ 5	SQ 6	SQ 7	SQ 8	SQ 9
Literature desk research	X	X	(Corp. docs)		Outcomes	Outcomes			
Qualitative interview		X	X	X			X	X	X
Quantitative interview				X			X		
Answer (section)	3.4	2.3	5.2	5.2	5.3	5.3	6.2	6.2	6.2

Table 1.1: This table connects all sub-questions (SQs) to the research methods that will be applied to research them.

for the model to be used in this research. This part of the research, aimed at answering sub-question 1 is based on a literature research.

The third part of the research then aims to gather all the required input and results in a working but untested model. This part also qualitatively analyses the outcomes in order to understand whether the numerical outcomes matches the organisations preferences as detailed during qualitative interviews throughout the research.

The fourth part of the research evaluates the model through a comparison with decision making without the assistance of a DSS. This starts off with a quantitative research establishing the interviewees preference and the model input. The interviewees preference is then compared to the model output and the results and evaluated with the interviewee. Then, the interviewee is asked his or her opinion on working with the model. In this manner, the usage is evaluated with the key players involved in the decision making.

The fifth and final part goes into the implementation of the model into the current process of decision making. This is done using insights from the qualitative part of the interviews held to evaluate the test case. This is complemented with knowledge gained during the research. This then is combined into a set of recommendations that should tailor all lessons into a single action perspective for implementation.

2

Current process of decision making

This chapter charts the decision making process and environment in place at the Koninklijke Nederlandse Reddingmaatschappij (KNRM), which forms the basis for the integration of a Decision Support System (DSS). And, in order for a successful implementation, the process may need to change. It is understood that a window of opportunity may present itself due to some changes in the organisational structure of the KNRM in general and of the Board of Executives (BOE) in particular, including a new Chief Executive Officer (CEO) and the formation of a formal Management Team (MT), entailing the promotion of a Chief Operations Officer (COO), hiring of a new Chief Technology Officer (CTO) and hiring a policy officer. This may provide a fertile environment for evaluation of current processes and procedures and change.

The research in this chapter builds mainly on three interviews, as detailed in section 1.1. The analysis of these interviews will allow the description of the current decision making process. In turn, this should provide a foundation for implementing the DSS within the process in a later stage.

The first section will detail the current situation the KNRM is in, after having completed two recent innovation processes involving the design and acquirement of two new classes of rescue vessels. These processes provided a number of lessons learned that in turn provide insight into potential directions for process improvements.

The second section deals with research methodologies used to understand the current situation and learn the perspectives on developments from within the BOE.

The third and fourth sections present the outcomes. Where the third section focuses on the decision making process, the fourth section focuses on the potential role of DSSs within this process. Then, the findings are summarised in the conclusion, focusing on summarising operational demands for the DSS and the model it is based on.

2.1. Background

Recently, the KNRM conducted two innovation projects, both aimed at the design of a new class of lifeboats. However, both processes have known significant issues that hampered their progress and completion. The first one is the NH1816 project. This project aimed to develop a successor for the successful Arie Visser class. The project started off with an ambitious cooperation with De Vries Lentsch[1] Delft University of Technology (TUD) and Damen Shipyards. This cooperation aimed to develop the perfect hull through research, which resulted in an axe-bow design. After the first hull of this class has joined the operational fleet, an evaluation of this project was executed by an external organisation in order to anchor lessons learned and improve the process for the future. Most of the observations in mentioned in this section are based on this evaluation report.

Within the KNRM, at a certain point, a decision was made between three variants for this NH1816 class. It could either be based the Arie Visser-hull, a slightly modified version of the Arie Visser hull

[1] A yacht designer and naval architect.

and the axe-bow, developed with the cooperation partners. In an evaluation of the project it was found that those persons from the KNRM involved in this decision process, seem to have been invested in the axe-bow and may have been influenced by the cooperation partners. This has resulted in a rescue vessel that is assessed to be well designed for long range deployments, but less suitable for the tasks as a rescue vessel and the difficult manoeuvring parts of the operations. Furthermore, the highly advanced digitised integration is not appreciated by many crew members, not all of whom are very experienced or comfortable working intensively with computers. Albeit a good ship with many advantages on many aspects, the ship was not well received amongst users throughout the country.

It led the organisation to question how the process could have led to such an outcome and hired an external company to investigate this question. This has resulted in a number of findings, some of which are relevant for this research. First of all, it was found that some people involved in the decision where, as mentioned earlier, invested in the axe-bow design option as they had been closely involved in the process. Furthermore, a lot of emotions were involved in the decision making, while other people felt overlooked and unable to contribute in the process. The KNRM employs many experienced people who have been with the organisation for many years and have built up a significant amount of tacit knowledge. Conservatism also seems to have played a role, as there is a tendency within the organisation to prefer known and trusted equipment over innovative solutions. This is in contradiction to the amount of design work that is done in-house or under responsibility of the KNRM. The professional organisation of the KNRM is rather small (for instance in comparison to international sister organisations) and therefore the manpower to undertake these projects in-house or under the responsibility of the KNRM is limited. Therefore, following the market is recommended in the evaluation of the project, while innovating or taking full charge should be the exception. This stems from the labour intensity of knowledge processes and the significant risks resulting from taking responsibility for the design. It also limits opportunity to benefit from external knowledge and developments. Then, there was a lack of clear communication rules, which led to the repeated discussion on decisions already taken and false expectations amongst participants. But most profoundly, no process structure and definition of roles and responsibilities. This led to a lot of uncertainty, people bringing things forward in the wrong phase of the development, people not bringing their concerns forward and so on.

The mixed success of the first hull of the NH1816 resulted in the cancellation of building any further hulls and the project went back to the drawing board, which is where it currently stands[2]. Now, a new project is started, named NH1816#2. In this process the organisation is continuing its search for the replacement for the all weather rescue vessel, but it intends to stay closer to the original Arie Visser hull design. Before starting off the project, the KNRM will build a process flow to take the lessons learned from the first project into account, as will be illustrated in section 2.3.

After the NH1816 project, the KNRM has taken up the Van Wijk project, aimed at designing and building a successor to the Valentijn medium sized rescue vessel. This process as well, saw some flaws. The most profound one, has been an operation to harvest the knowledge and lessons learned in the organisation and amongst users of the craft. Although an effective strategy on multiple accounts, such as building support and involvement, the execution has shown room for improvement. The initial question was formed very wide with no clear coordinating guidance or rules. This led to an excessive response, ranging from recommendations related to the shape of the hull up to nuts and bolts details. It required an enormous effort to reply all suggestions and keep everyone involved, even if the relevance of their remark would not come to light for months to come, as was mentioned in two of the interviews. It would have been much more effective to ask specific questions and state objectives, in order to align the response with the aim of the consultation. Having a process flow would help managing expectations and significantly increase the value of the output of the process.

The interviewee also mentioned that, although many people contributed, most of them felt not heard, as it was impossible to include all comments in the design and choices had to be made. Even people who contributed multiple things, most felt still not recognised if even one or two suggestions couldn't be implemented. This costed the initial design a lot of support amongst volunteers. Expectations management, or guidance and rules as mentioned above, could increase the understanding for choices turning out another way and therefore contribute to the support for the final outcome of the process.

[2] As of the 1^{st} of October.

In this case too, an ambitious variant was initially selected and detailed up to creating a life size mock-up of the wheelhouse. Then it was found that the project was not on the right track and was returned to the drawing board. Eventually, a second design has been produced, which is a slight modification of the current design, marginally extending its hull and integrating up-to-date equipment. Once again, a key decision had to be re-evaluated as the outcome of the initial decision making process was not satisfactory. This makes one wonder if the decision making could benefit from a model to improve the success rate of the decision making process. Evaluating the wrong option or variant is a costly business and it is better prevented.

This section evaluated recent innovation processes at the KNRM and showed that both the NH1816 and the Van Wijk projects generated a number of important lessons identified. The lack of a structured process flow has been core to many of these lessons. Furthermore, in both projects, the decision making process initially selected a sub-optimal design - or failed to convince users and crew members of the quality of the vessels. It would be interesting to see if modelling the Decision Problem (DP) can contribute to 'better' decisions and enhance transparency, as a tool to include crews in the process by allowing them a better understanding of what is going on.

The next sections will go into detail on the interviews that were held with the CEO and the CTO, amongst others discussing their views on these projects, the lessons identified from them, the process flow and eventually their reflection on the usage of modelling tools to assist in the decision making.

2.2. Data gathering

As described earlier, a window of opportunity for changing the process of decision making may open up given the changes in the BOE. Therefore, most gains are to be made from obtaining both the point of view of the experienced decision makers that have been part of recent innovation projects, as described in the preceding section, as well as the point of view of the key decision makers that have recently joined the BOE. In order to acquire the experiences from the recent innovation projects and the lessons that were learned from them, an interview was held with a project engineer[3]. The project engineer has played a key role in the projects described in the previous section.

Second of all, observations were obtained from two key players in the decision making process that are new to the organisation and were able to provide fresh insights and an outsider view upon these innovation projects from the recent history. These viewpoint were obtained from the CEO, who was interviewed on the 1^{st} of July and from the CTO, on the 23^{rd} of July. These latter two interviews have been transcribed, the transcriptions can be found in appendices A and B.

These interviews were held in a semi-structured manner. The first two interviews lasted approximately one hour, while the latter lasted over three hours. The interviews were split in two parts, first of all addressing sustainability and its relation to the strategy of the KNRM. In this part, the following questions were used as a foundation for the interview:

1. How would you personally define 'sustainability' and what does it entail in your opinion?
2. What is the strategic aim envisioned for the KNRM to become more sustainable? Why is sustainability of strategic importance?
3. What kind of sustainability projects would, in your opinion, match this strategy and the KNRM as an organisation?
4. Where would you expect the most impact to be achieved?

The second part of the interview has been devoted to charting the current innovation process and the decision making process used to agree on decisions. The fundamental questions that were posed in this part of the interview are the following:

1. What does the process look like? Who initiates it? What steps or phases does it entail? How are criteria balanced against each other?
2. What are the requirements of the process? What do you personally prefer? What do you like about it? What is your personal emphasis in such projects?
3. How could the process be improved? How do you envision the process to become in the future? What are your thoughts on the usage of DSSs?

[3]The interview was held on Friday June 5^{th}.

Although the criteria are not the main topic of the interview, they were also discussed in order to identify the organisations core values and get a better understanding of the organisation before defining them in detail in chapter 5.

Through this method of interviewing, a clear picture of the decision making process in innovation projects has been obtained - as well as a preliminary understanding of what values are at the core of the decision making, how the organisation sees its own development within cultural and societal developing world. This is all highly relevant and valuable information in the context of decision making and can therefore be translated into operational requirements towards the DSS, as will be summarised in the conclusion of this chapter.

2.3. The decision making process

Having established how the interviews were held, this section analyses the results from the interviews. The conclusions are qualitative and need to be embedded both in the final model to be used, as well as in the procedure for its usage.

During the interview, the CEO mentioned the organisation, to date, didn't establish criteria to measure sustainability - or evaluate decision options. This, as it was confirmed by both interviewees, raises the question how core values of the organisation are balanced out against recently introduced strategic themes, such as sustainability, which was recently declared a strategic organisational objective. Furthermore, both interviewees extensively elaborated on the mindset towards sustainability that still has to come a long way. In that sense, the BOE is setting the objectives and the flag on the horizon, in order to bring about the change in the mindset.

When it comes to sustainability, the opinion on its definition differs amongst the BOE. For instance, the CEO views sustainability in a way about as wide as the definition goes, from energy neutrality to circularity and re-usability of products. The CTO on the contrary, initially clearly isolated the environmental aspect, although, during the interview, also included noise and vibrations as health and human well-being criteria, in particular for rescue vessel sustainability performance. The CEO emphasized the importance of the safety of, in particular, the sea-going crews, but other volunteers and employees as well. In this light, establishing the boundary of what parts of the definition of sustainability add value to the KNRM as an organisation, is likely to prove a valuable discussion. This exercise aims at establishing a shared vision and/or understanding of what 'sustainability' entails for the KNRM. The model can play a role in that aspect, acting as a guideline and starter for the discussion. The model requires the BOE members to define 'sustainability' by means of a number of criteria.

The model however would, rather than put a flag on the horizon, introduce the first step of the implementation by introducing a method that can be used for the decisions of tomorrow. As such, it requires the decision maker to take the next hurdle and also quantify the meaning of sustainability. This shapes the general direction in more detail and therefore enforces the decision makers to shape their vision into more detail. On the other hand, this step would be required anyhow and using the method would assist decision makers in taking a methodological approach to this. It would thus only bring the task forward. Defining sustainability in more detail also provides more clarity as to the direction of the motion, both towards employees, as to suppliers and other external stakeholders. On the other hand, involving the employees in setting up the framework may engage them and, as such, gain their backing for the framework and thereby for the sustainability agenda in general.

Having such a framework also contributes to having an identical frame of reference when it comes to evaluating projects. Both interviewees mention some employees could have improved their knowledge, or the usage of false arguments as was mentioned in one of the interviews. Having a common frame of reference would thus bring clarity to a discussion, as the criteria and their ratings can serve as a common ground for understanding the matters. It also enforces users to look beyond discussions based on narrative and single criteria, as the question how such a criterion relates to the remainder of criteria is always a valid one.

Another part of the mindset originates from conservatism, which was mentioned also by both interviewees. As mentioned, most volunteers and employees are fond of what they have and therefore have a natural tendency to reject change. This may stem from the fact that within the organisation prepare for adverse weather and tough conditions. Therefore, they are looking for equipment they can rely on and that is well tested and well known. In order to break this habit, the proposed method would enforce employees to compare the status quo to potential alternatives, thus empowering them to prove their right by means of the common frame of reference, through the model.

As both the CEO and the CTO aim to address the mindset, both show leadership to achieve change. The CEO aims to achieve this by setting the example and by leveraging ambassadors, giving them means and a podium in order to achieve their projects and show their ambition within the organisation. The CTO aims to achieve this by empowering employees through shared responsibility. He aims to achieve this by using a triple-D approach, which is aimed at the co-creation of solutions rather than defending organisational choices internally. Involving employees in rating variants in the model could then be used to integrate the opinion of employees in the decision making, thus making their input explicit and showing how their input contributes to the overall outcomes. This could support the empowerment and increase the feeling of shared responsibility.

When it comes to the process, the CTO mentioned that no such process exists when it comes to innovation. Within the organisation, he mentioned, everybody has an opinion on it, but no formalised process exists. This is quite the contrary to what the CEO said, as he mentioned a process like peeling down an union. The difference may originate from the latter process being an informal process, while no formal process exists. As such, the process starts off with the most ambitious option, and pursue it until it needs to be discarded for whatever reason (within the definitions of this research, it wouldn't qualify as a variant). Then, the next most ambitious option, and so on and so on. However, there is no formalised list of criteria that applies to an option in order to be discarded, a wide variety of arguments or narratives can achieve this, and both true and personal opinionated arguments or narratives have succeeded in either pushing forward[4] with options as well as discarding them[5].

This then raises the question on which criterion the most ambitious project is selected? During the interview, the CEO mentioned this to be based on sustainability. But with the wide notion of sustainability illustrated during the interview, even this would have to be measured through the integration of many criteria. Furthermore, no clear set of requirements seems to exist in order to discard options or to select variants. But, most profoundly, in order to establish which project is the most sustainable, a comparison must be made amongst options or variants in order to have a reference with which to compare. And such a comparison would also benefit from the scrutiny of a structured method, such as the methods offered by MCDM.

And when it comes to the decision making process flow, there are also some developments in this area. For instance, the CTO mentioned he is setting up a schematic decision flow process for the development of the new NH1816#2 rescue vessel which is about to be designed. This flow scheme is also shown in figure B.1. The process aims to integrate a stage-gate process flow (Cooper, 1990) with a scrum/aikido process (Schwaber & Beedle, 2002). The gates in the stage-gate process are used to manage expectations, as each step in the process is to focus on a certain part of the project, with clear objectives that have to be met in order to proceed to a new stage. This would ensure people are not going into details that are not relevant until in a later stage of the project. It also aims to state objectives that are required for follow-on stages. In this respect, it is not meant to return to decisions taken earlier on, these should form the foundations for the remainder of the project. Setting up this structure is also based on lessons learned from the Van Wijk project, as this project saw an inventarisation amongst volunteers in order to collect their requirements, lessons and requests for the Van Wijk design. Yet, albeit valuable, the return ranged from major and contradictory viewpoints to highly detailed requests, well beyond what was needed in that phase of the design. Thus, the new process details what level of detail is expected in what phase, in order to manage expectations and increase the value of the input.

In the second interview with the CTO, he also mentioned that having a set of criteria before making a

[4] This has also been found in the evaluation of the NH1816 project.

[5] An example was discussed, which was the discarding of solar panels for the lifeboat stations, based on the tax exemption the KNRM holds.

decision could also provide clarity towards suppliers and aid them to tailor and optimise their offering towards the KNRM. This then contributes to the transparency of the process and also aids in clarification of a choice of supplier. One could even consider providing these criteria to the suppliers in advance, in order for them to focus their designs and attention to these specific performance parameters. This may then lead to solutions that are more adapted to the needs and wishes of the organisation. On the other hand, there is also a risk in this, as it requires the organisation to think for their customer and act in the nature behind the criteria rather than strictly optimizing for the measurement used. The latter may lead to for instance accepting side-effects that are unwanted by the customer or overlooking common performance parameters. Having a solid set of criteria and measurement instruments may assist in overcoming this problem, but can not overcome it. Whether the advantages outweigh the disadvantages depends on the set of criteria and performance measurements, the supplying company, the customer and their mutual relationship.

Thereby, establishing a set of decision criteria should provide a full and complete picture of the core values of the organisation. This both empowers a supplier to enact the mission, vision, strategy and values important to the customer and reduces the pitfall of tailoring solutions to fit the chosen measurement.

As was observed during the interviews, sustainability was recently introduced as a strategic theme. Yet, no vision currently exist as to how to balance this criterion against other relevant criteria. Modelling the decision problems and set of preferences aims to provide insights in this balance and can also contribute to transparency, when the set of preferences is communicated internally. It would show all involved in the organisation what is to be expected of future decisions and how the values of the organisation are represented within these decisions. When it comes to defining sustainability, the case is similar. The definition differs amongst the BOE, while an organisation-wide definition would be needed. Modelling the DP would also require capturing the definition of sustainability in criteria, which would result in a organisational vision on what sustainability entails for the organisation.

With regards to the process, no formal process exists. On the hand hand, an informal process is used, referring to the layered union model, which aims to achieve the most sustainable, yet feasible option. Or, in other terms, the most sustainable variant. However, the qualification of 'the most sustainable' option requires a definition or quantification of what it entails. Yet, this definition seems to lack and opinions on what it should be differs amongst the members of the BOE. Furthermore, any criterion requires to be balanced with the other criteria relevant to the decision.

It was also observed that initiatives to design a process flow are under way, in particular as a reaction on the lessons learned from the NH1816 and the van Wijk project. This effort provides opportunities for synergy when integrated with modelling of the DP. This would require finding a model that can easily be adapted for decisions based on a selection of the set of preferences relevant to the stage of the project.

So, both the definition of sustainability and the process provide opportunities that could benefit from modelling the DP.

2.4. Review on the usage of decision aids

During both interviews, the interviewees were asked to reflect on the usage of decision making models to support the decision making. Both were positive, however they made some valuable remarks with regards to some requirements to the model in order to increase its chances of success and usage by the organisation.

First of all, one interviewee mentioned it is important for the model to be easy to understand, in order to avoid the feeling of a black box. That would scare people off, as it would give them the feeling of losing control and grip of the situation. And this would also entail the math involved. The calculations should be understandable and one should be able to understand what is happening and how output relates to the input provided. As such, the model should also contribute to the transparency of the decision making. If the model is adequately transparent and understandable, it can also play a role in the organisations accountability towards its stakeholders, both internal (staff and volunteers) and external (for instance industry partners and donors).

The support for the model may also be enhanced by a plenary session clarifying the concept to those comprising the decision making team and perhaps for a wider group of people playing a part in the decision making, for instance through providing input or evaluations. Such session would contribute to the understanding of the model and overcoming initial hurdles towards its usage, as were mentioned by the interviewees.

Related to the understandability, it is also important to make the model easy to use, as was mentioned in one of the interviews. This should be done in order to reduce the workload of people, but perhaps even more to overcome the hurdle people may experience from working with this kind of model or tool.

In order to support the transparency, it would be supportive if the model would not only provide some sort of an outcome, but also the rationale behind the outcome, to allow for understanding and also stimulate discussion amongst DMs. An example would be that from ten variants, the top two score almost equally, then DMs can retrace what the strong points of each variant are and base their choice thereon, rather than on a marginal difference in the outcome scoring.

Both interviewees mentioned that the organisation has not thought over how to balance certain criteria beyond those that would form the minimal requirements of performance. Yet how to evaluate variants then seems to be based on personal opinions end beliefs brought together in group processes rather than an objective evaluation. The model needs to overcome this and integrate the evaluation of criteria in a meaningful way. It needs to show how criteria are balanced, and closely align with the organisational viewpoints.

One interviewee also mentioned it is important to incorporate peoples opinions and show them their input is valued and appropriately taken into account. Employees tend to have strong feelings and opinions about projects, which are not to be discarded. First of all, for the employees to feel empowered and included in the process. And secondly, as these opinions come from years of experience, they also have value originating from tacit knowledge and experience held by these employees. In that sense, the model should also be able to deal with the opinion of multiple participants in the decision making, potentially taking into account their own field of expertise. These opinions would than have to be integrated into the organisational standpoint, because, as one interviewee mentioned, in the end the organisation has to choose in order to be able to move forward.

And finally, it is desirable to have a model that can be adapted to specific situations, for instance by using the model with only a limited number of criteria. In regard to the new process flow that is currently being developed (as has been discussed in section 2.3), it could be valuable to compare options at the end of different stages of the process using the model, in which case some criteria can be relevant in a later stage than other criteria. Therefore, it would be beneficial to have a model that can also be operated using only a part of the full set of preferences.

As such, the interviews showed that both interviewees have a positive attitude towards using a DSS. The interviews provided a lot of valuable information to be used for the model selection. In short, the model should be easy to use and understand, enhance transparency, clarify results rather than just provide an outcome, incorporate tacit knowledge and experience and it should be adaptable to be used in partial decisions too.

2.5. Conclusion

The KNRM has recently undertaken two major innovation projects to renew two classes of rescue vessels. First of all, the NH1816 was designed to replace the current Arie Visser class all-weather rescue vessel. And second of all, the Van Wijk class was designed to replace the Valentijn class of medium sized rescue vessel. Both projects have presented some important lessons identified and the organisation is currently in process of improving the processes for the future. As such, an MCDM-based DSS could very well play a role here, as the models can contribute to provide transparency by charting the preferences that are to be applied to the decision making. This could also contribute to shaping expectations amongst stakeholders.

An evaluation of the NH1816 project showed a lack of structure, rules and guidelines, decisions made based on conservative beliefs and (strong) personal opinions and beliefs, rather than a well balanced and fact-based decision. Furthermore, even though the processes aimed to include many internal knowledge and viewpoints, eventually people felt not heard, which resulted in a limited support of the outcome of the process.

But most profoundly, both innovation processes included a core decision that was eventually evaluated as - in hindsight - not being the optimal choice. The usage of a model has shown to result in better decisions (Macmillan, 2000) and should therefore be valuable for the KNRM.

Qualitative interviews were used to gain in-depth understanding of the organisations' perception of the notion 'sustainability' and the current innovation process in place at the KNRM. During the interviews, the lessons learned from the NH1816 and Van Wijk were discussed. Finally, the perception on the use of DSSs was evaluated and conditions for the tool were discussed.

When it comes to sustainability, the opinions on what the notion entails differ widely. This is also reflected in both interviewees mentioning no set of evaluation criteria exists for choosing amongst options. Decisions are generally taken based on personal beliefs, experience and gut feeling, while no rigorous evaluation process is in place. In a conservative environment, this tends to a negative and hesitant attitude towards innovation. Both interviewees mention this attitude to hamper sound and objective decision making. A DSS would introduce such a rigorous and objective method. It would also enforce the organisation to think about evaluation criteria and their internal (weighting) relation.

Another contribution of a DSS would be that it provides clarity amongst stakeholders what is required of them and what they are looking for in the alternatives on the table. Either through scoring alternatives on the criteria or by developing variants that aim to excel on these criteria, stakeholders are challenged to view the project through the lens of the organisation and thus to optimise their solution for the organisation.

Currently, no formal innovation process has been designed, but efforts to do so are being carried out in advance of the new projects that were recently started. As these processes are based partially on a stage gate design, while also implementing scrum and aikido principles. In particular in the stage gate steps of the process, a DSS can assist in choosing what concepts to take along to a next round or phase and what concepts to discard. In the process, one could define what criteria are used to evaluate concepts and ideas in that phase. The usability of a part of the set of the preferences will thus be evaluated as it would provide value in these kind of processes.

Then, the model and the considerations for choosing it were also reflected upon. When it comes to the model, both interviewees support the benefit of using a MCDM-based DSS. A number of core requirements were mentioned:

1. The model shouldn't be a black box; the calculations used should be understandable and traceable. There should be a clear relation between in- and output.
2. The model should be transparent. It should show input and foundations for the outcome and present it in an understandable manner.
3. The model should be easy to operate. This is to be understood both in a practical sense (not requiring complex actions) and in the sense of effort. Using it should require as little effort as possible.
4. Can cope with the input and viewpoints of multiple persons, experts or groups, providing their input on a single decision problem.
5. Should present an overview of the full problem, without isolating criteria beforehand[6].
6. Albeit designing the model to present a full description of the decision making, the model should preferably also work with a selection of the full set of criteria to assist in a segmented decision making process.

[6] In the interview, a discussion took place on excluding financial criteria on the basis that given the decision, it should be investigated whether the outcome could be financed, by addressing additional funds and donors. This discussion requires a careful deliberation and follow up in a later stage.

7. The model should be able to tap into the tacit knowledge of experienced employees and crew members into the comparison.

The support of the model may be supported further by holding a plenary session amongst decision makers to overcome initial hurdles by building understanding of the model and clarify the benefits towards the envisioned users. This thus contributes to the support of the model amongst those involved in the decision making.

All in all, the interviewees reflect positively on using a DSS. And the interviews also brought other benefits to light, such as clarification of the notion 'sustainability', finding a balance amongst criteria and enhancing transparency. And after having operationalised what performance characteristics would benefit the organisation and this DP, the next chapter aims to find a model that matches the requirements and considerations.

3

MCDM-model selection

This chapter aims to identify the Multi-criteria Decision Making (MCDM)-model suitable to assist the Board of Executives (BOE) of the Koninklijke Nederlandse Reddingmaatschappij (KNRM) in making decisions related to sustainable investments. The demands and selection criteria used to determine what model fits this case, are detailed in chapter 2. These requirements are translated into technical requirements related to the model and are used to select an appropriate model and/or class of models. Therefore, the first three sections will introduce the MCDM models in a divergent manner. The fourth section will converge towards identifying an appropriate model. This will lead to the conclusion of this chapter, the model that is to be used throughout this research.

In this research, it is posed that sustainability criteria should be fully integrated in the decision making process, rather than analysing them by themselves. This is as it allows the balancing of such criteria against other relevant criteria. This contrasts against many other methods, such as the Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA) or similar methodologies based on them. Pope, Annandale and Morrison-Saunders (2004) assess sustainability criteria in a separate process. Separating the sustainability assessment into a separate process would induce two additional steps in the decision making process, being the sustainability assessment first of all, and then a step to balance its outcome against outcomes of other performance criteria. If a sustainability assessment is conducted ex-post, this may result in either revisiting the original decision or changes in the chosen plan. This is most likely to cost additional effort and resources (Pope et al., 2004), and can be easily circumvented by integrating the sustainability assessment in the initial decision making. This comes at the cost of an increased complexity of the initial decision, which then strengthens the case in support of using Decision Support System (DSS)s.

As there is a general trend towards ever increasing complexity of decision making, the model that fits this case should be flexible towards future change. Furthermore, it should be able to cope with a large number of criteria (at least >10 criteria), and, also in relation to the preceding, it should be possible to insert or remove criteria in order to maintain the fit with developments in the organisation.

Furthermore, the model that fits this case is transparent, can handle a large number of criteria, allow input by multiple entities and is easy to use, providing insights at limited effort of decision makers. It should be rather a tool to spark conversation amongst decision makers than present a single optimal outcome. If possible, it should include (expected) future development and changes, in order to provide insights in either postponing the decision making or expected changes in perception.

3.1. Model representation of the decision making problem

In order to match a model with the current Decision Making Situation (DMS), the DMS needs to be modelled first. In the end, it's the characteristics of this modelling that determines the model that best fits the DMS.

First of all, a generic model of the DMS is created. It takes the feasible decisions, options or actions (generally known as 'variants'), along with the organisations preference, which is composed of a set of criteria. Note that in this case the set of preferences does not coincides with a single person, although the frequent use of the term 'decision maker' may - falsely - seem to imply this. The decision maker in this case refers to the organisation choosing an investment option in order to meet organisational needs or desires. The set of organisational preferences is assumed to be a combination of the preferences of individuals that are involved in these decisions and therefore will be composed of an accumulation of these individual preferences. The way in which individual preferences are accumulated to represent the organisations' preferences is elaborated upon in chapter 5.

With respect to the variants, these refer to feasible options to chose from. In order to arrive at feasible options, they could be - depending on the method applied - vetted prior to the actual decision making using a set of requirements or thresholds one is not willing to compromise on. An example of such a preliminary vetting is presented by Loetscher and Keller (2002a)

The variants on itself don't provide any information as such. Instead, it is their performance in relation to the set of criteria that makes up the DMs preferences, that can be used to calculate an output. This model is visualised in figure 3.1.

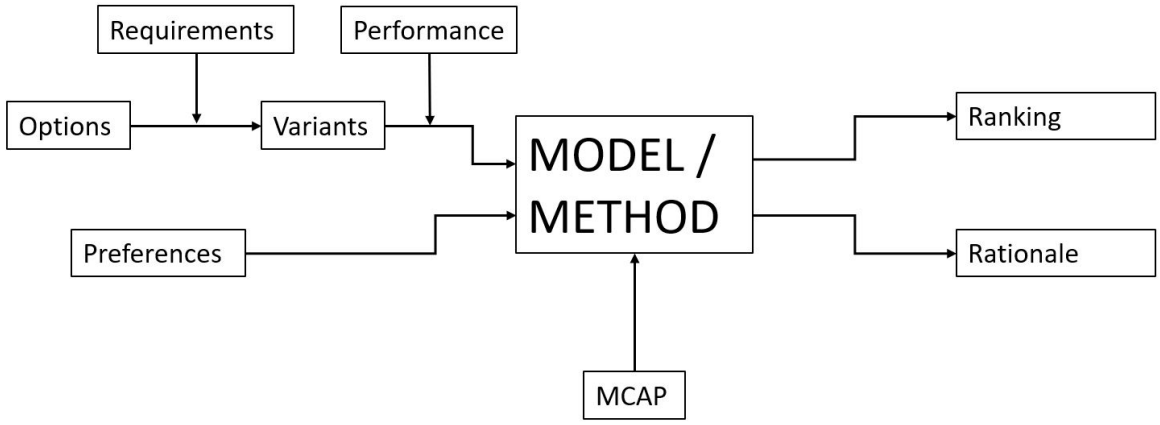


Figure 3.1: Generic MCDM model.

When it comes to the DMS itself, it should be noted that this model aims to capture the DM preference, which is in this case the preference of the 'entity' KNRM, as an organisation. As detailed in chapter 5, this preference is captured by synthesizing the preferences of key players in the decision making process in the organisation, mainly consisting of the members of the Board of Executives (BOE).

The methodology of capturing the preference is adopted only after choosing the model and the method, allowing it to be adapted as required by the method.

Since the investment decision requires the balancing of all criteria relevant to the investment decision, the preference mapping should capture a holistic representation of these preferences[1]. This has an impact on the model that can be used, as many methods either struggle to handle a large amount of criteria, or are simply unable to deal with them. Furthermore, using many criteria in some models results in an exponential increase in the amount of work needed to derive the final ranking. This is troublesome, as the nature of the DMs organisation is that it is compressed for time and therefore an easy-to-operate model is required[2].

The initial requirements that were posed by the organisation requested to compare projects of a totally different nature. These would therefore qualify as variants of which the criteria are not measured on the same continuum of a given criteria. Therefore, the problem qualifies as a DMS with discrete variants. This limits the model selection. The variants are denoted as shown in equation 3.1 (Guitouni & Martel, 1998)

[1] As was also stipulated in the interview by the Chief Executive Officer (CEO). See appendix A: Initial interview with the CEO for more details.

[2] As was also detailed in the aforementioned interview.

$$\mathbb{A} = a_1, \dots, a_j, \dots, a_m \in A \tag{3.1}$$

Equally, the attributes or performance criteria are represented as shown in eq 3.2.

$$\mathbb{F} = c_1, \dots, c_i, \dots, c_n \tag{3.2}$$

Furthermore, a number of methods uses a set of weights, denoted as shown in equation 3.3.

$$\mathbb{W} = w_1, \dots, w_i, \dots, w_n \tag{3.3}$$

Then, the Decision Making Problem (DMP) at hand is deemed to be a multi-decision maker problem. In a later stage, the preference of the different DMs is aggregated into a single decision. Yet, the set of DMs is presented in equation 3.4.

$$\mathbb{K} = k_1, \dots, k_i, \dots, k_n \tag{3.4}$$

Finally, the performance of the j-th variant in respect of the i-th criterion is denoted as e_{ij}, and the full performance matrix is denoted as $\mathbb{E}$, as shown in 3.5.

$$\mathbb{E} = \begin{Bmatrix} e_{11} & \dots & e_{1j} & \dots & e_{1n} \\ \vdots & & \vdots & & \vdots \\ e_{i1} & \dots & e_{ij} & \dots & e_{in} \\ \vdots & & \vdots & & \vdots \\ e_{m1} & \dots & e_{mj} & \dots & e_{mn} \end{Bmatrix}, \quad \text{or} \quad \mathbb{E} = \begin{array}{c|cccc} n & a_1 & \dots & a_j & \dots & a_n \\ \hline c_1 & e_{11} & \dots & e_{1j} & \dots & e_{1n} \\ \vdots & \vdots & & \vdots & & \vdots \\ c_i & e_{i1} & \dots & e_{ij} & \dots & e_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ c_m & e_{m1} & \dots & e_{mj} & \dots & e_{mn} \end{array} \tag{3.5}$$

The performance values in $\mathbb{E}$ can - depending on the method - be based on solely quantifiable, solely qualitative estimates or a hybrid set of both.

The analysis of the DMS serves an aim. In general, four categories of aims are recognised (Guitouni & Martel, 1998; Roy, 2016):

- $P.\alpha$, or the choice problematic. In this problematic, the outcome focusses on the single best outcome. This conclusion may thus be derived from a limited subset of the criteria or through a decision pathway.
- $P.\beta$, or the sorting problematic. In this problematic, variants are sorted into categories based on their performance.
- $P.\gamma$, or the ranking problematic. This problematic focusses on determining the ranking order of the variants, sorting them from best to worst performance.
- $P.\delta$, or the description problematic. This problematic focusses on describing the DMS, for instance, defining the sets of criteria $\mathbb{F}$, a set of appropriate actions $\mathbb{A} \in A$, their performance related to the criteria ($\mathbb{E}$), sometimes completed by, thresholds, aspiration or rejection levels and/or weights.

Each problem category has its own requirements when it comes to the kind of model that can be used. In particular, it has requirements related to the Multicriterion Aggregation Process (MCAP), which defines the mathematical procedure of calculating the model outcome (Guitouni & Martel, 1998; Roy, 2016).

An example of a basic MCAP, would be the synthesizing criterion. In order provide information with respect to the decision, a value is to be assigned to each alternative in the set $\mathbb{A} \in A$. This value is a unique criterion synthesizing all n criteria (Roy, 2016), as detailed in eq. 3.6.

$$v(a_j) = V[g_1(a_j), g_2(a_j) \dots, g_n(a_j)] \tag{3.6}$$

The choice of the MCAP thus defines the following parts of the model Roy (2016):

- A logic of aggregation, detailing the conditions under which attributes are compared, accepted or refused.
- Various inter-criterial and technical parameters, such as the usage of weights, scaling constants, vetoes, aspiration levels and rejection levels. The specific role each criterion can play with respect to others is defined by the numerical values assigned to different parameters.

This emphasizes the importance of making the right choice of the MCAP. An overview of relevant methods and MCAPs is presented in the next section, closely following Greco, Ehrgott and Rui Figueira (2016), as their classification is widely used in the field of MCDM.

3.2. Model families

This section provides an overview of the three main families of models, some remarks on the remaining models and finally some remarks related to dealing with uncertainty.

3.2.1. Outranking methods

Outranking methods use an operational approach based on a synthesizing preference relational system. These methods include the families of methods such as Elimination et Choix Traduisant la Realité (ELECTRE) and Preference Ranking Organisation Method for Enrichment of Evaluations (PROMETHEE). This MCAP is mathematically explicit and is based on the comparison of variants (Roy, 2016). Outranking methods then calculate a binary relation **S** between variants a_1 and a_i. These binary relations, which are also known as the outranking relations, indicate the relation between these variants, which could have three or four outcomes:

1. A clear preference for either variant, **P**.
2. A weak preference relation, **Q**, which is only occasionally taken into account.
3. The DM is indifferent regarding these variants, **I**.
4. The variants are incomparable, **R**.

The outranking relations are based on various inter-criteria parameters and on discriminating thresholds (and veto thresholds) and a logical aggregation mathematical aggregation method. These aggregation methods tend to be far more complex than approaches based on a synthesizing criterion (Roy, 2016).

When all binary relations have been established, they are then used to calculate the ultimate aim of the DM, whether this is selection, sorting, or ranking (Greco et al., 2016).

With regards to the case at hand, this introduces an additional step in the process of calculating the outcome - a step that increases the complexity of a set of models that is already more complex and reduces the transparency. Therefore, this family of models is deemed less suitable.

3.2.2. Single synthesizing criterion

This set of methods use an operational approach based on a synthesizing criterion. This criterion is the result of the mathematical aggregation of all performances $g_1 \dots g_n$, as denoted in equation 3.6. Examples of such methods include Multi-Attribute Value Theory (MAVT), Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART), Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), Analytical Hierarchy Process (AHP) and Analytic Network Process (ANP).

In its most simple form, the aggregation equation, using either a summation or a product, is shown in equations 3.7 and 3.8:

$$v(a_j) = \sum_{i=1}^{n} e_{ij} \tag{3.7}$$

, or

$$v(a_j) = \prod_{i=1}^{n} e_{ij} \tag{3.8}$$

This could easily be extended by adding the weights, as shown in equation 3.9.

$$v(a_j) = \sum_{i=1}^{n} w_i e_{ij} \tag{3.9}$$

The value $v(a_j)$ is a score that presents the performance of the i-th variant in respect to the full set of performance criteria. This value can thus be compared with the values obtained for other variants, allowing both for sorting options and aiding the decision. Since the value $v(a_j)$ is calculated for each variant a_j individually, it is also quite simple do execute a sensitivity analysis on a single variant and observe the changed outcome relative to the remainder of options.

All in all, the core working principle of these methods is rather basic. Therefore, this class of models is suitable for the case. The requirements of simplicity and transparency should however be maintained also when selecting the final aggregation formula V to uphold these requirements in a later stage.

3.2.3. Multi-objective Optimisation

This is a set of models with focusses on optimizing continuous variables. As stated before, this case uses discrete variants, which eliminates this family of models in toto. Furthermore, these models, as of today, only operate with a small number of criteria. The case prescribes an unlimited number of criteria, as it is intended to map out the full set of preference criteria of the KNRM.

3.2.4. Non-classical MCDM approaches

In this category, one would find for instance interactive approaches and mixed approaches. Although these approaches may have their respective advantages, they are deemed not applicable to this case. For instance, an interactive approach is useful for non-compensatory cases, which this case is not. Mixed approaches again increase the complexity and reduces the transparency of the model. This is summarised in table 3.1, displayed below:

Model	Problematic	Preference structure	Compensation
Outranking methods	$P.\gamma$ (occasionally $P.\alpha$ or $P.\beta$)	{**S, R**} (occasionally {**P, I(, R)** })	Partially
Single synthesizing criterion	$P.\alpha$ (occasionally $P.\gamma$)	{ **P(, Q), I** }	Totally or partially
Multi-objective optimisation	Optimising one criteria	{**P(, Q), I**}	Totally
Non-classical MCDM-methods		Various	

Table 3.1: An overview of the main characteristics of the MCDM model families. Note, that individual models within each family can divert from these averages.

3.2.5. Uncertainty

Not all the models that exist today are able to work with uncertainty. Other than that, most models tackle uncertainty by integrating fuzzy sets into the model. The fuzzy evaluation method is particularly suitable for expressing experts' thinking and preferences characterized by uncertainty, ambiguity, non-observability, and scarcity (Zagorskas & Turskis, 2020).

When looking at the use-case for the KNRM, there is indeed uncertainty. Yet, I would argue against integration in the model and against using a fuzzy implementation, due to the added complexity and

reduced transparency. In particular when it comes to the public at large, only few people would know how to interpret fuzzy sets. Their usage would thus hamper the transparency.

Integrating fuzzy sets may however further improve the quality of the DSS and lead to better decisions. Therefore, its implementation is suggested for further research.

In this case, the data for the calculations is to originate from multiple experts. In this way, the overall error margin should be reduced. Therefore, hypothesis H.1 is posed. What number of experts is required to sufficiently reduce errors, is to be determined.

Hypothesis H.1: By integrating the input from a large number of experts, the overall error margin in their judgements is reduced far enough not to influence the outcome.

3.3. State of the art

In modern days, innovation is speeding up, pressuring companies to keep investing in research and development. Yet, from the many ideas that are generated within a company or research and development department, companies only have resources to take only a few of these ideas further and develop them into products and take them to the market. Therefore, companies are often confronted with the question to decide which project or investment to spend their limited resources on.

This development coincides with an ever increasing demand for sustainability. Therefore, it is interesting to see how companies evaluate the sustainability of these projects and how this impacts their decision making.

When it comes to decision making, a research by Macmillan (2000) shows the benefits of using a DSS for these decisions. And given the aforementioned developments, it makes sense to evaluate the literature that integrates these developments and provide insights in DSSs that have been developed for assisting companies in these decisions. However, rather than researching this in general, this literature review focuses specifically on how these DSSs deal with evaluating sustainability criteria within these tools and which underlying methods or models are used.

When assessing the literature with regards to these topics, there is an extensive field of literature on Multi-criteria Decision Making (MCDM), which includes two dedicated journals (the Journal of Multi-Criteria Decision Analysis and the International Journal of Multi-Criteria Decision making) and societies, such as the International Society on MCDM, the Euro Working Group on Multi-criteria Decision Analysis (MCDA) and the INFORMS section on MCDM who organise conferences on the topic. Therefore, it is an extensive field of research with many contributors and a lot of work already done, which has resulted in a significant body of literature in many directions and with many backgrounds. An overview of MCDM methods been presented both by Triantaphyllou (2000) and by Velasquez and Hester (2013). Although some methods have appeared since, most of them are based on the core methods that are mentioned by these scholars. As described before, this literature review provides an overview of a specific selection of this research.

The literature research was conducted searching for scientific publications using both the databases of Web of Science Core Collection and Scopus. A search was also ran on EBSCO host, but it yielded no relevant results and is excluded from further analysis. Google Scholar was excluded because of the limitations in search queries, such as not being able to deal with wild cards and advanced nesting. Furthermore, the outcomes of the Google Scholar search process are neither transparent nor replicable, making it unsuitable for scientific research.

The search was conducted on the 24^{th} of May 2020 and yielded 90 unique hits from 336 authors and from 80 different sources. Authors occur twice at most. This leads to the conclusion that this literature review is not able to identify a clear expert in this field or an author that has done significantly more research into this specific intersection of these three recent topics. On the other hand, the number of citations show a somewhat different picture. As table 3.2 shows, there are some articles, that are significantly more influential than others.

Furthermore, figure 3.2 shows there is only one country that reports more research than some other, much larger countries. Close to 9% of the articles originates from the United Kingdom, which exceeds

No	Paper	Total citations	Citation p/year
1	Strantzali and Aravossis (2016)	138	27.6
2	Dey (2006)	107	7.1
3	Orji and Wei (2015b)	65	10.8
4	Zavadskas, Liias and Turskis (2008)	59	4.5
5	Rossi, Salinari, Poni, Caffi and Bettati (2014)	50	7.1
6	Camargo Pérez et al. (2014)	43	7.1
7	Pizzol et al. (2016)	39	7.8
8	Chuanglin, Haimeng and Guangdong (2016)	32	6.4
9	Ashley et al. (2008)	32	2.5
10	Verghese, Horne and Carre (2010)	31	2.8

Table 3.2: The number of citations per article

even the United States and China[3].

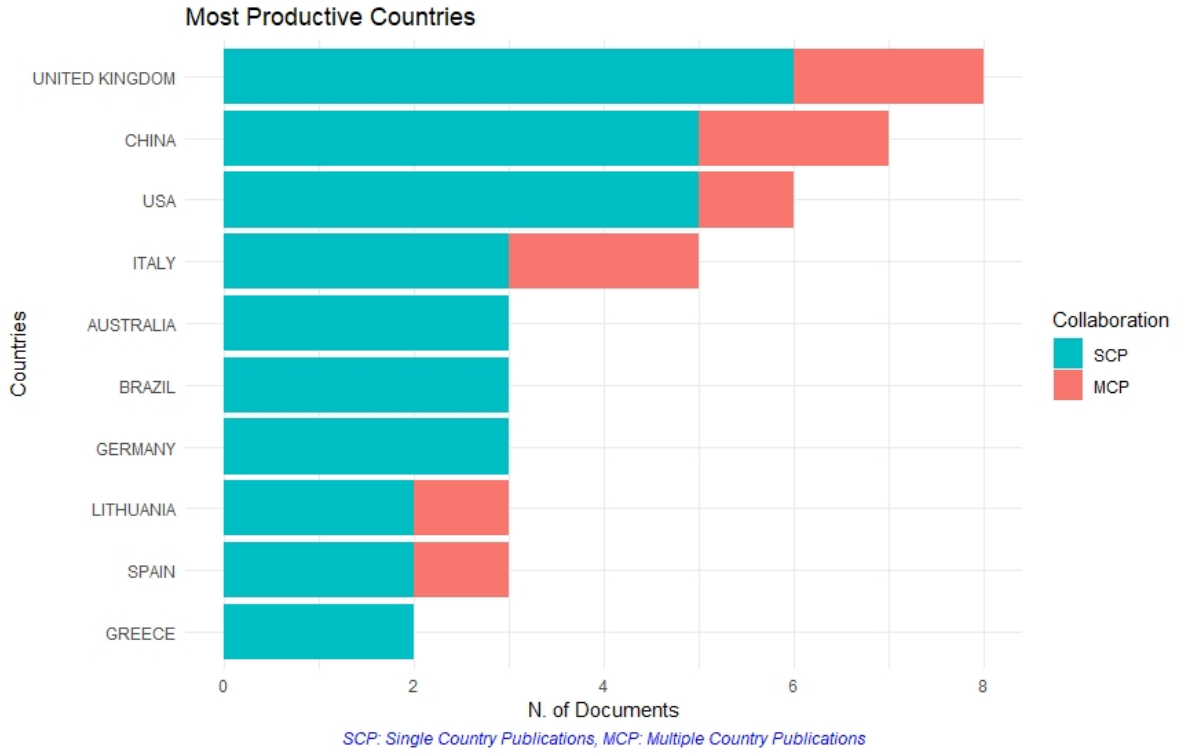


Figure 3.2: Number of articles per country - based on the corresponding author

Table 3.3 shows the sources that published the analysed articles. This shows that interest originates mostly from scholars from the field of sustainability, rather that from management or economics. This is peculiar, as the latter would in particular benefit from the methods that are developed in these articles.

The articles were written between 1997 and 2020, with a steady increase in the topic over the year, which resulted in an exponential growth over the years. This is visualised in figure 3.3.

Another recent development observed during the literature review is the increase in integration of methods in order to negate some of the downsides of core methods. This was also confirmed in a research by Velasquez and Hester (2013). Although in most cases this consists of the integration of two methods

[3]This analysis is based on the corresponding author's address or affiliation rather than his official nation of origin, which was not known to the author.

No	Source	No of articles
1	Sustainability	4
2	Anals of Operations Research	3
3	Environmental Science & Policy	2
4	International Journal of Production Research	2
5	Journal of Cleaner Production	2
6	Renewable and Sustainable Energy Reviews	2
7	Sustainability (Switzerland)	2

Table 3.3: Number of articles per source

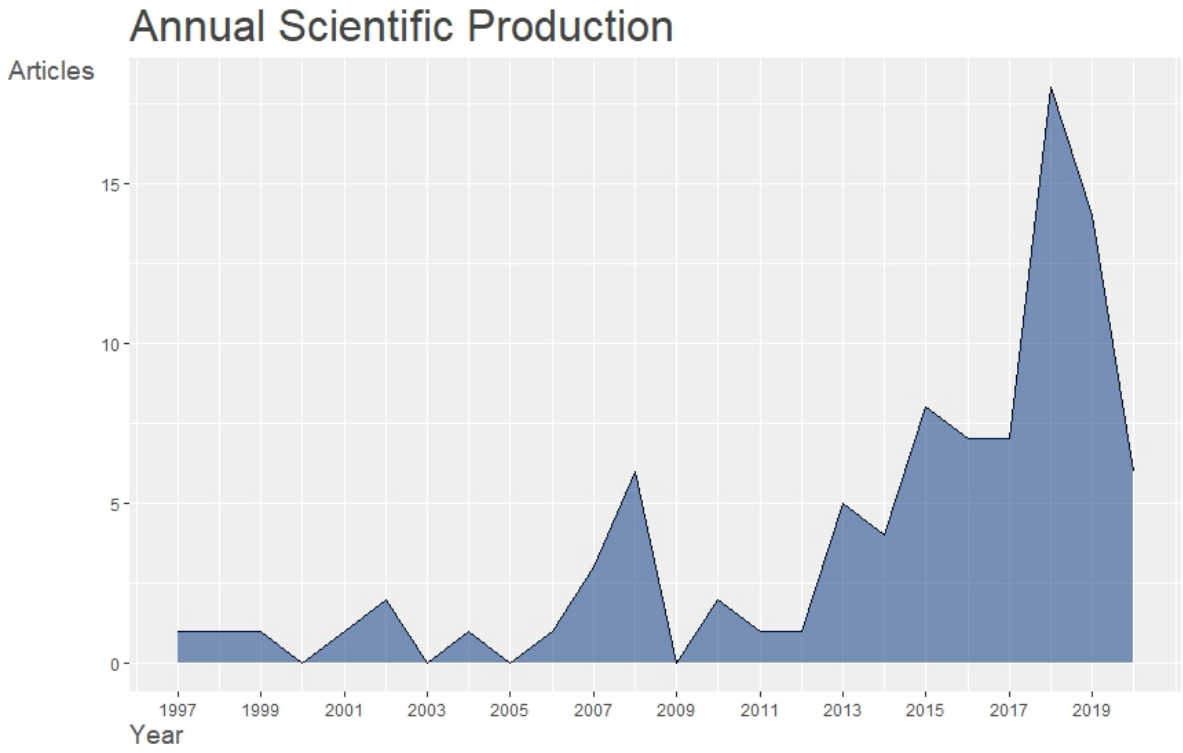


Figure 3.3: Number of articles written per year

in order to combine their respective properties, Loetscher and Keller (2002b) provides an interesting example of the integration of a threshold-defined preliminary filtering method to exclude all variants that are not relevant for evaluation. Filtering them prior to further analysis saves the analyst both time and effort and is expected to result in a better consistency in his judgements of the remainder of the options.

Furthermore, Macmillan (2000) found a relationship between the usage of decision support tools and the overall performance of companies in the upstream oil and gas industry, which she established to be a high-risk high-uncertainty industry. This research clearly identifies benefits for practitioners that originate from the usage of decision support tools.

After analysing the search yield, the yield was filtered through analysing the abstracts of the articles on relevance in relation to the research question in this article. Thereafter, the full text of the remaining articles was analysed, which resulted in discarding an additional 12 articles (3 because they were not on MCDM, 8 because they were not on sustainability and 1 because it wasn't about investment decisions). This step brought the number of selected articles down from 51 to 39. The remaining articles are analysed in depth, leading to the results that are presented in the next section.

First of all, the research shows that the interest amongst scholars to use MCDM methods to include sustainability is significant. It stands out the methods are mostly used for evaluating energy-related projects and projects related to construction and the built environment. This is also shown in figure 3.4. The wide application shows the versatility and adaptability of the method, as all scholars under review agree to the usefulness of the MCDM method in their specific case.

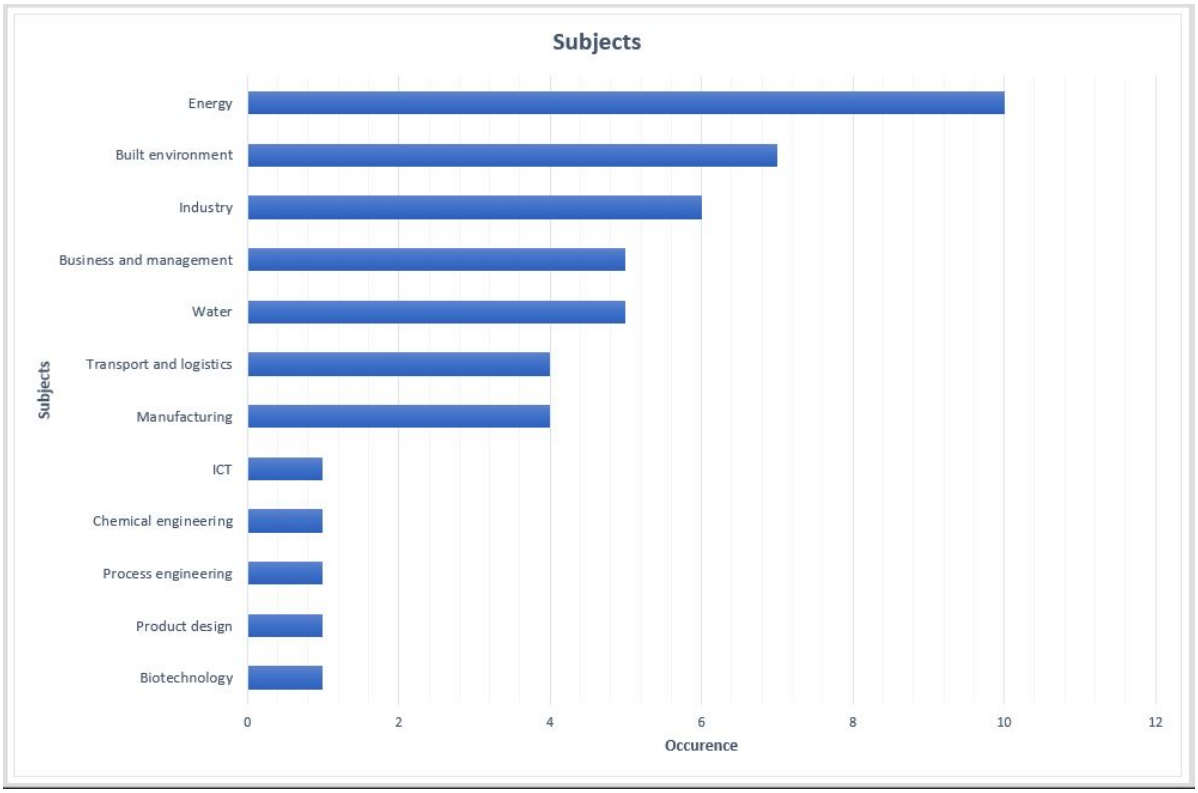


Figure 3.4: Contributions are made in many different subjects and topics

One of the things that stands out is that most scholars assess the invest decision or project selection question to be a discrete problem (34 out of 39). They thus limit themselves to selecting a Multi-attribute decision making (MADM) model for their cases or subjects. This is a logical result as these methods can easily deal with more criteria when compared to continuous models (which are mostly used to solve problems involving only two or three continuous criteria). Therefore they are more suitable for the complex problems that investment decisions pose.

Only one article uses a continuous model by introducing an agent-based bio-inspired system to solve a Multi-objective decision making (MODM) problem, thus introducing the fields of machine learning and Artificial Intelligence (AI) to the field of MCDM (Drezewski, Kruk & Makowka, 2018). This is a very promising development, as their model and system is able to handle far more complex problems by accepting near-perfect solutions, based on bio-inspired evolution algorithms (Drezewski et al., 2018). However, these kind of models are highly complex and therefore less transparent, albeit their value for identifying solutions to these problems. Furthermore, as the model iterates and develops, it may become even harder to comprehend. All-in-all, this may pose difficulties, both for decision makers as well as for boards of directors that have to be accountable for their decisions towards both shareholders and society.

When it comes to the methods that are used, an overview is shown in figure 3.5. The figure shows a clear preference towards using the AHP method, developed by Saaty (1980); Saaty and Sodenkamp (2010). This was also observed to hold for the urban transportation environment (Camargo Pérez et al., 2014). A few arguments are often mentioned for the use of this method:

- It can handle both qualitative and quantitative criteria. Or, in other words, it can handle both

tangible and intangible criteria.
- It incorporates preferences weights.
- It can handle the input of multiple decision makers.
- It is transparent and easy to understand.
- Somewhat related to the previous argument, it is highly suitable as a tool for discussion amongst decision makers, for instance aimed at consensus building.

There are also some downsides to using AHP. Most profoundly, as the method is based on pairwise comparison, the more criteria are incorporated, the more tedious and labour intensive it gets to apply the method. As a general rule, it is accepted that no more than about eight criteria should be incorporated in the model. This may present problems for the future, as decision making gets more and more complex and more and more criteria are deemed relevant to the decision making. A limited number may then no longer suffice, or one risks to get involved in a tedious and tiresome process of filling out the initial decision matrices. This also tends to result in inconsistencies. There are some scholars that have established ways to negate this downside, of which a promising example is presented by Rezaei (2015).

It was found many scholars (representing 8 out of 37 articles, e.g. (Della Spina, 2019; Hasan, Sagbas & Capraz, 2014; Kamari, Jensen, Christensen, Petersen & Kirkegaard, 2018; Moody et al., 2018; Pizzol et al., 2016)) defined another method or model, which is usually case-specific. Often, these models show a strong similarity with existing methods, yet often include a specific process or hierarchy of criteria.

Furthermore, a trend towards hybrid methods (9 out of 37, e.g. (Bai, Kusi-Sarpong, Badri Ahmadi & Sarkis, 2019; Finnerty et al., 2017; Hasan et al., 2014; Kamari et al., 2018; Moody et al., 2018; Orji & Wei, 2015a, 2015b; Pizzol et al., 2016; Rogulj & Jajac, 2018)) is observed, to optimally combine the advantages of different methods. The use of fuzzy or grey methods is often included to deal with ambiguity in human preferences or criteria that are based upon expert opinion. Both these trends were also observed by (Camargo Pérez et al., 2014, pp. 77).

When it comes to the criteria used, no clear trend has been observed, other than that either the triple bottom line (Elkington, 1997; Hubbard, 2009), or an extended version [4] thereof are most often used. The division in economic, environmental and social is occasionally used as arguments, yet most often used for categorisation or higher-level division of criteria. The quantification of these categories differs amongst (almost) all researches. In that sense, no clear set of criteria or quantification can be observed. This may either be because of the individual nature of these problems or because methods haven't been defined for many industries at all. In any case, the definition of a set of general and standardised criteria hasn't been identified yet and may be topic for further research.

When it comes to including sustainability however, it is interesting to see that the triple bottom line approach (separating sustainability as a whole in an economic, an environmental and a social component) (Elkington, 1997; Hubbard, 2009) is often used. In 9 articles (e.g. (Amrina & Vilsi, 2015; Budak, Chen, Celik & Ozturk, 2019; Godskesen et al., 2018; Orji & Wei, 2015b; Pilkauskiene & Leleur, 2014; Salisbury, Brouckaert, Still & Buckley, 2018; Schröder, Lauven, Beyer, Lerche & Geldermann, 2019; Strantzali & Aravossis, 2016; Turan, 2011), this division is used to establish or rank the sustainability as a property of investment options or innovation projects, for instance to evaluate the sustainability of suppliers (e.g. (Orji & Wei, 2015b)). Other scholars take a more holistic approach and try to evaluate the sustainability properties along with other characteristics of a proposition simultaneously (6 articles in toto, e.g. (Ashley et al., 2008; Dey, 2008; Ferrer-Martí, Ferrer, Sánchez & Garfí, 2018; Finnerty et al., 2017; Hasan et al., 2014; Ilker Topcu, Ulengin, Kabak, Ekici & Unver, 2020)). In this case, the three categories of the triple bottom line are still used as main categories, but often complemented with additional categories, of which technological criteria are most often added. This is also observed to be a trend of recent years, which occurred first in 2008.

This study aimed to identify the usability of MCDM methods for including sustainability criteria in investment decisions and/or innovation project selection. Although no clear or immediate answer has

[4] Technological criteria are most often added.

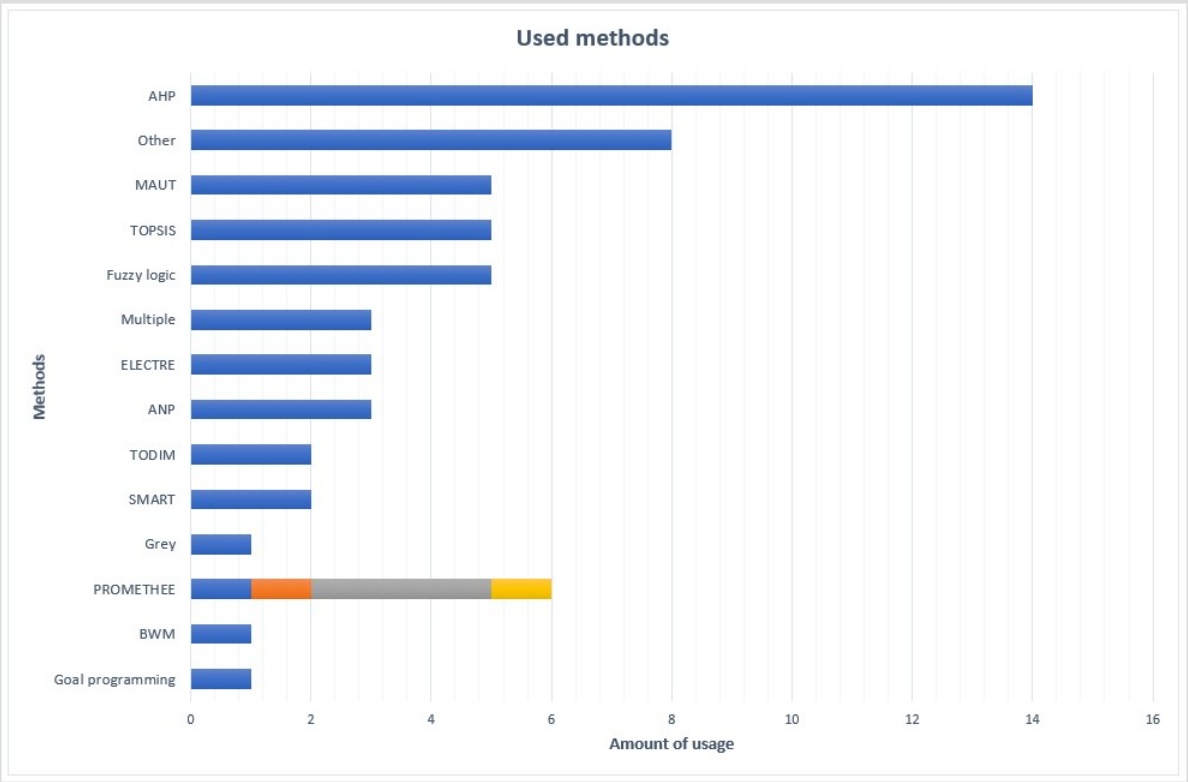


Figure 3.5: Overview of the MCDM methods that were used in the articles. Note that the Preference Ranking Organisation Method for Enrichment of Evaluations (PROMETHEE) column is built up of PROMETHEE general (blue), PROMETHEE I (orange), PROMETHEE II (grey) and PROMETHEE V (yellow). Furthermore, the column 'Multiple' addresses articles that compare methods amongst each other, while 'hybrid' refers to articles that use multiple methods to obtain the optimal result.

been obtained from studying the literature, there are some interesting findings. First of all, even though MCDM methods have been around for a couple of decades, their value in investment decision making or innovation project selection, in particular when incorporating sustainability criteria is a relative young subject of research, which clearly shows a recent uptake amongst scholars. This shows that the combination of family of methods and problem offers potential practical applications. All articles under review in this study - how different in set-up or topic they may be - all agreed on the fact that using a MCDM method offered added value to solve the issue at hand. Added to that, the limited number of research done up to now and the wide spread in topics, shows that there still is a lot of ground to cover.

From this perspective, it is easy to explain why there hasn't been any prior attempt to generalise criteria or digest general criteria from previous work. At the time of this research, there just hasn't been enough to go on and generalising it would not make sense. This is also reflected in the wide spread of different methodologies and sets of criteria used to cover the problem.

One of the most relevant questions posed in this research, is whether it is actually viable to identify a set of criteria that are generic amongst many situations, trades and industries. However, as much as this is a scientific question, it is a philosophical question at the same time, and one can argue whether or not an answer to this question actually exists. As no answer was found to this question, our best estimate is that having a generic set of criteria is not likely to present a tailor-made solution to any situation. Instead, it is more likely to add its value either to start a discussion amongst investment portfolio managers and boardroom executives, challenging them to start measuring and weighting in sustainability properties when evaluating decisions. Furthermore, it may present a starting point to further investigate what a tailor-made solution may look like. In this case, a generic set of sustainability criteria could very well be used as a stepping stone to develop the tailor-made solution and thus help companies take the effort to include sustainability criteria in investment evaluations.

A valid question that could not be clarified in this research, is whether a difference in method prefer-

ence exists between scholars and practitioners. This would be relevant to choose the right model for the right target audience. When it comes to practitioners, there is off course a great variety of uses thinkable, which sophistication may differ just as much. On the other hand, practitioners may benefit from transparent models, as they have to be accountable for their decision making both towards shareholders and to consumers.

This literature review shows that there is a lot of uptake of this topic recently. And therefore, as of now, there is so much development, that it would make sense to revisit this literature research when this field of literature has matured and more research has been done. In particular regarding the incorporation of sustainability criteria in this regard. This is also related to a wide variety of meanings and definitions that are being used in the world, there is need for clarity and uniformity. This could be achieved through a uniform method or starting point.

Although it may not be immediately clear what criteria should be incorporated, some observations are yet to be made, observations that are highly relevant both for future research as well as for practitioners. To measure or evaluate the sustainability of propositions, criteria are divided often in the three categories of the triple bottom line. In more recent times, the triple bottom line is extended with other categories. It makes sense to use a holistic scope to evaluate all relevant criteria in the same model. If not, a decision maker would have to use another overarching model to weigh sustainability outcome against remaining criteria. In a two-step process, the decision maker is limited in conducting sensitivity analyses, as he tends to lose the details of the sub-factors in the first evaluation. Although a holistic approach may seem extensive just to evaluate sustainability aspects of a proposition, in the end it should allow for a better overview of the entire decision and therefore result in a better decision.

Investment decisions or innovation project selection are often classified as discrete MADM problems, which is also reflected in the usage of methods. AHP is used most often, due to its ability to handle both quantitative and qualitative criteria. However, this method is ill suited to deal with a large number of criteria, due to the increase in the number of pairwise comparisons that are involved. There are developments that address this that may result in higher consistencies.

All in all, there is a significant uptake and many developments in the usage of MCDM methods to support investment decisions or evaluate innovation projects, reflected in the increase of work in recent years. All articles agree to conclude that these methods have value in these cases of decision making and should be used by practitioners for optimising their decision making.

In relation to the case at hand, it shows that MCDM methods have often been used by many scholars in prior similar research. These scholars generally applaud the applicability of these models and their contribution in the decision making process. Scholars most often used the AHP method to deal with these cases, distantly followed by tailored amendments of models (combined as 'others'), and the PROMETHEE method family[5]

3.4. Model selection

As stated before, the selection of the model is one of the most important steps in this research, in terms of the effect on the outcome. A wrong choice of model can lead to a diametrically opposed order ((Wenstöp & Carlsen, 1988), as quoted by Guitouni & Martel, 1998).

In the literature, two models have been identified that build a framework that can be used for model selection based on a number of model properties. The first model was build by Guitouni and Martel (1998), the second by Wątróbski, Jankowski, Ziemba, Karczmarczyk and Zioło (2019). The arguments in this framework have been related to the case and are presented in the first subsection. The second subsection converges the outcomes and prior conclusions into a final model selection.

3.4.1. Selection models

Guitouni and Martel (1998) provide a framework with 6 criteria for model selection. This framework

[5]Note that this refers to the combination of PROMETHEE methods. Individual models. e.g. PROMETHEE I, haven't been used significantly more than any of the other methods.

is based on 7 guiding principles, based on parameters of the DMS. The six criteria in the framework are made up of guiding principles 2 to 7; guiding principle 1 is a requirement for the framework to be applicable.

The first guiding principle requires identifying the number of stakeholders involved. Within their framework, the DMS under scrutiny qualifies as a single stakeholder problem, where the KNRM qualifies as single DM. This holds, even though the preference set that is to be used should integrate the expert opinion of multiple experts within the organisation. This would also entail that the group dynamics within the decision making process are not modelled. This aligns with the aim of the model, which is to provide decision support rather than decision (process) analysis.

The second guiding principle related to the DM cognition (Guitouni & Martel, 1998). In our case, the interview with the CEO showed a clear preference for simple choices, i.e., pairwise comparisons. It also showed no clear trade-offs were defined, although the existence of trade-offs was confirmed, nor was there any belief an useful definition of the exact trade-offs, as they are deemed highly circumstantial. The moment of preference elucidation should be a priori, as the model outcome should allow a choice to be made regarding a way to move forward. With regards to the preference structure, as stated before, the introduction of binary preference relations (**S**) would introduce additional complexity and reduce transparency. Therefore, it is not preferred.

When it comes to the third guidance principle, this problem concerns a ranking problem, as neither alternatives should be discarded. Instead, the model should stimulate discussion on the outcome and allow for sensitivity analysis to assess the effects of future (expected) developments. Furthermore, the model should allow for easy interpretation and substantiation of the outcome.

The fourth guiding principle relates to the nature of information that is used as a foundation for calculation. As mentioned in sec. 3.2.5, although there is uncertainty present in this case, the choice is made to treat the data as being certain, upholding the hypothesis (see hypothesis H.1) that combining the opinion of multiple experts results in a small enough error margin to do so. Additional to that, the information used is cardinal of nature.

The fifth guiding criteria specifies the discrimination power of the criteria, whether the model allows for compensation between criteria and the inter-criteria information needed. The case requires compensation to be allowed, rather, it should provide insight into the compensations present in the system, to allow discussion on their desirability and acceptability, rather than enforcing them on the decision makers. When it comes to inter-criteria relations, the CEO mentioned that it is important to allow for weighting of criteria. Therefore, inter-criteria relative weights are to be determined in a later stage of the research.

The sixth concerns the hypothesis that found the MCAP. This will be assessed in hindsight. When a model is chosen, these hypotheses will be set to be limitations of the chosen model. An assessment will be made if these are acceptable and can be accommodated for. If not, the model should be denounced based on that hypothesis.

The seventh guidance principle refers to the presence of a software package. The same goes here, this will be checked after a model is selected.

Adding these conclusions, according to Guitouni and Martel (1998), the viable models would be Analytical Hierarchy Process (AHP) and EVAMIX. Among these two models, EVAMIX is intended to integrate ordinal and cardinal data, which reduces the clarity of the outcome, as a layer of unnecessary complexity is added. Therefore, it seems that AHP is the optimal model to use.

A more current tool is presented by Wątróbski et al. (2019)[6]. He uses a similar framework, based on four criteria and three sub-criteria.

The first criteria used refers to whether different weights of the individual criteria will be taken into account in the DMS. As mentioned before, this will indeed be the case. When it comes to the first sub-criteria, it refers to the type of weights, either qualitative, quantitative or relative. This can still be determined in this stage of the research. However, as I am inclined to prefer a method based on pairwise comparison, this would result in the usage of relative weights.

The second criterion refers to the scale that is used to measure performance ($\mathbb{E}$). This can still be determined at this stage of the research.

[6] An online version of this tool is available on the website http://www.mcda.it.

The third criterion refers to the presence of uncertainty. As detailed before, uncertainty is arguably not present. The sub-criterion with the third criterion relates to the kind of uncertainty (e.g. input data uncertainty and/or DM's preference uncertainty). This is not applicable to this case, nor are the two sub-sub-criteria with the third criterion.

The fourth criterion relates to the decision problematic. As mentioned before, this is considered a ranking problem. The sub-criterion with the fourth criterion details whether this is to be a partial or a complete ranking. Since all variants $\mathbb{A} \in A$ are pre-selected to be viable and relevant options, the ranking outcome should be a complete ranking.

This results in the following outcome in Table 3 in the article by (Wątróbski et al., 2019, pp.113): 1-?-0-3-?-0-2-0-0. When looking this up in the table, fifteen methods are deemed relevant in this case: EVAMIX, MAUT, MAVT, SAW, SMART, TOPSIS, UTA, VIKOR, combination of AHP and TOPSIS, combination of AHP and VIKOR, AHP, ANP, MACBETH, DEMATEL and REMBRANDT.

Of these, MAUT, MAVT, UTA and SMART are deemed not optimal, as they are based on trade-offs (Guitouni & Martel, 1998). Furthermore, single vector weight models, such as Swing and the SMART-family, doesn't allow checking the internal consistency of the weights vector (Rezaei, 2020). This may lead to the integration, and overlooking, of biases towards certain criteria.

When it comes to DEMATEL, this method focuses on the interdependencies amongst the criteria. As such, it shows which criteria are more influential on the outcome than others. Without some kind of prioritisation, this kind of analysis is useless for stakeholders. Using only the DEMATEL method can thus lead to a passive attitude (Kijewska, Torbacki & Iwan, 2018). On the other hand, the same research shows that using only the AHP-method, these interdependencies are overlooked, although they may provide valuable information about the set of criteria. Kijewska et al. (2018) thus argue that these methods should be integrated, showing the use of the integrated model in their work. For the sake of simplicity that is of the essence in this case, it makes sense to choose for the single use of AHP in an initial version of the DSS, although this comes at a risk posed by overlooking the interdependencies. The integration of DEMATEL into the DSS may be researched in the future, after the BOE has gained experience with working with the basic form of the DSS first.

3.4.2. Convergence

This subsection presents the convergence of the prior statements into a model selection.

First of all, as mentioned in section 3.1 the situation under review uses discrete alternatives, a first limitation has already been encountered. Furthermore, as described in section 2.4, the MCAP should use simple and understandable mathematical equations to calculate $v(a)$, as this is an essential requirement to ensure the transparency that is aimed for by the KNRM. A full overview of requirements was distilled from section 2.5.

The model that is to be selected should, as was derived in chapter 2, meet the following criteria:

1. It should resemble the organisations' objectives, aims and perspectives.
2. It should be transparent both to the board of directors as well as to the public at large.
3. It should be understandable to all users.
4. It should integrate a holistic set of criteria, therefore it should handle many criteria.
5. It should be easy to use, it shouldn't require too much work (as decision makers are quite occupied already).
6. The model should be able to harvest and integrate tacit knowledge of experienced employees and crew members into the comparison.

The demand for a model that is both easy to operate and easy to understand is also supported by prior research. Or, as Malmgren and Mjörnell (2015) put it: "Too much automation however, may be a risk if the user is not privy to the logic behind how the tools prioritise and suggest solutions."

These criteria have been translated into the following technical criteria:

1. The model should use discrete variants or options to choose from.
2. The model should be able to handle a relatively large number of criteria (>10).
3. The model should use pairwise comparisons.

4. The model should avoid using binary preference relation **S**.

When analysing the model families, it was identified that a single synthesizing criterion-model would be most applicable. Within this family of models, a model then needs to be identified which uses a transparent MCAP for accumulating the synthesizing criteria that is easy to understand by the users. This follows directly from the requirement the model shouldn't be a black box.

The AHP method is a method that meets this requirement and therefore qualifies as a viable solution for this case. A choice for the AHP method would also be supported by the outcomes of the two selection frameworks by Guitouni and Martel (1998) and by Wątróbski et al. (2019). The selection would also be supported by the analysed literature, as the AHP method was by far the most used method by other scholars in similar cases.

The combined outcomes thus suggest that AHP is the optimal model. Using this model has one shortcoming, as it doesn't support many criteria. Increasing the number of criteria would significantly increase the number of pairwise comparisons and thus the workload for the DSS user. Bai et al. (2019) even poses that the AHP is only viable up to 8 criteria, mostly due to fatigue amongst decision makers. This would then result in a decreasing consistency. Therefore, the case requires a method that can handle more criteria.

Such a method has been presented by Rezaei (2015). Here, a modification to the AHP that limits the comparisons to compare criteria only amongst both the most important or influential criterion (best) and against the least important of influential criterion (worst). Reducing the number of comparisons limits the fatigue amongst decision makers and thus entails a better consistency under an equal number of criteria or decision makers being able to deal with more criteria while maintaining an appropriate consistency (Liang, Brunelli & Rezaei, 2020; Rezaei, 2015).

This improvement limits the only downside to the choice of the model, even as the usage of a method based on pairwise comparisons still requires quite some effort. All evidence presented thus points towards the Best-Worst method (BWM) as an optimal fit for this case. Therefore, I intend to use the BWM, as an improvement and simplification of the AHP method (Liang et al., 2020; Rezaei, 2015).

3.4.3. Implications

Having chosen the BWM, it is essential to establish the effect of the choice both on the remainder of the research as well as for the end user.

The BWM uses pairwise comparisons to evaluate criteria weights and variant overall scores. This means, that the amount of pairwise comparisons increases significantly both from adding an extra criterion as well as adding an extra variant to the equation.

Furthermore, the BWM is a structured and stepwise method (Rezaei, 2015). This implies, that criteria have to be established and agreed upon before the weights can be established. Then, the weights are needed to complete a case study and verify the working of the method.

This has many advantages for this case. For instance, it contributes to the understanding of the outcome and the transparency towards the user. There are also two downsides to using this model. Since it requires multiple steps and many pairwise comparisons, gathering these comparisons takes up more time than other methods would. Also, adding or removing criteria would require some rather sophisticated operations. And the translation from relative preferences into weights may not be immediately understandable by the users. Although these downsides are likely to be offset by the advantages, addressing them during the implementation is likely to support the uptake of the model.

Then, the BWM is only consistent for two or three criteria (Rezaei, 2016). Since the KNRM is expected to use a large number of criteria[7], the model and the weights-vector $\mathbb{W}*$ is expected not to be fully consistent. Although this is not likely to hamper the models usability, this needs to be established through determining the consistency ratio. Furthermore, the concentration ratio enhances insight in the reliability and flexibility of the model (Rezaei, 2020). The concentration ratio is also a measure for the uncertainty of the DM in providing the pairwise comparisons.

[7]Based on the initial interview with the CEO, as detailed in appendix A.

All in all, as the BWM allows for measuring the consistency of the obtained data, the introduction and verification of both a consistency ratio and a concentration factor are required to provide insight into these phenomena in the resulting dataset.

3.5. Conclusions

This chapter aimed to find a method and a model that matches the case. Therefore, the operational requirements that have been deducted in the previous chapter, have been operationalised and a model has been identified that performs accordingly and this way, the BWM has been found to match this case.

An initial categorisation learned that the problem qualifies as a ranking problem, as the organisation is not just interested in the optimal choice, but in particular interested in how and why variants rank the way they do. Also, the chosen model should avoid binary relations, as they conflict with the core requirements of transparency and ease to understand. These conclusions lead to identifying a single synthesizing criterion model.

The decision problem under scrutiny always compares discrete options, therefore, a multi-attribute decision making method should be used. Furthermore, uncertainty can be incorporated using fuzzy logic. On the other hand, using experts' opinion, or just reflecting on the opinions of decision makers, this method is not about incorporating uncertainty, it focuses on showing opinions or best estimates rather than facts.

Then, two frameworks have been used to assist in the model choice. Both models presented the AHP method to match this case, along with a number of other models. In particular the framework by Wątróbski et al. (2019), which was the more recent of the two, presented fifteen applicable models. The fact that much more models were deemed viable, likely originates from the fast development of the field in recent years, which has resulted in the emergence of many additional models and theories. Using convergence logic, most of these models have been eliminated and AHP has been identified as overlapping and viable for this case.

This resulted in the selection of the AHP family. And from within this family, the BWM has been selected, as it offers advantages related both to the required number of pairwise comparisons and the internal consistency of these comparisons.

And although this research does not pretend to have scrutinised all available models, it presents a methodological way to select an appropriate model. This resulted in the selection of the BWM. The chapter concluded with the implications of this choice, which relate to the number of comparisons, the stepwise procedure and the (in)consistency. With respect to the number of comparisons, both adding a criterion or adding a variant has a significant impact on the number of comparisons to be conducted, which relates to the workload for the DM. The number of comparisons also influences the consistency. Due to the large number of criteria - and the number of comparisons, which is directly related to it - the model is likely to be inconsistent, as a result of the human nature. However, the BWM is capable of measuring a consistency ratio and a concentration ratio, which are measures for this this inconsistency. Thus, the method incorporates a way to qualify and quantify the inconsistency, allowing for a judgement.

The next chapter will provide details of the model itself and the steps involved. The chapter will continue discussing how data has been accumulated and analyses the outcomes. The result of the chapter is an overview of the preferences of the KNRM, expressed as the set of decision criteria and their respective optimal weights.

4

Implementation of the Best-Worst method

This chapter evaluates the implementation of the Best-Worst method (BWM) tailored towards the usage in the situation at hand, tailoring to the needs of a sea rescue institute and aiming to incorporate the lessons learned during the initial interviews with the decision makers within this organisation, as presented in chapter 2. Thereby, this chapter presents the ground work needed to determine how data is to be gathered in order to fill the model for the specific case at hand.

As found in chapter 3, the main advantage over the Analytical Hierarchy Process (AHP) is a reduction in the number of pairwise comparisons, in particular when determining the weights-vector $\mathbb{W}$. In order to establish this vector, the AHP method first establishes the matrix $\mathbb{O}$ (sized $n \times n$), denoted in equation 4.1, which contains the relative importance of a_i over a_j, denoted as a_{ij}.

$$\mathbb{O} = \begin{Bmatrix} a_{11} & \dots & a_{1j} & \dots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \dots & a_{ij} & \dots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \dots & a_{nj} & \dots & a_{nn} \end{Bmatrix} \tag{4.1}$$

Systematically establishing these preference relations one by one, as would be the case for the AHP method, would require n^2 comparisons. Taking into account all comparisons with the criteria themselves, $n(n-1)$ comparisons remain. Then, half of these are reciprocals of the other half, e.g. a_{ji} is the reciprocal of a_{ij}, thus equal to $\frac{1}{a_{ij}}$. Therefore, the minimum number of comparisons required for this method, equals $\frac{n(n-1)}{2}$. Using the Best-Worst method (BWM), the number of pairwise comparisons can be further reduced to $2n-3$ comparisons (Rezaei, 2015). This can be achieved, as the BWM uses the a_{Bi} and a_{Bj} to establish a_{ij}, using equation 4.2. In this equation a_{ij} thus refers to the relative preference of the i-th criterion (for instance *Safety for the user*) over the j-the criterion (for instance *Workload for the user*).

$$a_{Bi} \times a_{ij} = a_{Bj} \tag{4.2}$$

This chapter has been divided up in multiple sections, each formulating how the core components of the Decision Support System (DSS) will be assembled in the next parts of the research. Section 4.1 details the aggregation of the set of criteria for each Decision Maker (DM). Section 4.2 defines how the weights are accumulated and calculated from the relative preferences obtained from the DMs. Then, section 4.3 will go into detail on gathering the performance of the variants in respect to the criteria and the calculation of the synthesizing criterion. Finally, the chapter will end with a conclusions, summarising the main findings.

4.1. Criteria

The method doesn't really specify how criteria relevant for the Decision Making Problem (DMP) are gathered, as the original method is based on a single DM. Even in methods including multiple DMs, such as for instance the Bayesian method presented by Mohammadi and Rezaei (2020), there is no reference as to how the set of criteria is agreed upon. This implementation aggregates the criteria based on an equal representation, while also taking into account the expertise and background of the DM. This way, a set of criteria is to be obtained reflecting the DMs and thereby the organisation of the Koninklijke Nederlandse Reddingmaatschappij (KNRM). Therefore, initially, all DMs are to define a set of criteria relevant for strategic investment decisions individually, which are then aggregated into a single set, depending on the number of DMs involved in the Decision Making Situation (DMS). Other than the DMs, lessons identified from comparable DMS are also to be included by incorporating a small literature research, aiming to identify what other scholars deemed relevant.

Based on the interviews held up to this stage of the research (see chapter 2), there are a lot of criteria involved in the decisions under scrutiny for this research. Therefore, it is important to emphasize that there is a limit to the number of criteria the human mind can compare within a single set of pairwise comparisons, which is typically found to be around eight criteria (Bai et al., 2019). Therefore, a layered structure is needed, dividing criteria into subsets in order to overcome the problem of having to compare too many criteria in one set.

Thus, a complete set of criteria should be acquired, covering all relevant aspects of the DMS at hand. Section 4.1 deals with gathering the set of criteria for each participant. Section 5.2.4 deals with the calculation of the vector with the preference weights from the relative preferences stated by the interviewees. Then, section 4.3 deals with scoring the performance of the variants in order to obtain the single synthesizing criterion to assess the variants' performance. The chapter then ends with a conclusion.

4.2. Weights

When it comes to establishing the weights, the BWM employs a more elaborate and mathematical method, building strongly on Rezaei (2015, 2016). It entails the following steps:

Step 1

Determine the set of criteria for the decision analysis. The set of performance criteria has been defined in equation 3.2. The final set of criteria will be derived by integrating the sets of criteria defined by the individual MT-members.

Step 2

The Best (denoted by B) and Worst (denoted by W) criterion are to be identified. B denotes the most important criterion, which should have the most impact on the outcome. As for W, it is the least important criterion. The criteria were rated by all MT-members

Step 3

Next, the preference of B over all the other criteria is established using a number from the range 1 to 9 (1: B equal important to other criterion; 9: B is much more important compared to the other criterion). This was also done during the second round of interviews with the experts. This results in the Best-to-Others vector (BO), as shown in equation 4.3.

$$BO = (a_{B1}, \dots, a_{Bij}, \dots, a_{Bn}) \tag{4.3}$$

Step 4

Then, the preference of all other criteria over W is also established using a number from the range 1 to 9 (1: Other criterion as important as W; 9: Other criterion extremely preferred over W). This was also done during the second round of interviews with the experts. This results in the Others-to-Worst (OW) vector, as shown in equation 4.4.

$$OW = (a_{1W}, \dots, a_{jW}, \dots, a_{nW})^T \tag{4.4}$$

Having defined these vectors, the remainder of the weights can be found using equation 4.2. And given that equation 4.2 holds, the pairwise comparisons are deemed consistent if equation 4.5 holds.

$$a_{Bi} \times a_{iW} = a_{BW} \tag{4.5}$$

However, due to the human nature in these processes, humans are - generally - not able to achieve full consistency. Therefore, an inconsistency factor ξ is introduced.

Step 5
Now that all required data for the weights has been collected, the optimal weights can be calculated and the consistency evaluated. The optimal weights can be obtained as shown in model 4.6, which finds the weights such that the maximum deviation of the pairwise comparisons and their corresponding weight ratios ($\forall j$) is minimised.

$$\min \max_j \left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_W \right| \right\}$$

s.t.

$$\begin{aligned} \sum_j w_j &= 1, \\ w_j &\geq 0, \ \ \forall \ j \end{aligned} \tag{4.6}$$

Model 4.6 can be transformed into model 4.7.

$$\min \ \ \xi$$

s.t.

$$\begin{aligned} \left| \frac{w_B}{w_j} - a_{Bj} \right| &\leq \xi, \ \ \forall \ j \\ \left| \frac{w_j}{w_W} - a_{jW} \right| &\leq \xi, \ \ \forall \ j \\ \sum_j w_j &= 1, \\ w_j &\geq 0, \ \ \forall \ j \end{aligned} \tag{4.7}$$

Model 4.7 clearly shows a hyperbolic relation between a_{Bj} (or equally, a_{jW}) and criterion under scrutiny (w_j).
However, research shows the non-linear programming problem has multiple solutions and therefore a more detailed analysis of the outcomes is required. In order to do so, ξ^* is used to calculate the range of the weight values. Therefore, first of all, equation 4.8 defines an interval with a left limit and a right limit of A.

$$A = [a_L, a_R] = \{x : a_L \leq x \leq a_R, x \in \mathbb{R}\} \tag{4.8}$$

This interval can also be defined by its centre value (a_c) and the width (a_w) of the interval. This is shown in equation 4.9.

$$A = \langle a_L, a_R \rangle = \{x : a_c - a_W \leq x \leq a_c + a_W, x \in \mathbb{R}\} \tag{4.9}$$

Step 6
In order to establish the optimal weights vector, first of all, for each weight, the interval for each weight has to be calculated. This can be done by transforming eq. 4.7 into the the model 4.10 to calculate the lower, or left values of the interval, w_{jL}.

$$\min \ w_j$$

s.t.

$$\begin{aligned} \left|w_B - a_{Bj} w_j\right| &\leq \xi^* w_j, \ \forall \ j \\ \left|w_j - a_{jW} w_W\right| &\leq \xi^* w_j, \ \forall \ j \\ \sum_j w_j &= 1, \\ w_j &\geq 0, \ \forall \ j \end{aligned} \tag{4.10}$$

Similarly, the upper, or right value (w_R) of the weights interval can be calculated. This is shown in model 4.11.

$$\max \ w_j$$

s.t.

$$\begin{aligned} \left|w_B - a_{Bj} w_j\right| &\leq \xi^* w_j, \ \forall \ j \\ \left|w_j - a_{jW} w_W\right| &\leq \xi^* w_j, \ \forall \ j \\ \sum_j w_j &= 1, \\ w_j &\geq 0, \ \forall \ j \end{aligned} \tag{4.11}$$

This gives us the first weight interval w^*, which equals $[w_L, w_R]$ and $\langle w_C, w_W \rangle$.

Alternatively, another solution is suggested to circumvent the multiple outcomes of the non-linear BWM (Rezaei, 2016). To obtain a set of weights, a linear approximation of model 4.7 could be used, which is shown in model 4.12. Using this model, a second weights-vector is obtained.

$$\min \ \xi$$

s.t.

$$\begin{aligned} \left|w_B - a_{Bj} w_j\right| &\leq \xi, \ \forall \ j \\ \left|w_j - a_{jW} w_W\right| &\leq \xi, \ \forall \ j \\ \sum_j w_j &= 1, \\ w_j &\geq 0, \ \forall \ j \end{aligned} \tag{4.12}$$

The outcome of the model 4.12 is compared to the weight interval w_C, presenting the graphical representation of both vectors in a single graph. Either one will be adopted as the most representative weights vector, based on the best resemblance of the interviewees preference situation. The outcome of this choice is detailed in section 5.2.4.

This vector is the closest approximation of the true weights vector $\mathbb{W}$[1]. The quality of which the Decision Maker (DM) is able to judge his own preference weights is not established, which goes beyond the scope of this research. Given the likely occurrence of inconsistencies, model 4.7 could have multiple optimal outcomes, with the optimal weights $\mathbb{W}*$ being intervals rather than fixed numbers (Rezaei, 2016). As such, the DM or group of DMs could chose either optimal solution based on additional knowledge or personal or group preferences.

Having thus established the weights, next, the performance of establishing the weights is calculated.

4.2.1. Performance

The establishing of the weights is executed through solving numerical equations. This is a best estimation of the outcome and rarely presents an exact solution (for sets consisting of more than 2 criteria). Therefore, this section introduces some parameters to assess the performance of the established weights.

Then, the variants also need to be viable solutions to the problem at hand. How this is established, isn't part of this research nor the method presented here.

Step 7

The original BWM research (Rezaei, 2015, 2016) also defined an indicator for the consistency based on the output found using models 4.7 and 4.7, referred to as the Consistency Ratio (CR). In particular ξ^* provides an indication for the internal consistency of the pairwise comparison system. This can be transformed into a CR using a Consistency Index (CI) based on the maximum value for ξ, ξ_{max}, which, in turn, is based on the maximum score in the pairwise comparison, a_{BW}. The relation between ξ^*, the CI and CR is shown in equation 4.13.

$$CR^O = \frac{\xi^{L*}}{CI} \tag{4.13}$$

The values for the CI are shown in table 4.1, containing the CI, which is related to the maximum preference of one criteria over another, which should equal the preference of the best over the worst (a_{BW}) (Rezaei, 2015).

In order to assess whether the consistency of the input is valid, it has to be compared to a threshold providing a minimum requirement for the consistency. In this research, the table presented by Liang

[1] This vector was defined in equation 3.3.

	a_{BW}								
	1	2	3	4	5	6	7	8	9
Consistency Index (max ξ, ξ^{max})	0	0.44	1	1.63	2.3	3	3.73	4.47	5.23

Table 4.1: The Consistency Index (CI) (Rezaei, 2015).

et al. (2020) is used, which presents thresholds depending both on the number of variables (shown on the columns of the table) and on the preference of the Best over the Worst, a_{BW} (on the rows of the table). This table holds for the output consistency index presented in equation 4.13 and is shown in table 4.2.

	n (# of criteria)						
a_{BW}	3	4	5	6	7	8	9
3	0.209	0.209	0.209	0.209	0.209	0.209	0.209
4	0.158	0.235	0.274	0.293	0.310	0.315	0.327
5	0.211	0.285	0.302	0.331	0.348	0.361	0.374
6	0.216	0.292	0.357	0.392	0.406	0.417	0.423
7	0.209	0.331	0.373	0.393	0.404	0.411	0.430
8	0.227	0.341	0.403	0.423	0.438	0.454	0.460
9	0.212	0.365	0.406	0.423	0.445	0.459	0.475

Table 4.2: The threshold values for the output-based consistency ratio (Liang et al., 2020).

Liang et al. (2020) also presents a method to calculate an input consistency index providing consistency feedback to the DM while determining the weights.

$$CR^I = \max_j CR_j^I$$

where

$$CR_j^I = \begin{cases} \frac{\left|a_{Bj} \times a_{jW} - a_{BW}\right|}{a_{BW} \times a_{BW} - a_{BW}} & a_{BW} > 1 \\ 0 & a_{BW} = 1 \end{cases} \tag{4.14}$$

In equation 4.14, CR^I refers to the global input-based consistency of the set of vectors, while CR_j^I represents the local consistency level for each criterion c_j. The input-based consistency, both global and local, was presented to the interviewees during the second interview. In order to assess the overall consistency based on the input-based consistency, a threshold is needed as well. In this research, the thresholds as defined by Liang et al. (2020) are used, which depends on the number of criteria n and the preference of the best criterion over the worst criterion, a_{BW}. The thresholds are presented in table 4.3.

Step 8

Having established the consistency ratio, the concentration ratio κ can be calculated. This ratio is based on c_{BW} and defined as shown in equation 4.15 (Rezaei, 2020):

$$\kappa = 1 - \frac{\psi}{max_{a_{BW,n}}(\psi)} \tag{4.15}$$

Where ψ is defined as shown in equation 4.16.

	n (# of criteria)						
a_{BW}	3	4	5	6	7	8	9
3	0.167	0.167	0.167	0.167	0.167	0.167	0.167
4	0.112	0.153	0.190	0.221	0.253	0.258	0.268
5	0.135	0.199	0.231	0.255	0.272	0.284	0.296
6	0.133	0.199	0.264	0.304	0.314	0.322	0.326
7	0.129	0.246	0.282	0.303	0.314	0.325	0.340
8	0.131	0.252	0.296	0.315	0.341	0.362	0.366
9	0.136	0.268	0.306	0.334	0.352	0.362	0.366

Table 4.3: The threshold values for the input-based consistency ratio (Liang et al., 2020).

$$\psi = \sum_{j=1}^{n} \left(w_j^{max*} - w_j^{min*} \right), \forall j \tag{4.16}$$

In this equation, w_j^{max*} and w_j^{min*} resemble the lower and upper bounds of the weight for criterion j, and $max_{a_{BW},n}(\psi)$ is the maximum possible sum of the optimal interval ranges of the weights for a problem with the same c_{BW} and the number of criteria n.

The value for $max_{a_{BW},n}(\psi)$ has been calculated by Rezaei (2020), the results of which are presented in table 4.4. The table once again shows the number of criteria along the columns, while the preference of the best over the worst is shown along the rows of the column.

	n (# of criteria)					
a_{BW}	4	5	6	7	8	9
2	0.149	0.252	0.326	0.380	0.422	0.456
3	0.283	0.480	0.630	0.749	0.844	0.922
4	0.395	0.656	0.861	1.023	1.157	1.268
5	0.460	0.782	1.026	1.223	1.386	1.526
6	0.52	0.890	1.183	1.427	1.638	1.820
7	0.566	0.966	1.283	1.550	1.782	1.987
8	0.597	1.016	1.348	1.630	1.876	2.095
9	0.618	1.057	1.412	1.718	1.990	2.233

Table 4.4: The value for max(psi)

Now that also the performance of establishing the criteria has been established, a first test of the usability of the weight vector can be conducted. This provides a first condition for the usage of the model.

4.3. Scoring the variants

The establishing of the weights is an essential step in the BWM in order to be able to establish the synthesizing criterion, which is needed to numerically compare the variants. The next steps will therefore include the variants, which need to be detailed prior to evaluating them. Furthermore, the DM should preferably be intimately familiar with them. Furthermore, the variants should be detailed with respect to the criteria taking into account for the evaluation, in order to allow for evaluating the performance of the variants in respect to these criteria. That being said, one of the strengths of the BWM is that the performance doesn't need to be exactly measurable, rather, an experts judgement suffices.

Step 9

In the next step the variants are separated from the remainder of options using the minimal criteria an

option has to meet in order to meet the needs of the KNRM. This can be done using either a minimal performance on a (sub)set of the set of criteria $\mathbb{F}$ or through a set of additional criteria that need to be met in order to be eligible as a variant. Such a set of criteria and threshold performance should ideally be defined prior to entering the process; going through the process only adds value and only contributes to a better decision if there is something to choose from (Keeney, 1996).

Step 10
Then, all variants are scored on their performance on the criteria selected to be part of $\mathbb{F}$, thus establishing $\mathbb{E}$. These performance scores are integrated into a single synthesizing criterion as shown in equation 3.9, entailing a summation of the product of the score and the weight of this criterion.

Step 11
After having defined all single synthesizing criteria, the variants can be sorted along the value of the single synthesizing criteria. The variant scoring the highest single synthesizing criteria should be the 'best' option. Furthermore, both the synthesizing criteria and the decision matrix itself ($\mathbb{E}$) are eligible for an in depth analysis in order to understand the outcome and, for instance, project expectations for the future in order to understand the effects of time on the outcome.

This concludes the steps to be taken to compare different variants and assess their performance relative to a set of criteria reflecting the core values of the organisation.

4.4. Conclusion

This chapter presented the BWM as it was implemented during this research. It thus provides the background and fundamental mathematics behind all sheets used to obtain the criteria representing the values of the KNRM and the weights given to these criteria.

The main advantage of the BWM originates from the reduction of de number of pairwise comparisons, as explained earlier. This reduces the effort required to establish the weight vector $\mathbb{W}$.

Second of all, the introduction of secondary comparisons, further increases the risk of inconsistencies. Using the BWM however, has a positive impact on the consistency (Rezaei, 2015). Furtermore, presenting the internal consistency to the interviewee (as calculated in equations 4.14 and 4.14) also allows the interviewee to evaluate his consistency during the process of establishing the vectors BO and OW.

The combined effects of a reduction in the number of pairwise comparisons and the improved consistency result in the method being capable of dealing with a larger number of criteria to begin with.

All in all, the BWM comprises of a number of simple steps, while yet creating a rich source of analysis of the outcome. The next chapters show how this theory is put into practise and the values and respective weights for the KNRM were established.
Now, the next chapter present how these sets were established, specifically tailored to the organisation. Then, the sets are put under scrutiny in an evaluation case. And finally, the model is nested into the current decision making process of the organisation.

5

Establishing the model

After having established how the method will be used for the Decision Support System (DSS), the data the model requires to operate needs to be assembled. In the first section, the method for data acquisition is detailed. Then, an overview of the assembled data is presented and integrated into a single set of preferences and weights that should resemble the Koninklijke Nederlandse Reddingmaatschappij (KNRM). In the third section the gathered data is analysed and compared with qualitative data that was acquired during the qualitative interviews earlier. This should, amongst others, provide an answer to sub-questions five and six.

5.1. Data gathering

This section will detail the data acquisition procedures that were followed to obtain the required data for the model. As described in chapter 1, the data is to be obtained through interviews with those involved in the decision making throughout the organisation.

The data gathering has been split in two main parts, as the input from the first part had to be accumulated and processed before the collection of the data for the second part could take place. Both parts together were aimed at establishing the preferences as mentioned in figure 3.1.

The first interviews were held to accumulate the criteria. Table 5.1 presents an overview of all interviewees and their role within the organisation. The table shows a diverse and balanced group of interviewees selected, from multiple disciplines in the organisation. The original plan was to interview all members of the Board of Executives (BOE) of the KNRM. However, due to availability, some BOE members delegated someone from their department to participate in the research. This way, a balanced view of the organisation and integrate different perspectives on the Decision Making Situation (DMS) are deemed to be established. Having accumulated them, they were integrated into a single set of criteria.

In the second stage the weighting of criteria, $\mathbb{W}$, has been established. In order to do that, the final set of criteria was needed, which thus was established first. This set was also presented to the interviewees, in order to provide them with a general overview of the set-up, which is deemed useful to better understand the frame when weighting the criteria. This second step was combined in the second interview with the evaluation of the test case, in order to accommodate the interviewees.

Both interviews were practised with a test subject to check the procedure and identify gaps in the preparation, allowing for a pre-emptive correction. With regards to the data sheet used for the accumulation of the weights, although based on an existing template, an additional test was executed to ensure the proper working before presenting it to the interviewees.

Step 1

The interviews for the first phase have been conducted through elaborating on what criteria would be involved when assessing strategic investment decisions. All interviews started off with an introduction in the basics of the BWM. This was used to introduce the method and clarify the objective of the interview. This introduction generally lasted ten to fifteen minutes and was held using a digital presentation, which

is shown in appendix C. Then a brainstorm session was initiated to stimulate the interviewee to come up with all criteria deemed relevant for the decision making when choosing amongst different investment options. This brainstorm session was supported either by visualising the structure on a whiteboard or using a mindmapping tool when the interview was held online[1].

The criteria were then integrated using the procedure described in appendix J. Upon completion of the pre-defined procedures, some dilemma's remained, which were addressed in an additional interview.

Step 2

Having finalised the set of criteria, second set of interviews were used to obtain the weights for the criteria. This was done by filling out the forms shown in appendix M, in sheet-by-sheet manner. Although, based on their comfort using the system, some interviewees were offered to continue filling out the sheet individually.

An overview of interviewees is presented in table 5.1, including references to their respective answers for both parts of the interview. The table also shows where the outcomes of each interview can be found, both for the first and the second interview.

Name	Department	Criteria	Weights
Interviewee 1	CEO	Appendix D	Appendix N
Interviewee 2	CTO	Appendix E	Appendix O
Interviewee 3	COO	-	Appendix P
Interviewee 4	Communication and fund raising	Appendix G	Appendix R
Interviewee 5	Finance	Appendix I	Appendix T
Interviewee 6	Policy advisor	Appendix H	Appendix S
Interviewee 7	Project engineer	Appendix F	Appendix Q

Table 5.1: Interviewees and overview of results.

An overview of the consolidated set of criteria is presented and explained in depth in section 5.2, along with the weights vector that is being distilled from the second part of the interviews. Section 5.3 then analyses how the outcome came to be and what this entails for the practical use of the model and for the organisation as a whole. Having thus analysed the results from the interviews, the section 5.2.4 presents the procedure of integration of the weights and the final weights vector.

5.2. Data overview

This section provides an overview of the criteria that are to be used as an input for the model. The evaluation starts of with an evaluation of the set of criteria that are the basis for the model, starting off with the criteria for the requirements.

5.2.1. Requirements

As all participants stipulated the importance of including the requirements in the discussion, this section provides a short summary on the remarks regarding the requirements. It is important to note that a full evaluation of the requirements is outside of the scope of this research and may be adapted on a case-by-case basis. The definition of the requirements are also ready part of the present process, as the requirements are defined in the definition of the set of project requirements for the minimum viable solution[2].

The requirements could be integrated in the model, but a manual selection of the variants from a set of options could also suffice. If chosen to select a variant manually, it is of the utmost importance that a clear and transparent process is used for selection of the variants, to prevent any actor from claiming in a later stage that any option has been invalidly discarded.

[1] These interviews were held during the national lockdowns related to the Covid-19 pandemic.

[2] As a translation from the Dutch term 'Plan van Eisen', which contain, amongst others the 'Functionele Stafeisen'.

The outcome of the interviews provided some guidance on the criteria that may be used to execute such a process, either manually or integrated in the model. The participants comment on including some of the core values from the mission of the organisation into the requirements, such as providing rescue free of charge, professional and independent. These values could be included into the requirements. Furthermore, any strategic objectives could also be included. Then, other criteria can also be included, such as a minimal level on any criterion. This does not interfere with the inclusion of the criterion in the performance measurement - after passing a minimal level, different variants can still distinguish themselves in their performance on this criterion. For instance, in relation to the design of rescue vessels, this may very well apply to reliability. As all interviewees acknowledged the importance of this criterion, a minimal level could very well be required from the options. Thus, the model provides high flexibility to the users.

And since the requirements are currently implemented in the process, there seems to be no need to go any further into details on this aspect of the model in the context of this research.

5.2.2. Criteria

The criteria were collected in the first step of the data gathering, as per the plan set out in the first section of this chapter. During the interviews concerning the current decision making process (see also chapter 2), it was found that the current procedure was unstructured and no current set of decision making criteria currently existed. Therefore, during the this round of interviews, all interviewees were asked to identify a set of criteria. That no shared set of criteria existed was also visible in the result of the interviews, as a great variety of criteria was mentioned and criteria mentioned differed widely across the different interviews. The individual sets of criteria are presented in an appendix for each interviewee, as per table 5.1. This then resulted in a large number of criteria mentioned over the width of the interviews, leading to many, and maybe even too much, insights in the decision making process.

This section will continue to go into more detail regarding the evaluation of sustainability and safety within the sets of criteria. The integration of the criteria into a single set is detailed in the next subsection.

Sustainability

During the initial interviews with the CEO and CTO (see chapter 2), both the CEO and CTO focused on sustainability and safety as important criteria for the organisation. Therefore, additional attention is paid to the way they are implemented in the final set of criteria.

First of all, it is important to note that all interviewees valued sustainability to play a role in the decision making process, even enough to assign it its own category. This is also reflected in both the individual sets of criteria, as well as the integrated set of criteria, shown in figure 5.1.

The definition of sustainability closely follows the triple bottom line approach (Elkington, 1997; Hubbard, 2009), which sections sustainability into three main concepts. These concepts are environmental factors, social factors and economic or financial factors. However, due to the importance of the financial aspect for a small charity as the KNRM, this group of criteria was mentioned by all interviewees to be comparable in importance to sustainability, rather than as a part of sustainability. As such, sustainability has been defined by environmental factor and social factors, which was complemented by some additional factors, such as the sustainability throughout the entire chain of production, adaptability to future developments and the opportunities for the stimulation of economic usage.

So, although the triple bottom line is resembled in the data presented by the interviewees, some nuances have been made to tailor to the specific needs of the organisation.

Safety

As one can understand, safety is a critical criterion for the KNRM, as the organisation should be able to conduct its tasks during rough and adverse weather conditions. Furthermore, the organisation relies upon volunteers to man the lifeboats and feels strongly responsible to supply the volunteers with the best and safest equipment available. This is further confirmed by the CEO[3] and CTO[4] during the initial

[3]Held on the 1^{st} of July.
[4]Held on the 23^{rd} of July.

interviews, as reflected in chapter 2.

However, safety can be interpreted from many angles, can be assessed from a purely statistical (risk-) perspective, from a technological perspective, from a practical perspective or from a social perspective. What stood out is that interviewees mentioned safety not once, but twice, both from a social/user perspective and from a technical perspective. This seems to resemble that the KNRM operates high tech equipment and also that it is a charity depending on volunteers, showing an emphasis on the human aspect of safety and an intrinsic motivation to provide the volunteer or employee with equipment that is safe to use. Since this opinion was expressed more often, it is also reflected in the final set of criteria as shown in figure 5.1.

Having collected the set of criteria from each individual interviewee, these criteria have been integrated into a single set of criteria, resembling the opinion of the KNRM, as detailed in the next subsection.

5.2.3. Integration

The individual sets of criteria showed both overlap and criteria mentioned by specific interviewees only. This section presents the methods used to integrate these sets into a single set reflecting the KNRM as a whole, rather than any individual.

As a starting point for the integration, the set of criteria presented by the CEO was used, as this best represented the average outcomes by the other interviewees. Then, all criteria mentioned by the other interviewees, that were not included by the CEO, were evaluated. Criteria were added to the set in three cases:

1. If they were mentioned by two other interviewees, or
2. The criterion at hand was relatable to the field of expertise of the interviewee, or
3. If they were mentioned by one other interviewee and in the literature, using a number of sources from a small literature review on the topic (Al Garni, Kassem, Awasthi, Komljenovic & Al-Haddad, 2016; Awasthi, Chauhan & Omrani, 2011; Şengül, Eren, Eslamian Shiraz, Gezder & Sengül, 2015; Georgopoulou, Lalas & Papagiannakis, 1997; Hubbard, 2009; Kannan, De Sousa Jabbour & Jabbour, 2014; Kiliç & Kaya, 2015; Lee & Chan, 2008; Ortt, Langley & Pals, 2013; San Cristóbal, 2011; Stein, 2013; Yang, Bonsall & Wang, 2011).

Finally, the criteria originally mentioned by the CEO were evaluated. If they were mentioned by the CEO alone, they were removed. After these steps, all criteria included were either mentioned by two or more interviewees. Criteria mentioned by one interviewee were also mentioned in the literature.

Then, the fit of individually mentioned criteria in the final model was evaluated. First of all, a number of criteria has been added based on the specific area of expertise of an interviewee. Furthermore, if such criterion would fill an obvious void in the model, an argumentation for its inclusion was defined. Then, the criteria and these arguments were presented to the representative of the organisation, to decide upon these dilemma's. An overview of the dilemma's and the choices made is included in appendices J and K.

During the interviews, many criteria were mentioned and, given the limitation to approximately seven criteria which can be judged at the same time, all interviewees opted to split the criteria into multiple subsets, following roughly an identical structure, in line with the division in departments of the organisation and introducing three categories for overall strategic criteria, such as criteria related to the mission and vision of the organisation. This structure was then also followed during the integration process.

The final set of criteria was then proposed to the Chief Technology Officer (CTO) for his endorsement before moving on to the next set of interviews. During this discussion, attention was paid to the number of criteria resulting from the initial integration (see appendix J). The integration resulted in a high number of criteria, which may hamper the decision making and result in a time-consuming decision making process. Therefore, it was suggested to the organisation to design and execute an additional procedure to reduce the number of criteria. In these conversations, which also addressed the dilemma's as described in appendix K, it was found that the criteria satisfyingly reflected the organisation and therefore a reduction was not desirable as it would make the decision making process prone to overlook essential

factors valued by the organisation. Then, it was proposed to select the criteria relevant to a case on a case-to-case basis. This was endorsed by the CTO and a procedure to include this conclusion into the process of this research was implemented.

Yet, the number of criteria included remained a topic of discussion, which resulted in many insights during the remainder of the research. These insights are reflected both in chapter 7, when the final implementation of the model is reviewed, as well as in the discussion, which is chapter 9.

The integration resulted in a total of 89 criteria, divided over 19 subsets, with a maximum of four tiers. As stated before, the main categories follow the division of the organisation in departments, consisting of financial criteria, operational criteria, technological criteria and reputation (representing the fund raising and relations management department). Other categories represent the organisation as a whole, consisting of sustainability, link with the strategy, impact of the project and project specifics.

This concluded the integration of the criteria. The final set is presented in figure 5.1 and analysed in the next section, section 5.3.

All categories and criteria come included with a short description based on the input by the interviewee introducing the criterion.

5.2.4. Weights

The weights were measured during the first part of the second interview, as detailed in step 2 of the data gathering process described in the first section of this chapter. During this interview, the interviewees filled out the implementation of the BWM in Microsoft Excel. This workfile is shown and explained in appendix M.

In order to accumulate the weights, all interviewees were asked to evaluate all subsets of criteria individually. All in all, each interviewee evaluated 19 subsets of criteria, filling one calculation sheet for each subset. This procedure is presented in more detail in appendix M. In order to evaluate the weights, the interviewees were asked to select both the best and the worst. Then, the interviewee was asked to state his preference of the best over every other criteria in the subset, thus filling the BO-vector. Then, the interviewees were to state their preference of any criteria in the subset over the worst, thus establishing the OW-vector. In both instances, the interviewee was to use the nine point scale detailed in the next section.

During the interview, both the local input-based consistency, while CR_j^I, and the global input-based consistency, CR^I, were presented to the interviewee. If these numbers showed a significant deviation from the threshold, the participant was asked to review his input. It was observed the global input-based consistency was more restrictive than the output basedConsistency Index (CI). And, when the global input-based consistency only exceeded the threshold by a limited amount, the output-based consistency turned out to be within the threshold value. Therefore, it is important to use this threshold sensible.

During the interviews, two flaws in using the consistency as a hard measurement were found:

1. When s_{BW} was evaluated to be a lower number, the consistency was found to be extremely restrictive. Interviewees indicated to intently deviate from absolute consistency in order to achieve additional detail or differentiation in the weights, while strict adherence to the consistency threshold would prohibit this. In the case where a_{BW} was assessed as a 2 on the scale, consistencies couldn't be calculated. The issues found in the scale likely also have played a role in this sense (as detailed in the next session.
2. The consistency measurement failed in subsets consisting of two criteria only. In this case, the set would be allowed to be only fully consistent, which was remarked upon by the participants as being extremely restrictive and impeding the provision of additional details. In particular with only two criteria in a subset, the effect of the input on the weights was extremely visible and understandable, which stimulated interviewees to experiment with the weight outcomes in relation to the value for a_{BW}.

All in all, in particular the CI provided valuable information to the usability of the outcome and a good indicator to the usability of the set of weights. Furthermore, the input-based consistencies provided a valuable addition to the model for the less advanced DSS user, providing a good indicator. Yet, an

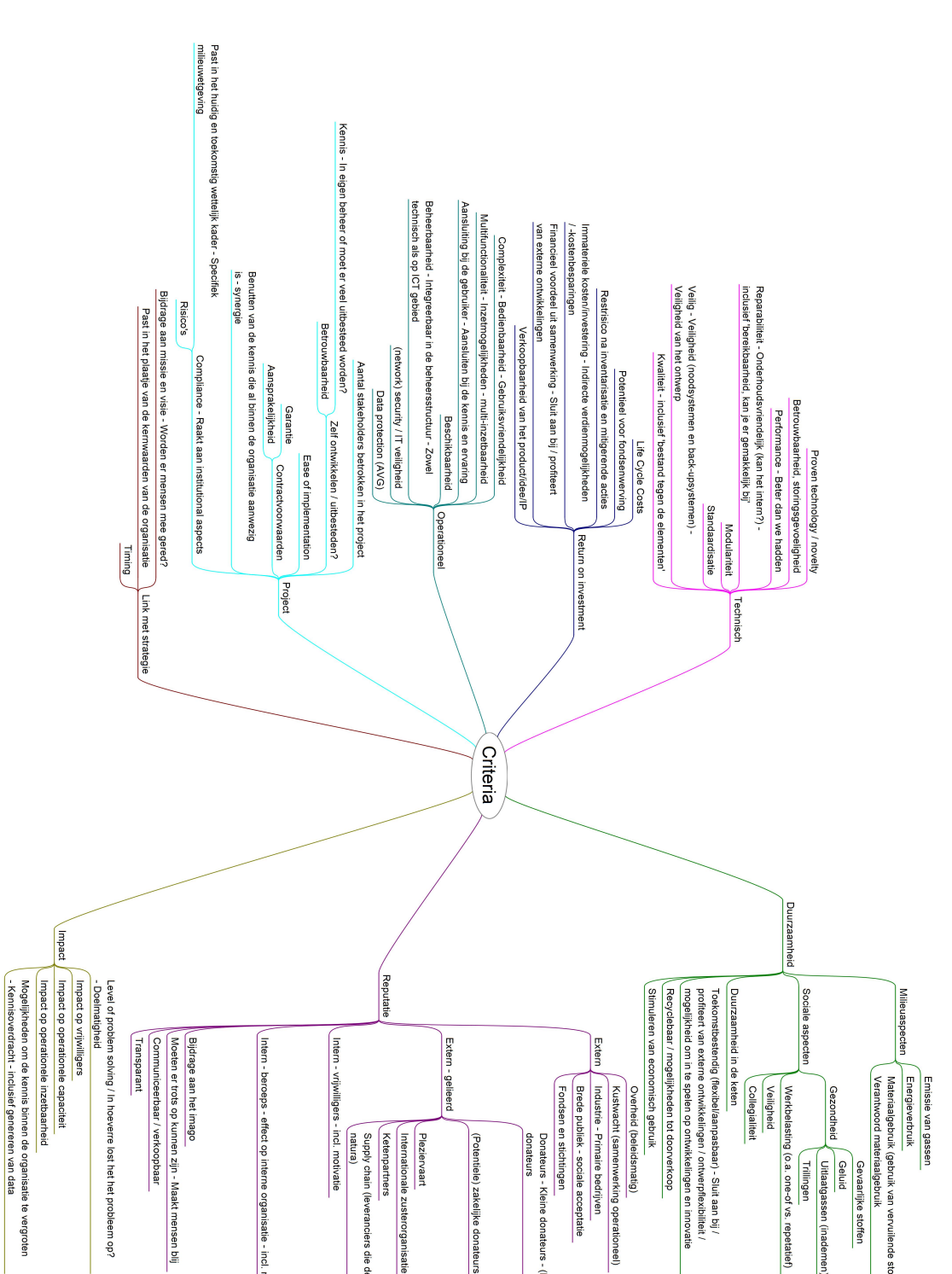


Figure 5.1: The integrated set of criteria.

advanced user is recommended to use the output-based consistency only.

During the interview, the weights were calculated using equation 4.12. The findings for each tab in the datafile were presented and endorsed by the interviewee before continuing to the next tab. Upon completion of all tabs, all criteria weights were integrated for that interviewee and an overview was presented to him/her. Then, the interviewee was again asked for his/her endorsement. This way, all individual weights were obtained and as such endorsed by the interviewees[5].

Only after the interview, the weights were calculated using the average of the range of the outcome of the equations 4.10 to 4.11 for all interviewees. The outcome of this vector was plotted against the outcome of the linear model from equation 4.12. An example of such a figure is shown in figure 5.2. This outcome was obtained with criteria one as Best and criteria four as Worst. The respective vectors were $BO = [1, 2, 1, 3, 2]$ and $OW = [3, 2, 2, 1, 2]$. This example shows the outcome of the linear model in blue, and the range average in red.

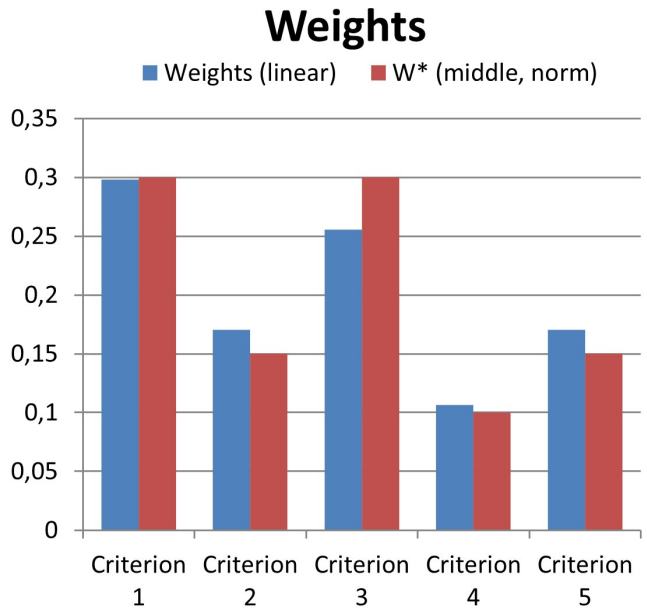


Figure 5.2: An example of a figure showing both weight vectors.

In this example, the range average calculated the weights of criteria one and three as (almost) equal. On the other hand, the interviewee showed a preference towards criteria one, as is expressed in the third value of the OW-vector. This is one amongst more examples why the weights obtained from equation 4.12 were found to resemble the best fit. Instances where the contrary was true have also been encountered; but tended to coincide with an inconsistent input by the interviewee[6]. Overall, the outcome obtained from equation 4.12 seems to present the best representation of the opinion of the interviewee.

Another argument to go with this vector, lies in the fact that this is the outcome presented to, and endorsed by, the interviewee. As mentioned before, the interviewee never got to see the other weights, as they were only calculated after having completed the interview.

During the interviews, participants were asked to reflect on the outcome of the model visualised in the bar graph for each tab in the workfile. The participants were asked if this visualisation resembled their

[5]Some interviewees filled in the weights sheet on their own occasion, in which case the interviewee only endorsed the resulting weights upon completion of filling out the full sheet, rather than upon completion of the phase in which the weights were established.

[6]These inconsistencies occurred in the latter part of the weights workfile of those interviewees that filled out the file on their own account.

preferences and if they could follow how the output resulted from the input provided (relative preferences). As observed in section 3.4.3, this was the most complex calculation in the model. And although participants commented they couldn't necessarily follow the mathematics behind the calculation they did see the relation between the input provided and the outcome, which was the aim of understanding the mathematics of the model. So, it would seem this risk didn't surface here and the objective of traceability was achieved.

In the final part of establishing the weights, all interviewees were shown the outcome of the full weights vector, using the figures (both the unsorted and the sorted bar graph) as also shown in the respective appendix for each interviewee. The interviewee was then asked to endorse the full set of criteria as well, which all interviewees did.

5.2.5. Scale

During the interview a nine-point scale was used. The advantage of this scale is having a clear centre and incorporates multiple steps towards the maximum. It also offers the opportunity to score tangible criteria and criteria that require an estimation from the DM. A scale was used which is quite common in Multi-criteria Decision Making (MCDM) (Saaty, 2004), giving the user an interpretation of what is meant. The scale is shown in figure 5.3.

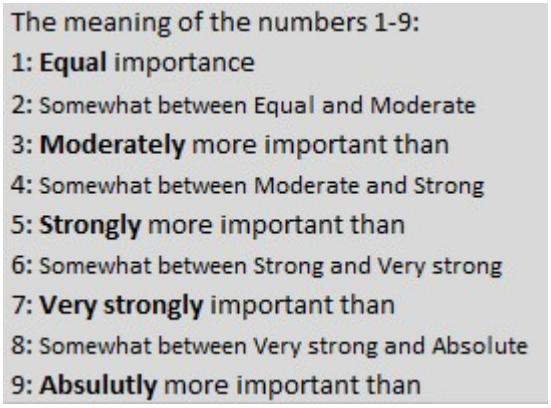


Figure 5.3: The scale used for establishing the weights during the interviews from step 2.

During the interview, many interviewees scored BO and OW low on this scale, in order to bring the weights closer to one another. As an example, one interviewee scored all preferences in a subset of six criteria with ones and twos on the scale only. This was done in order to minimise the difference in weights between criteria. Some remarked they would prefer weights to be even closer together; closer than the scale allowed. This likely results from the hyperbolic nature of the weight calculation, which originates from the fraction in Multicriterion Aggregation Process (MCAP), as detailed in equation 4.7 and visualised in figure 5.4. This results in the difference in weight (in the outcome of the linear equation) being larger when the preference is altered from a 3 to a 2, compared to changing it from an 8 to a 7. How much this influenced the outcome is difficult to say. Yet, it is recommended to further research options to alter the MCAP in order to eliminate the fraction and use a linear relationship instead.

In this sense, there seems to exist a mismatch between the wording of the scale and the interpretation by the DMs. There is much work done on this subject already (e.g. Franek and Kresta (2014); Harker and Vargas (1987); Huizingh and Vrolijk (1997); Ishizaka and Labib (2011); Raju Meesariganda and Ishizaka (2017); Saaty (1977); Stevens and Galanter (1957) which may provide the insights needed to improve this part of the model. Therefore, a literature research is recommended as a viable starting point.

From the initial review of the research and by reflecting the interviews, two solutions seem to match the case at hand and are worth looking into in more details. First of all, the scale could be translated into different ratio's, using a pre-defined mathematical translation, such as a square root of the preference.

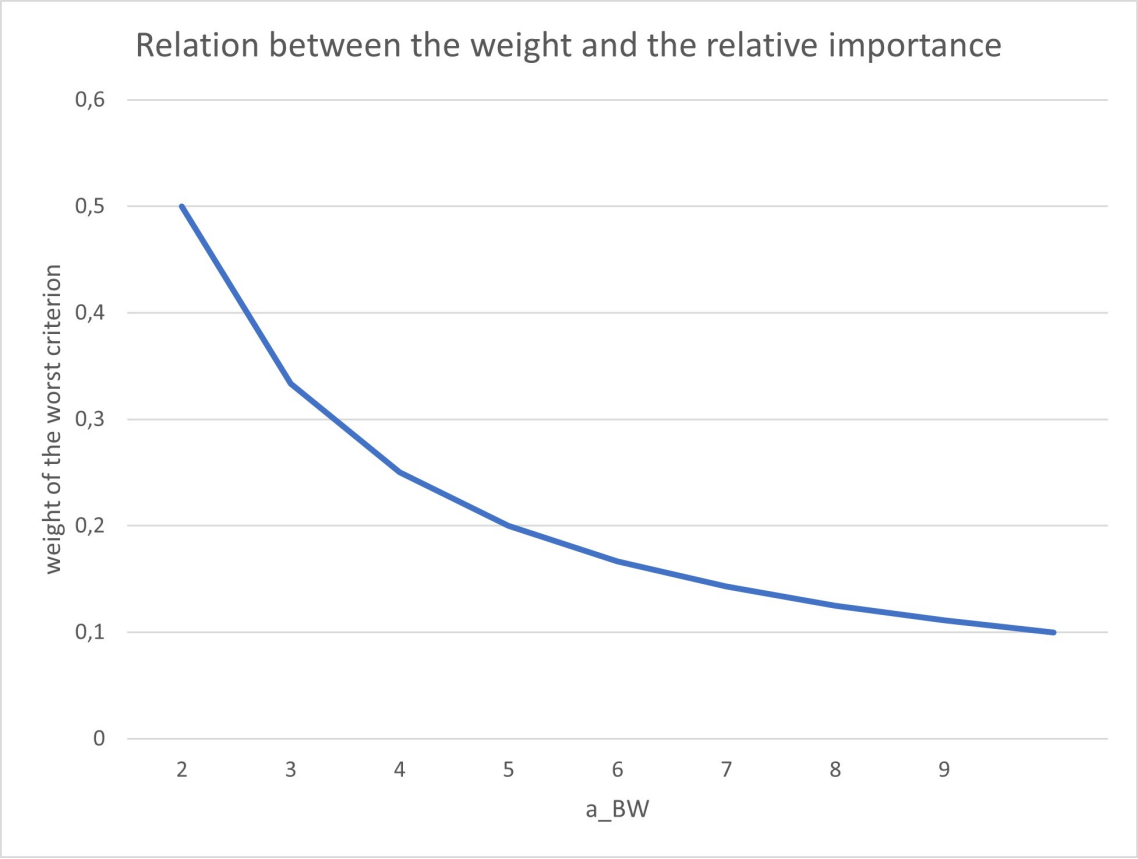


Figure 5.4: This graph shows the relation between the weight for a set of two criteria, in which case w_j equals w_W, and the relative importance between the weights, a_{BW}.

An overview of such mathematical translation is given by (Franek & Kresta, 2014, table 1, p. 166). It is reckoned either the balanced method, the root square method or the logarithmic may be applicable in this case, but more research is needed to confirm this theorem.

A second option, which is highly unconventional in MCDM, is to research the applicability of a linear relation between w_i and w_j can be used. This may be executed through the introduction of a constant or step.

By choosing for a ratio scale from 1 to 9 based on an representation of a broad criterion (vis-a-vis a narrow measurement scale of a single performance measurement such as 'the amount of CO_2 emission transmitted when sailing one hour at full power'), the risk of tailoring towards a certain measurement (as meant in section 2.3) can be reduced. This has many consequences. For example, the weights allow to compare one 'unit' of safety with one unit of life cycle costs. In the current implementation, it is neither quantified what either unit entails, this is free for interpretation by the user of the tool. On the other hand, a unity, or equal understanding amongst decision makers is of the essence for the correct implementation of the DSS. Obviously, there is a tension here, in which the BWM provides a mechanism to compare criteria with a completely different scale of measurement and even criteria without any scale of measurement. A shared understanding of the meaning is of the essence and should be established and shared by all DMs, for instance during a group meeting. An example of such an understanding is that part of each variant description a (financial) risk evaluation should take place and be reflected upon by a project team, clarifying how to deal with these risks. For instance, it should be clarified what risks are to be transferred by means of an insurance. Then, the waiver costs are to be included in the *life cycle costs*, while only the risk excluding this transferred risk should be evaluated when scoring the *financial risk after mitigation measures*[7]. This finding (overall) was also supported by

[7] This name was adapted after the integration, as most interviewees didn't mention insurance, while the expert from this field did. Therefore, the criterion was included, yet not as an individual criterion by itself.

multiple interviewees during the second round of interviews and even specifically stipulated during the evaluation by one interviewee.

All in all, during this research, some problems were ran into when the weights for criteria were to lie rather close to one another. Further research is needed to establish if this effect can be reduced and a stepwise scale can be formulated.

5.2.6. Weight integration

The weights were integrated using an equal representation method. Therefore, first of all, a weights vector is calculated for each individual. Then, geometric means are calculated to find the weights representing the entire group of DMs This is also referred to as an Aggregation of Individual Priorites (AIP) method (Mohammadi & Rezaei, 2020). Thereby, this research follows the method described by Ishizaka and Labib (2011), as they found that the geometric mean method must be adopted instead of arithmetic mean in order to preserve the reciprocal property of the set (Aczel & Saaty, 1983; Saaty, 2004). The equation for the geometric mean used is shown in equation 5.1. In this equation, w^*_{int} is the integrated weight, while w^*_n is the weight for the n-th interviewee.

$$w^*_{int} = \sqrt[n]{\prod_{n=1}^{n} w^*_n} \tag{5.1}$$

There is discussion amongst scholars how to deal with outliers, some arguing that outliers do not reflect the opinion of the group and should be suppressed in the overall outcome (Mohammadi & Rezaei, 2020). For this research, also given the composition of the group of participants in the research, the input from each individual is deemed equally important, even if it would concern outliers. This is done as there was an (almost) equal representation from each specialism and department. Mohammadi and Rezaei (2020) also show the AIP method using an equal representation entails losing information, such as the centrality feature and dispersion property. Furthermore, outliers have a significant influence on the group outcome. Although this holds, this is deemed to be less of less relevance in the current implementation when compared to the equal representation of the n-th DM in the aggregated set of weights, as this contributes to the transparency of the chosen method.

One could argue that the technological department is overrepresented with both the CTO and a project engineer participating. A sensitivity analysis was conducted without the weights of the project engineer, which resulted in a maximum change of 5% in the direct outcome of the scoring of the weight, or a 27% difference in the outcome when normalised for the average weight. This, however, consists of an outlier; in the remainder of the set, 23% is the highest percentage. Whether this is desirable or not, is up to the KNRM to decide. This is in line with having a one out of seven vote in the overall outcome and the input is therefore found to have a significant influence in the overall set of weights. This may thus cause an imbalance in the representation of the different departments.

The final set of weights contains two weight vectors, a 'gross' weight vector and a 'nett' weight vector. Herein, a gross weight refers to a weight valid within its own subset. A nett weight then is the final overall weight, calculated through multiplication with the weights of a weights mother criterion or criteria. The former is used in the remainder of the model, allowing to calculate normalisations when one or more criteria are deselected. The 'nett' weights allow for analysis of the relative importance of weights from an organisational perspective.

The integration of the weights is shown in table 5.2. The result of the integration is shown in table 5.3, showing both the gross weights, which is the geometric mean of the individual weights of all the participants. The final weights vector then contains the nett weights, having multiplied all subcategory weights with the weight of the mother category. This set was then normalised to regain the condition the sum of the weights vector is to equal 1. The colour coding shows the most influential criteria for each subset (up to the second tier) in blue, the second most important criteria in green and the third most influential in yellow.

Overzicht van de gewichten

Criterium	Jacob Tas	Gert-Jan Wijker	John Geel	Fieke van Schaik	Nancy Barten	Jeroen Wooning	Walter Schol	Geometric Means	Netto	Normalised
Link met de strategie	0,261364	0,045236	0,194019	0,267857	0,122744	0,197279	0,244344	0,167085015		
Bijdrage aan de missie en visie	0,657143	0,714286	0,571429	0,5625	0,1	0,411765	0,644444	0,454457188	0,07593299	0,10059482
Past het in het plaatje van de kernwaarden en strategische thema's	0,271429	0,214286	0,285714	0,125	0,157143	0,470588	0,244444	0,23323888	0,03897072	0,05162779
Timing	0,071429	0,071429	0,142857	0,3125	0,742857	0,117647	0,111111	0,155634431	0,02600418	0,03444093
Impact van het project op de organisatie	0,05303	0,052776	0,331875	0,164835	0,122744	0,07483	0,090498	0,103503851		
Level of problem solving	0,263889	0,168514	0,085859	0,371795	0,16185	0,295455	0,5	0,229805848	0,02378511	0,03152338
Impact op vrijwilligers	0,425926	0,044346	0,257576	0,211538	0,242775	0,159091	0,196078	0,186316562	0,01928448	0,02554778
Impact op operationele capaciteit	0,087963	0,252772	0,171717	0,211538	0,416185	0,159091	0,098039	0,176056405	0,01822252	0,0241409
Impact op operationele beschikbaarheid	0,175926	0,407982	0,434343	0,141026	0,121387	0,295455	0,147059	0,21771779	0,02253463	0,02985352
Mogelijkheden om de kennis binnen de organisatie te vergroten	0,046296	0,126386	0,050505	0,064103	0,057803	0,090909	0,058824	0,066671182	0,00690072	0,00914197
Eigenschappen van het project	0,022727	0,254284	0,030635	0,164835	0,122744	0,034014	0,054299	0,067843739		
Aantal stakeholders dat een rol speelt	0,064171	0,155556	0,128205	0,127536	0,331633	0,105263	0,092879	0,126874339	0,00860763	0,01140325
Zelf ontwikkelen vs. uitbesteden	0,037433	0,116667	0,128205	0,0955652	0,136054	0,157895	0,092879	0,100951934		
Kennis	0,2	0,333333	0,2	0,2	0,714286	0,25	0,5	0,303663755	0,00207978	0,00275526
Betrouwbaarheid van externe partijen/leveranciers	0,8	0,666667	0,8	0,8	0,285714	0,75	0,5	0,623353728	0,00426932	0,00565593
Ease of implementation	0,374332	0,038889	0,17094	0,191304	0,042517	0,157895	0,043344	0,104764768	0,00710763	0,00941608
Contractvoorwaarden	0,149733	0,233333	0,053419	0,191304	0,081633	0,263158	0,383901	0,162128293		
Garantievoorwaarden	0,166667	0,8	0,25	0,2	0,714286	0,25	0,333333	0,326652237	0,00359298	0,00475992
Aansprakelijkheidsrisico	0,833333	0,2	0,75	0,8	0,285714	0,75	0,666667	0,545022669	0,00599492	0,00794197
Benutten van kennis en mogelijkheden	0,149733	0,388889	0,416667	0,057971	0,204082	0,157895	0,232198	0,194483027	0,01319446	0,01747981
Compliance	0,224599	0,066667	0,102564	0,336232	0,204082	0,157895	0,154799	0,15905806		
Past in het huidige en toekomstige wettelijke- en beleidskader	0,75	0,833333	0,142857	0,666667	0,333333	0,75	0,666667	0,517358219	0,00558286	0,00739609
Risico's die voortkomen uit compliance	0,25	0,166667	0,857143	0,333333	0,666667	0,25	0,333333	0,351381033	0,00379179	0,0050233
Operationele aspecten	0,159091	0,254284	0,129346	0,10989	0,194046	0,112245	0,135747	0,149992415		
Complexiteit	0,321396	0,156863	0,268421	0,284483	0,171429	0,227006	0,315488	0,241032961	0,03615312	0,04789507
Multifunctionaliteit	0,055096	0,156863	0,063158	0,043103	0,285714	0,064579	0,130019	0,092154477	0,01382247	0,01831179
Aansluiting bij de beoogde gebruiker	0,192837	0,117647	0,268421	0,155172	0,045714	0,039139	0,034417	0,092556103	0,01388271	0,0183916
Beschikbaarheid	0,03214	0,376471	0,236842	0,103448	0,085714	0,086106	0,195029	0,123032416	0,01845393	0,02444747
Beheerbaarheid	0,077135	0,078431	0,031579	0,103448	0,068571	0,129159	0,130019	0,080939818	0,01214036	0,01608335
IT veiligheid	0,128558	0,078431	0,078947	0,155172	0,171429	0,227006	0,097514	0,124694493	0,01870323	0,02477774
Databeveiliging	0,192837	0,035294	0,052632	0,155172	0,171429	0,227006	0,097514	0,111251585	0,01668689	0,02210653
Technische aspecten	0,079545	0,158328	0,064673	0,10989	0,061372	0,112245	0,135747	0,097489931		
Proven technology	0,114043	0,226069	0,059966	0,035984	0,044776	0,06383	0,050898	0,066903884	0,00681492	0,0090283
Betrouwbaarheid	0,287356	0,14053	0,383781	0,183519	0,145522	0,207447	0,257485	0,216239249	0,02108115	0,02792797
Performance	0,068966	0,14053	0,031982	0,122346	0,072761	0,111702	0,02994	0,071147246	0,00693614	0,00918889
Reparabiliteit	0,086207	0,14053	0,068532	0,09176	0,072761	0,111702	0,152695	0,099201945	0,00967119	0,01281224
Modulariteit	0,028736	0,02444	0,059966	0,073408	0,097015	0,111702	0,152695	0,06539666	0,00637552	0,00844618
Standaardisatie	0,068966	0,093686	0,095945	0,09176	0,097015	0,074468	0,101796	0,088294173	0,00860779	0,01140347
(technische) veiligheid	0,172414	0,093686	0,239863	0,309464	0,253731	0,207447	0,152695	0,19205163	0,0187231	0,02480407
Algehele kwaliteit	0,172414	0,14053	0,059966	0,09176	0,216418	0,111702	0,101796	0,118498169	0,01155238	0,01530441
Duurzaamheid	0,159091	0,105552	0,055434	0,065934	0,223827	0,197279	0,135747	0,120452802		
Milieuaspecten	0,30454	0,371747	0,221286	0,119318	0,362319	0,267123	0,128205	0,232829071		
Uitstoot van gassen	0,65	0,589286	0,644444	0,333333	0,571429	0,541667	0,708333	0,563495885	0,01580319	0,02093582
Energieverbruik	0,266667	0,071429	0,244444	0,333333	0,142857	0,291667	0,083333	0,176749486	0,00495692	0,00656685
Materiaalgebruik	0,083333	0,339286	0,111111	0,333333	0,285714	0,166667	0,208333	0,194124346	0,0054442	0,00721239
Sociale aspecten	0,30454	0,223048	0,379347	0,497159	0,217391	0,082192	0,435897	0,268184036		
Verzamelde gezondheidsaspecten	0,237467	0,3125	0,27957	0,3125	0,116279	0,419355	0,187845	0,249023087		
Gevaarlijke stoffen	0,160139	0,075472	0,238095	0,183673	0,494624	0,351351	0,095238	0,190900749	0,00153567	0,00203443
Geluid	0,225519	0,245283	0,238095	0,102041	0,139785	0,108108	0,238095	0,174034371	0,00139999	0,00185468
Uitlaatgassen	0,545994	0,245283	0,428571	0,183673	0,27957	0,351351	0,428571	0,331914141	0,00267002	0,00353721
Trillingen	0,059347	0,433962	0,095238	0,530612	0,086022	0,189189	0,238095	0,175082207	0,00140842	0,00186585
Werkbelasting voor de gebruiker	0,14248	0,0625	0,086022	0,3125	0,186047	0,225806	0,475138	0,173738323	0,00561236	0,00743516
Veiligheid voor de gebruiker	0,55409	0,5	0,494624	0,3125	0,511628	0,225806	0,281768	0,390873959	0,0126266	0,01672753
(invloed op) collegialiteit	0,065963	0,125	0,139785	0,0625	0,186047	0,129032	0,055249	0,099350568	0,00320937	0,00425173
Duurzaamheid in de keten van leveranciers	0,188261	0,055762	0,088514	0,099432	0,144928	0,143836	0,128205	0,113783737	0,01370557	0,01815692
Toekomstbestendigheid	0,075305	0,089219	0,147524	0,149148	0,108696	0,09589	0,128205	0,110233782	0,01327556	0,01758725
Recyclebaar	0,094131	0,223048	0,052687	0,085227	0,108696	0,267123	0,051282	0,104964664	0,01264329	0,01674963
Mate waarin economisch gebruik gestimuleerd kan worden.	0,033223	0,037175	0,110643	0,049716	0,057971	0,143836	0,128205	0,068753924	0,0082816	0,01097134
Return on investment	0,159091	0,023989	0,097009	0,082418	0,122744	0,07483	0,067873	0,078892906		
Life cycle costs	0,518256	0,377778	0,379347	0,449591	0,359133	0,346154	0,418562	0,403369283	0,03182297	0,04215857
Potentieel voor fondsenwerving	0,091278	0,222222	0,110643	0,163488	0,102167	0,192308	0,129063	0,137616205	0,01085694	0,0143831
Financieel restrisico na mitigerende acties	0,106491	0,051852	0,088514	0,06812	0,06192	0,128205	0,103731	0,083123788	0,00655772	0,00868756
Immateriele kosten/investeringen	0,127789	0,148148	0,221286	0,098093	0,136223	0,128205	0,129063	0,137528662	0,01085004	0,01437396
Financieel voordeel uit samenwerking	0,049696	0,111111	0,147524	0,122616	0,136223	0,128205	0,045496	0,096751795	0,00763303	0,01011212
Verkooppotentieel	0,106491	0,088889	0,052687	0,098093	0,204334	0,076923	0,172884	0,104151356	0,0082168	0,01088549
Reputatie	0,106061	0,105552	0,097009	0,034341	0,028881	0,197279	0,135747	0,083727096		
Externe partijen	0,09009	0,060565	0,069176	0,029551	0,278571	0,051948	0,158996	0,082341117		
Overheid	0,168514	0,074074	0,130435	0,164649	0,082192	0,105263	0,15814	0,120400627	0,00083006	0,00109966
Kustwacht	0,252772	0,111111	0,434783	0,123487	0,136986	0,184211	0,237209	0,190264342	0,00131172	0,00173774
Industrie	0,044346	0,222222	0,069565	0,048426	0,205479	0,184211	0,15814	0,113007553	0,00078048	0,00100747
Brede publiek	0,126386	0,370371	0,104348	0,416465	0,369863	0,342105	0,046512	0,198097892	0,00136572	0,00180929
Fondsen en stichtingen	0,407982	0,222222	0,26087	0,246973	0,205479	0,184211	0,4	0,263602404	0,00181732	0,00240756
Externe partijen geleerd aan de KNRM	0,135135	0,064603	0,08647	0,060284	0,171429	0,090909	0,158996	0,10173063		
(kleine) Donateurs	0,23622	0,238612	0,149733	0,174603	0,34965	0,288889	0,095652	0,203064464	0,00172962	0,00229138
Groep van (potentiele) zakelijke donateurs	0,393701	0,390456	0,224599	0,174603	0,20979	0,155556	0,191304	0,233314589		
Reguliere scheepvaart	0,344828	0,346154	0,342105	0,297872	0,2	0,342105	0,346154	0,31204494	0,00062012	0,00082153
Visserij	0,241379	0,192308	0,184211	0,170213	0,2	0,184211	0,192308	0,193939116	0,00038537	0,00051053
Offshore industrie	0,241379	0,192308	0,184211	0,255319	0,2	0,184211	0,192308	0,205483293	0,00040835	0,00054098
Commerciele pleziervaart	0,12069	0,076923	0,105263	0,106383	0,2	0,105263	0,076923	0,107725806	0,00021408	0,00028361
Baggervaart	0,051724	0,192308	0,184211	0,170213	0,2	0,184211	0,192308	0,155613842	0,00030925	0,00040969
Pleziervaart	0,07874	0,095445	0,112299	0,306878	0,13986	0,155556	0,191304	0,140447414	0,00115628	0,00153181
Internationale zusterorganisaties / IMRF	0,094488	0,119306	0,053476	0,116402	0,104895	0,088889	0,057971	0,087066917	0,0007416	0,00098246
Ketenpartners	0,15748	0,095445	0,385027	0,174603	0,13986	0,155556	0,127536	0,16099751	0,00137131	0,0018167
Supply chain	0,03937	0,060738	0,074866	0,05291	0,055944	0,155556	0,136232	0,083251005	0,0007091	0,0009394
Intern - reputatie onder vrijwilligers	0,202703	0,080754	0,17294	0,100473	0,035714	0,168831	0,105997	0,10891289	0,00911896	0,01208065
Intern - beroepsorganisatie	0,27027	0,080754	0,17294	0,075355	0,057143	0,168831	0,105997	0,116476759		
HR / Opleidingen	0,086193	0,085308	0,12069	0,142857	0,142857	0,134615	0,041	0,099994066	0,00097517	0,00129189
IT	0,071828	0,047393	0,12069	0,142857	0,142857	0,076923	0,069701	0,089206536	0,00086997	0,00115252
Operationele dienst	0,215483	0,35545	0,224138	0,142857	0,142857	0,134615	0,104551	0,174521	0,00170197	0,00225475
Financien	0,039904	0,07109	0,12069	0,142857	0,142857	0,134615	0,209102	0,110145046	0,00107416	0,00142303
Technische dienst	0,107741	0,21327	0,12069	0,142857	0,142857	0,134615	0,139401	0,140149853	0,00136678	0,00181069
C&F	0,143655	0,14218	0,224138	0,142857	0,142857	0,134615	0,352604	0,171896026	0,00167637	0,00222083
RvT	0,335196	0,085308	0,068966	0,142857	0,142857	0,25	0,083641	0,135567208	0,00132209	0,00175148
Bijdrage aan het image van de organisatie	0,09009	0,282638	0,291624	0,254137	0,114286	0,090909	0,256625	0,175024804	0,01465432	0,01941381
Kunnen er trots op zijn	0,054054	0,161507	0,057647	0,254137	0,114286	0,168831	0,027894	0,09480499	0,00793775	0,0105158
Communiceerbaar	0,022523	0,161507	0,03391	0,075355	0,114286	0,090909	0,079498	0,069301524	0,00580242	0,00768695
Transparant	0,135135	0,107672	0,115293	0,150709	0,114286	0,168831	0,105997	0,126455016	0,01058771	0,01402643

Table 5.2: The table showing how the integrated weights have been derived from the individual contributions.

Weights integration - result		
Criterion	**Geom. mean**	**Weights**
Link met de strategie	0,167	
Bijdrage aan de missie en visie	0,454	0,101
Past het in het plaatje van de kernwaarden en strategische thema's	0,233	0,052
Timing	0,156	0,034
Impact van het project op de organisatie	0,104	
Level of problem solving	0,230	0,032
Impact op vrijwilligers	0,186	0,026
Impact op operationele capaciteit	0,176	0,024
Impact op operationele beschikbaarheid	0,218	0,030
Mogelijkheden om de kennis binnen de organisatie te vergroten	0,067	0,009
Eigenschappen van het project	0,068	
Aantal stakeholders dat een rol speelt	0,127	0,011
Zelf ontwikkelen vs. uitbesteden	0,101	
Kennis	0,304	0,003
Betrouwbaarheid van externe partijen/leveranciers	0,623	0,006
Ease of implementation	0,105	0,009
Contractvoorwaarden	0,162	
Garantievoorwaarden	0,327	0,005
Aansprakelijkheidsrisico	0,545	0,008
Benutten van kennis en mogelijkheden	0,194	0,017
Compliance	0,159	
Past in het huidige en toekomstige wettelijke- en beleidskader	0,517	0,007
Risico's die voortkomen uit compliance	0,351	0,005
Operationele aspecten	0,150	
Complexiteit	0,241	0,048
Multifunctinaliteit	0,092	0,018
Aansluiting bij de beoogde gebruiker	0,093	0,018
Beschikbaarheid	0,123	0,024
Beheerbaarheid	0,081	0,016
IT veiligheid	0,125	0,025
Databeveiliging	0,111	0,022
Technische aspecten	0,097	
Proven technology	0,070	0,009
Betrouwbaarheid	0,216	0,028
Performance	0,071	0,009
Reparabiliteit	0,099	0,013
Modulariteit	0,065	0,008
Standaardisatie	0,088	0,011
(technische) Veiligheid	0,192	0,025
Algehele kwaliteit	0,118	0,015
Duurzaamheid	0,120	
Milieuaspecten	0,233	
Uitstoot van gassen	0,563	0,021
Energieverbruik	0,177	0,007
Materiaalgebruik	0,194	0,007
Sociale aspecten	0,268	
Verzamelde gezondheidsaspecten	0,249	
Gevaarlijke stoffen	0,191	0,002
Geluid	0,174	0,002
Uilaatgassen	0,332	0,004
Trillingen	0,175	0,002
Werkbelasting voor de gebruiker	0,174	0,007
Veiligheid voor de gebruiker	0,391	0,017
(Invloed op) collegialiteit	0,099	0,004

Table 5.3 continued from previous page

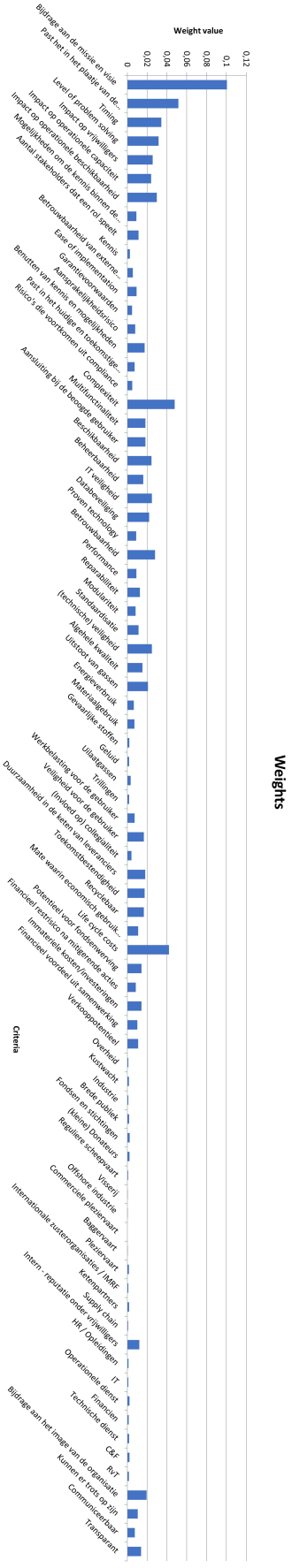
Weights integration - result		
Criteria	**Geom. mean**	**Weights**
Duurzaamheid in de keten van leveranciers	0,114	0,018
Toekomstbestendigheid	0,110	0,018
Recyclebaar	0,105	0,017
Mate waarin economisch gebruik gestimuleerd kan worden.	0,069	0,011
Return on investment	0,079	
Life cycle costs	0,403	0,042
Potentieel voor fondsenwerving	0,138	0,014
Financieel restrisico na mitigerende acties	0,083	0,009
Immateriele kosten/investeringen	0,138	0,014
Financieel voordeel uit samenwerking	0,097	0,010
Verkooppotentieel	0,104	0,011
Reputatie	0,084	
Externe partijen	0,082	
Overheid	0,120	0,001
Kustwacht	0,190	0,002
Industrie	0,110	0,001
Brede publiek	0,198	0,002
Fondsen en stichtingen	0,264	0,002
Externe partijen gelieerd aan de KNRM	0,102	
(kleine) Donateurs	0,203	0,002
Groep van (potentiele) zakelijke donateurs	0,233	
Reguliere scheepvaart	0,312	0,001
Visserij	0,194	0,001
Offshore industrie	0,205	0,001
Commerciele pleziervaart	0,108	0,000
Baggervaart	0,156	0,000
Pleziervaart	0,140	0,002
Internationale zusterorganisaties / IMRF	0,087	0,001
Ketenpartners	0,161	0,002
Supply chain	0,083	0,001
Intern - reputatie onder vrijwilligers	0,109	0,012
Intern - beroepsorganisatie	0,116	
HR / Opleidingen	0,100	0,001
IT	0,089	0,001
Operationele dienst	0,175	0,002
Financien	0,110	0,001
Technische dienst	0,140	0,002
C&F	0,172	0,002
RvT	0,136	0,002
Bijdrage aan het image van de organisatie	0,175	0,019
Kunnen er trots op zijn	0,095	0,011
Communiceerbaar	0,069	0,008
Transparant	0,126	0,014

Table 5.3: Overview of the resulting weights. The average weights are calculated for each subset, while the weights vector contain the global weights for the entire set. Criteria marked in blue have the highest weight within their respective subset, followed by the criteria in green and the criteria in yellow are in third places. Colors are only given for the first two tiers of criteria. The names of the criteria are presented in Dutch, as this was how the criteria were presented to the participants and translation is prone lead to misrepresentation.

The weights are also visualised in figure 5.5b, and the ordered weights are shown in figure 5.5a.

The evaluation of the weights shows a clear preference towards the category *link with the strategy*, as this is deemed the most important category and the criteria in the subset also represent the two

(a) The integrated set of weights ordered from largest weight to smallest.



(b) The final weights.

highest nett weights. Furthermore, criteria related to safety, reliability and availability are often cited and marked as being important. This makes sense, as this represents the core *raison d'être* of the organisation, as well as its core values. The remainder of the criteria further defines and details these values, however, the core is valued stronger by the DMs. Amongst the least weighted criteria are many criteria both from the reputation or stakeholder management perspective, and from the health aspects, which are categorised under the sustainability criteria. What stands out, is that most criteria in the tailing 20 to 25 %, are from a third our fourth layer of criteria. In fact, this raises the question whether such a depth contributes to the accuracy of the model? Similarly, one can wonder what the effect of a difference of criteria within a (sub)set of criteria is on the final weight of this criteria, as for all sets the pie to divide over the contestants is of the same size. The number of contesting criteria thus influences the average size of the piece of the pie. This is essential to uphold the weight of the category as such, but limits the comparability of the individual weights as such.

This obstructs the comparison of the weights amongst one another. More research is required to assess if for instance normalisation techniques may be used to overcome the effects of the layering structure on the outcome.

For now, an exception can be made for the evaluation of the main categories, as they do not have any layering effects[8]. Therefore, a separate figure is included to assess the scoring of the main categories, shown in figure 5.6.

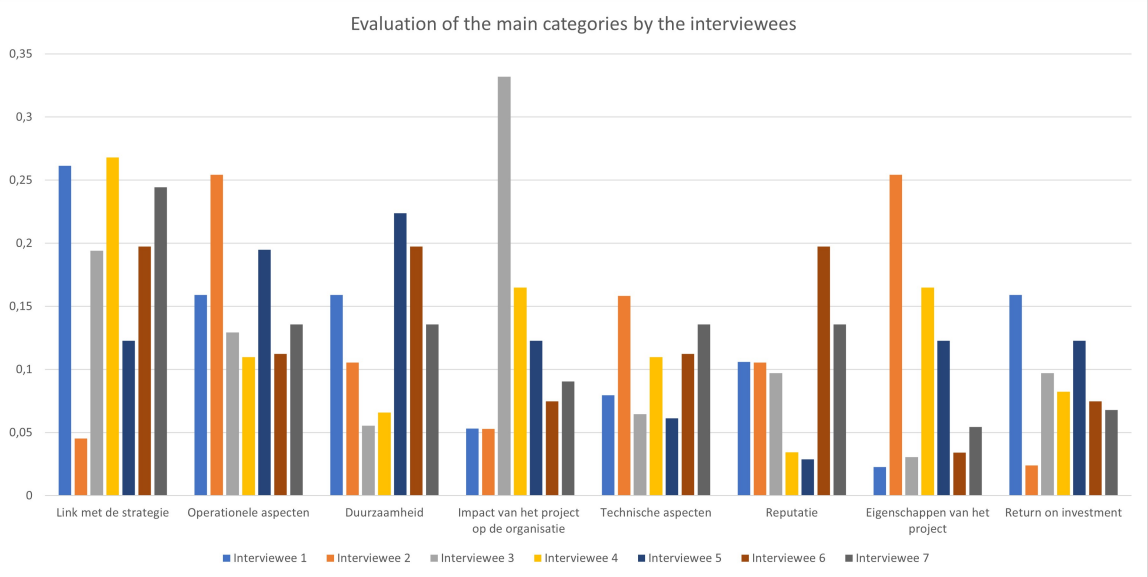


Figure 5.6: This figure shows the weight scoring for the main categories, ordered by the average weight score.

This figure shows most unity with respect to the importance of the *operational aspects*, the scoring of *technical aspects*, and the *financial aspects* to be the least relevant category. The least agreement was in the categories of the *impact of the project on the organisation* and the *project particularities*[9]. This analysis is not relevant to pinpoint outliers. Instead, it could be used to identify where opinions differ and as a discussion starter amongst DMs. This can thus be a tool to identify misalignments in the opinion of the board and trigger the discussion. This discussion may contribute to obtain a common frame of reference when it comes to the preferences of the organisation. While respecting individual differences, the group of DMs is to endorse a common frame of reference for the organisation as an individual entity, albeit being a aggregation of individual opinion.

The set of weights thus established is a starting point for the model, as many of these discussion

[8]The same goes for criteria within the same layer, but only one category is presented here as an example of the method, rather than a full evaluation of each subset.
[9]The latter statement was also verified using the second method of analysis as described in the next section.

points could be identified in the data set. During the usage of the DSS, and when the new process of decision making is operationalised, it is likely to need tuning, based on new insights, changes in the world surrounding the organisation and changes in the group of DMs. This way, in order to retain agility in the values and preferences of the organisation, the weights need maintenance. After the initial tuning, a frequent update will be required, for instance every other year.

Given the nature and background of the participants in this research, it is assessed the vector obtained in this research is a good starting point for the organisation, as many of the characteristics mentioned in the preliminary interviews (see also chapter 2) were reflected in the weights. In the next section, the model is analysed in more detail.

5.3. Analysis of the results

The results obtained as shown above, are analysed into more detail in order to assess the usability in the final model. Three analyses have been conducted. First of all, both the apparent contradictions between safety and sustainability, and safety and costs[10] are analysed. Second of all, the evaluation of sustainability is highlighted, along with the implementation of sustainability. Second of all, the difference of opinion on criteria weights amongst interviewees is studied in more detail. Then, an analysis was conducted to identify on which topics the DMs had a common frame of reference, and in what cases opinions differentiated. Similar to earlier, also in this case this analysis is to be used to start conversation and discussion amongst DMs, rather than point the finger to outliers. The discussion should lead to a shared frame of reference.

One of the questions this research aims to investigate is the apparent contradiction between sustainability and safety. It was often said, both in the evaluation of the NH-1816 and during the initial interviews, the organisation values proven technology, as it is directly linked to a sense of reliability and trustworthiness. And a more in-depth discussion with some interviewees during this round of interviews showed indeed its these underlying associated criteria that are valued[11]. The criteria already show safety to be part of sustainability, rather than being contradictory to it, which was underlined by all interviewees. Then, within the subset of the *technological criteria*, many criteria outweigh the *proven technology* criterion, such as *technological safety*, *safety of the user* and, most significantly, *reliability*. Neither of these criteria is expected to be in contradiction with sustainability. On the contrary, *Technical safety* and *reliability* were mentioned by some interviewees to have a link with safety in general, these criteria may be interlinked with *safety for the user*[12]. This is illustrated in figure 5.7. It shows the weights in the category *technological aspects*, with the weights along the y-axis. This leads to the initial conclusion there is no contradiction at all here. Instead, safety is found to be a part of sustainability rather than contradictory to it. This may be investigated further by researching if couplings exist in the performance of some of these criteria mentioned above.

When it comes to *safety* and *life cycle costs*, it is often assumed the safer option is also the more expensive one, which is therefore posed as hypothesis H.2. Therefore, the performance in respect to these criteria should change in concert. If a variant performs well in relation to either one, it is assumed to perform poor on the other account. This is, however, not necessarily the case. The model and the DSS built upon it, offer the opportunity not only to assess how a variant performs on this apparent contradiction, is also shows when a variant performs well on both accounts, or on neither. The model could therefore put hypothesis H.2 to the test. An example of such test is executed for the test case (see chapter 6)[13]. The added value then is a visualisation and appreciation of this apparent contradiction.

Hypothesis H.2: A safer solution is also the more expensive solution.

Concerning the implementation, one can observe from table 5.3 life cycle costs are valued higher at

[10] This apparent contradiction was mentioned during the initial interviews. Instead, the model also allows for, and shows, variants in which both criteria support each other, or score poor on both accounts.

[11] When applied on different types of lifeboats, these relations are likely to qualify for further research in the future.

[12] A statistical relation may only be established when the model is used in a real life case, rather than a fictional case, as is done in this research.

[13] It should be noted that the test case used was part fiction and can't therefore be used to test the hypothesis.

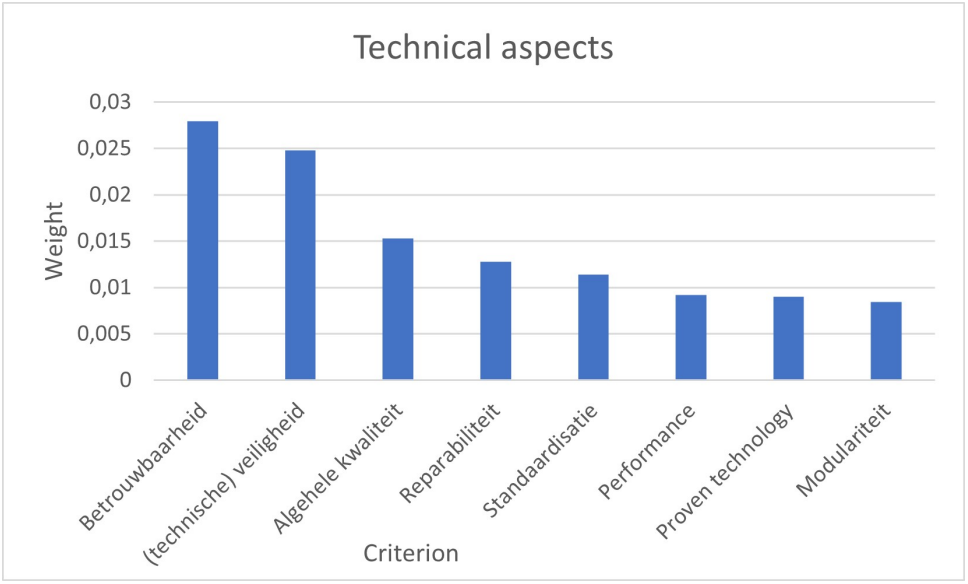
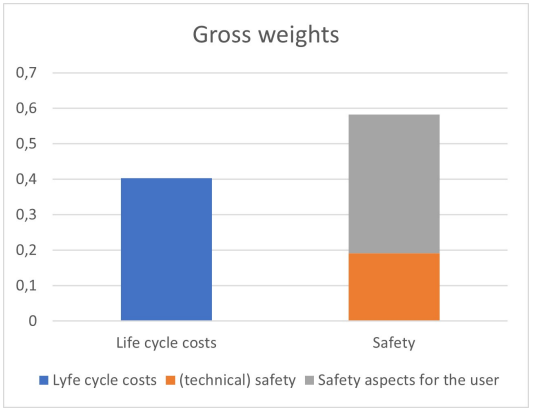
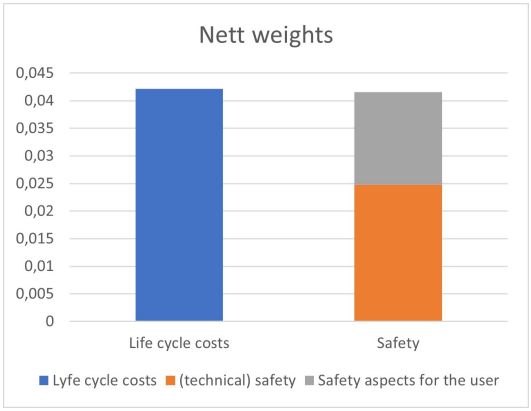


Figure 5.7: The weights of the criteria in the subset 'technological aspects', as a part of the integrated weights vector.

first glance. However, when adding technical safety to social safety, the difference is almost nullified. This is also visualised in figure 5.8b. Given that social safety isn't amongst the top 10 criteria (as can be observed from figure 5.5a), this would surely lead to comments from certain interviewees, as was also expressed during the evaluation of the weights for the individual interviewees[14].



(a) Comparing the gross weights of life cycle costs with safety.



(b) Comparing the nett weights of life cycle costs with safety.

Furthermore, one should take into account the comments made in the previous section (section 5.2.6) with respect to (directly) comparing criteria weights. *Social safety* is on the third layer, while the other two are on the second layer. This results in an extra multiplication and thus a reduction of the weight score. Then, the category of *return on investment* has fewer criteria than *technological aspects* has. Both phenomena contribute to the small difference between life cycle costs and (the sum of) both aspects of safety. This effect is also visualised by comparing figure 5.8b to figure 5.8a.

A further aspect hampering the comparison of the weights is the evaluation of the criteria asks the DM to score the performance of a project on these criteria, without knowing in advance what either a unit of *life cycle costs*, nor a unit of (*technical* or *social*) *safety* will comprehend.

Another implementation worth additional research may be found in the total isolation. In this case, one would take out all financial and risk relation criteria. This way, the DSS would evaluate the value only.

[14] One of the interviewees already commented on social safety not being in his top ten criteria, which was something he would definitely want to put up for discussion. See also appendix N.

Then, the DM would compare the value against financial aspects and risk in a second iteration, in which the value is shown by the DSS analysis showing the criteria having the most influence on the outcome. The DM would then have to make a decision in the second stage, weighing costs against benefits. This would however, subconsciously, increase the importance of finance related criteria. Furthermore, whether or not a certain benefit is worth additional spending can be a highly personal choice, as well as highly depending on perspectives. This may therefore hamper the objectivity which is one of the core aims of the implementation of a DSS in the first place.

When assessing the sustainability weights, visualised in figure 5.9, some observations stand out. First and foremost, *safety of the user* doesn't score the highest nett weight, although it was expected to do so. There are some aspects contributing to this, resulting from the model mechanisms and the categorisation of the criteria. One of the effects contributing to this outcome is the fact that the set of criteria containing *emission of gases* contains fewer criteria than the set containing *safety for the user*, which is not offset by the fact the weight for the latter set outweighs the weight for the former set.

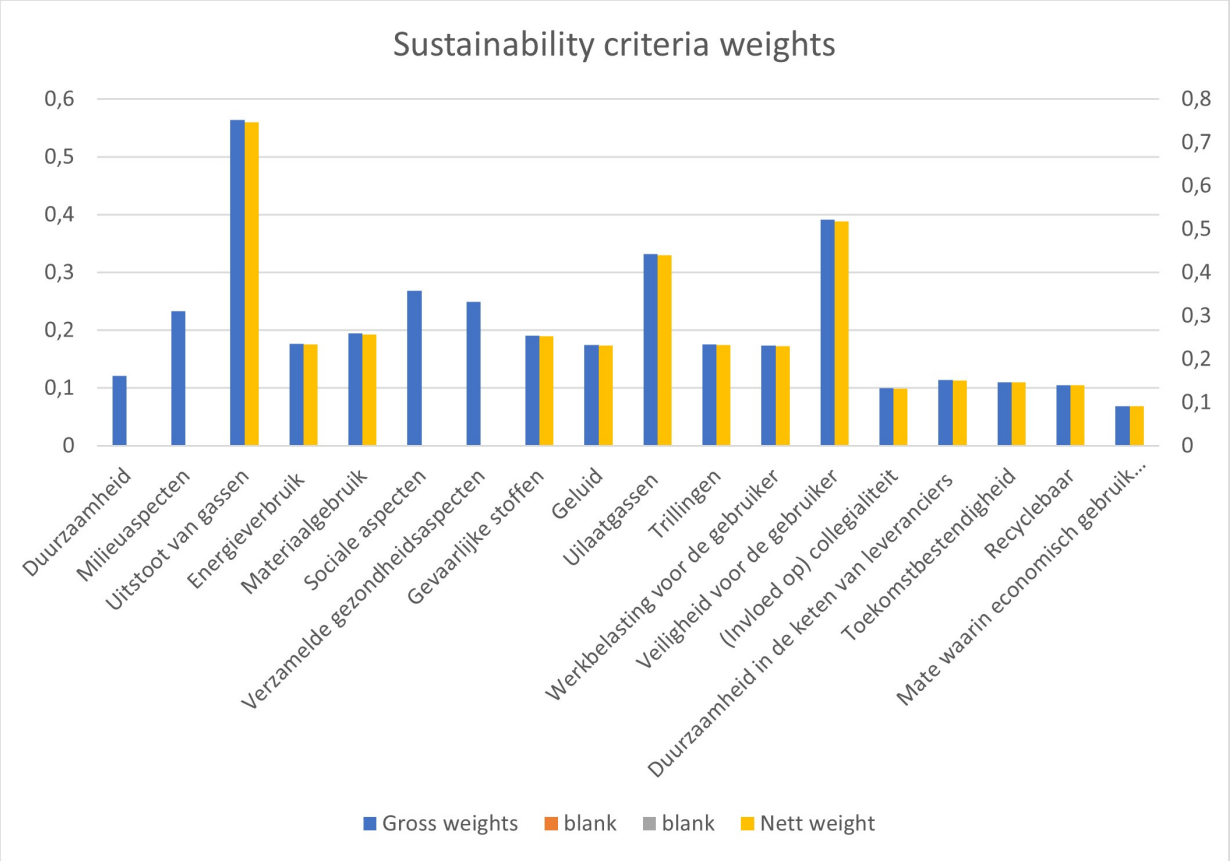


Figure 5.9: The weights for the sustainability criteria, both gross (blue) and nett (yellow).

Integrating these assessments, the way *safety* is implemented in the model, probably would require more research. In the current model, safety is embedded in the *technical aspects* and the *social aspects*, of which *safety* effectively is an integral part. However, this doesn't grab the importance the organisation stated during earlier interviews (see also chapter 2). A solution may be to include safety amongst the *link with strategy* criteria. Overall, the full structuring of the criteria may also benefit from additional research, in particular if the set of weights is used to compare weights rather than using the model in practise. It is likely beneficial to reduce the number of layers and reassess if criteria on a similar level are to be comparable to one another. In which case, the number of criteria in each layer should be equal for every set, significantly limiting the freedom for establishing the set of criteria.

The second analysis conducted aimed to gain insight in the level of agreement on the weight factors.

This could be established to assess which criteria weights the interviewees agree on and for which their opinion differs. This may provide ground for discussion or re-evaluation of the weights. First of all, the maximum difference in opinion amongst interviewees is established by subtracting the minimum weight obtained from an interviewee from the maximum weight obtained. This is included in figure 5.10b in yellow. Then, the cumulative deficiency was calculated as shown in equation 5.2.

$$\sum_{n} w_j^n - w_j^* \tag{5.2}$$

This is shown in figure 5.10b in blue. Then, these sets were normalised using the average weight, as shown in equations 5.3 and 5.4, and presented as percentages (hence multiplied by 100).

$$\frac{w_j^{max} - w_j^{min}}{w_j^*} * 100 \tag{5.3}$$

$$\frac{\sum_n w_j^n - w_j^*}{w_j^*} * 100 \tag{5.4}$$

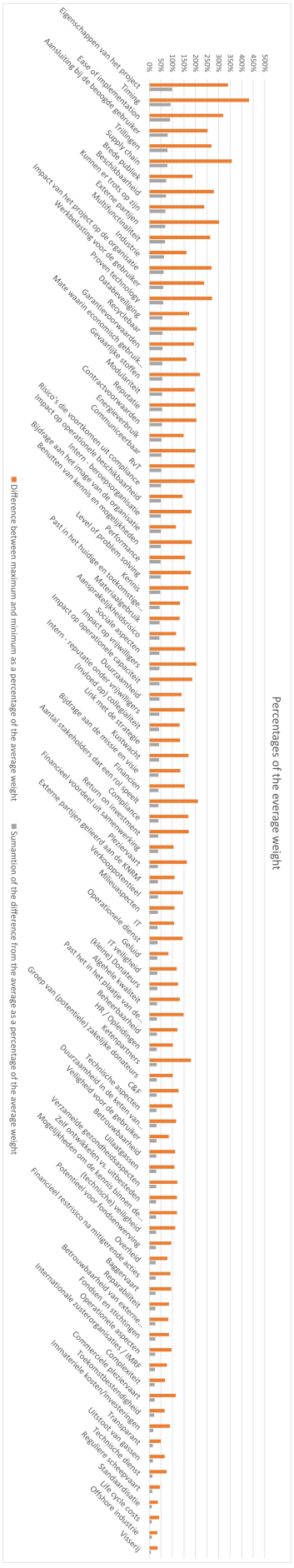
The outcome of this analysis is shown in the figures 5.10b and 5.10a.

This analysis found that both ways of assessing show a strong similarity. A study in more detail, in which the difference between the maximum and minimum weight value is much higher than the summation of the difference from the average, may indicate an outlier in the dataset. A clear example is the criterion 'timing', which was assessed to be the worst criterion of the set 'link with the strategy' by five out of seven interviewees. Instead, one interviewee mentioned timing to be the best criterion, with a significant difference from the remaining criteria in the category. This significantly impacted the outcome for this criterion. It turns out that the opposite also holds. In the same set, 'contribution to mission and vision' was mentioned five out of seven times to be the best criterion. It was mentioned to be the worst only once, which resulted in an outlier, as the interviewee mentioning it to be the middle criterion (the set consists of three criteria), scored it to be almost equal in importance to his best criterion. This way, the analysis aids in identifying in which cases an outlier is in play, and when opinions amongst the DMs differs within the entire group.

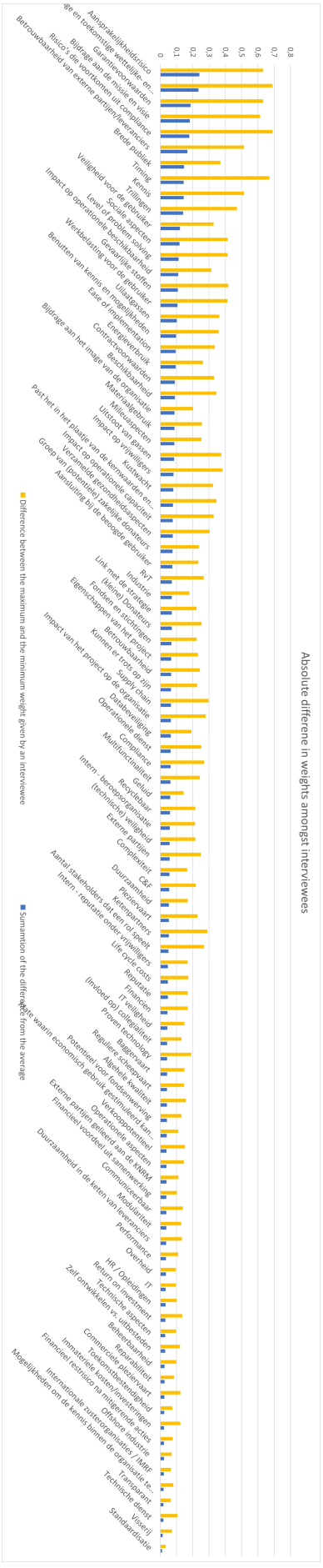
Identifying outliers does not necessarily point to errors or differences in understanding amongst decision makers (although this could also be the case). Instead, it could point towards interesting points of view, worth sharing with the decision makers. Thus, identifying outliers has the potential to identify innovative ideas or red monkeys (Steas, 2008). It should therefore be seen as a discussion starter rather than an obstacle. The discussion could identify new ways of thinking, and therefore updating and actualising the weights vector, reflecting an updated opinion held by the DMs.

As stated before, the analysis shows a rather significant differences amongst the participants. Noting the previous discussions on outliers and the implications of differences on the usability of the DSS, this research is not going into more details on this aspect. This may thus require further research in the future. On the other hand, the differences in the outcomes clearly shows the different perspectives held within the different branches and disciplines within the organisation. These backgrounds of these (sub)groups may lead to different opinions, interpretations, understanding and knowledge on topics or criteria in the model. The corporate set of values and preferences, in that respect, are a compromise originating from the different perspectives within the organisation, rather than a clear defined entity or parameter. Yet, although the origin of these differences may be explainable, their occurrence may hamper the DMs aligning behind, and supporting a single set of values. On the other hand, if this would be the case, it shows differences in preference occur amongst DMs, that need to be sorted anyway. The model then contributes to identifying this need for aligning preferences. These differences may also result in misunderstandings during the decision making process. Therefore, these differences are likely to contribute to the decision making process becoming unstructured.

Another insight presented by this analysis, results from identifying which criteria lead to discussion amongst DMs. It is important to recognise, first of all, that these differences in insights exist. If the



(a) Difference from the average weight as percentage of the average weight.



(b) Difference from the average weight.

difference occur widespread amongst the interviewees, this points towards either different insights from within the departments, a difference in insights amongst people, or a poor definition of the criteria by the researcher. Whatever the cause, clarification is needed in order to align the weights and align their support amongst the decision makers. As the analysis can point out these misalignments in the preferences of the DMs, they may initiate an effort to align viewpoints amongst DMs. A group discussion may then contribute to re-align the frame of reference.

In this phase, three analyses have been conducted to generate insight both on how certain phenomena are represented within the model. The, the data was also used to identify potential new ideas or insights amongst DMs, as well as potential misalignment within the group over viewpoints or frames of reference when assessing these preferences. This may trigger group discussions, which may then contribute to alignment amongst DMs, as well as the continuous updating of the frame of reference and the preferences, in order to keep it aligned with developments around the organisation and to keep is current and relevant.

5.4. Conclusion

The chapter started off with setting out the implementation of the BWM used during this research, thus translating the choice from chapter 3 into practise. Then, the research to establish both the set of criteria and the weights was detailed. As the requirements are not part of this research, this was executed using two rounds of interviews. The first round of interviews was concluded and the obtained criteria were integrated into a single set.

This set was the basis for the second round of interviews, in which the interviewees scored the weights for the criteria, based on their relative importance. Overall, the interviewees felt represented by the weights obtained from the interviews.

From the outset, safety appeared to be well embedded in the structure of criteria. However, as it turned out, amongst others, the layered structure, where *safety of the user* was a third tier criterion, and sets consist of different number of criteria, resulted in a reduced comparability amongst criteria weights. This is reflected for instance in the low nett weight of the criterion *safety of the user*, irrespective of its heigh gross weight, e.g. within its set of criteria.

The method used a linear scale for scoring the relative importance, while the MCAP contains a fraction, which results in a hyperbolic outcome for the weight, rather than a linear. Therefore, some of the interviewees scored the difference amongst criteria rather low, because they didn't feel represented by the outcome. In particular, interviewees found it difficult to express only a limited preference in the model, as even the lower numbers on the scale, resulted in a significant difference in the weights of the criteria under scrutiny.

Then, methods were identified to evaluate the representation of user input in the final outcome. Of course, the individual contribution didn't matter for this purpose, rather the aim was to identify lessons with respect to the method used and for the organisation as such. This learned that both the effect of individual outliers could be identified, which could serve as a discussion starter amongst DMs in order to identify the underlying argumentation for choosing this weight. It also highlighted which criteria was consensus on, and which criteria might require either further clarification on the exact meaning, or a group discussion amongst DMs in order to clarify the weight for the criterion.

6

Model validation

Having established the model parameters, the next phase entails the verification of the model through its application in a test case, which will be elaborated on in this chapter. The validation case aims to ask interviewees to use the model in a Decision Making Situation (DMS) that was prepared especially for this purpose. Although the case was mostly based on a real-life situation, the case was completed based on data from the internet and partly on fictional 'data' in order to present all interviewees a complete case, equal for all even when not all required data was available.

The first section of this chapter provides more details on the method used during the interviews and the validation case used. As part of the interview, interviewees were given concepts representing innovative alternatives from which one had to be selected. Interviewees gave an initial perception and preference regarding the concepts and after evaluating the concepts using the Decision Support System (DSS), again provided their evaluation and preference.

Then in the second section, the outcomes are evaluated. This would entail the interviewee comparing the outcome of his initial perception to the outcome when using the model. This shows to what extend the model represents the views of the interviewee, as it is intended to do. These outcomes are then evaluated with the interviewee, with the aim of understanding how the outcome came to be and if it is in line with the opinion of the interviewee.

In the third section, a basic sensitivity analysis was conducted in order to asses the influence of the individual scores on the model outcome. This is then used to assess the implications for the use of the DSS.

The chapter then summarizes the outcomes of this part of the research, which entails the assessment of the usability of the model.

6.1. Data gathering

Having established the criteria and the weights vector in the previous chapter, this part of the research aims to investigate if the model works for its intended users. This is examined through the evaluation of a case study that will presumably pose a dilemma for the organisation in the near future. As the DMS is highly relevant for the organisation, as much available data as possible was used to put together the case.

The aim was to present five alternatives within the case, presented to the interviewees in an objective and similar way. The alternatives aimed to resemble as well as possible the information, albeit less detailed, that would be presented by a contractor through a quotation and an offer when a tender would have been put out. Naturally, a contractor doesn't assess the impact on the reputation of the organisation amongst stakeholders or the impact on the internal structures of the organisation.

The information on the case was presented to the interviewees a couple of days prior to the interview, allowing them to read it in advance of the interview itself. The interviewees were also asked to choose

an option and substantiate their choice, based as much as possible on the information available in the case description. However, interviewees were not prohibited to conduct additional research if they wanted to do so. This additional data should be used by the interviewee to evaluate the case both with and without the use of the model.

As the objective was to compare these initial evaluations with the model outcome, it was important the interviewees had to establish their personal choice before filling in the data in the model, as seeing the results from the model may induce a bias. Therefore, participants were asked to score the alternatives, based on the narrative alone.

Having gone over the initial case evaluation, the interviewees are asked to score the variants on the criteria in the model. Then, the model outcome is evaluated and the ranking is explained by the model input.

The model outcome is then compared to the initial evaluation of the interviewee. Differences are established and the interviewee is asked to reflect on these differences. It is interesting to better understand where the differences come from and if the participant is convinced by the model outcome and analysis, to change his point of view. Otherwise, the difference in point of view is recorded for evaluation, preferably substantiated with an evaluation of the origin of the differences.

An analysis was run on the outcome, showing what criteria contributed most to differentiating between the alternatives that ended closest together. This was intended to provide insight into the rationale behind the outcome and what criteria mostly affected it. This outcome was presented and evaluated with the interviewee.

Finally, the interviewee was asked to reflect on the process and address everything that came to mind or what might contribute to improve the model and the procedure for using it in the future.

The interviews to evaluate the verification case was combined with the interviews for establishing the weights vector, in order to limit the infringement on the limited availability of the interviewees.

Function	Department	Case evaluation
CEO	Staff	Appendix N
CTO	Technical service	Appendix O
Fund raiser	Communication and Fundraising	Appendix R
Financial expert	Finance	Appendix T
Policy advisor	Staff	Appendix S
Project engineer	Technical service	Appendix Q
COO	Operational service	Appendix P

Table 6.1: Interviewees and overview of results.

The interview itself started off with asking the interviewees for their preference, having read the presentation of the alternatives, as presented in appendix L, using their usual method for individual decision making. The decision making was to take place individually, in order to isolate any group dynamics and associated psychological processes. The interviewee was asked to substantiate his or her decision.

The criteria used for this discussion were selected during an initial conversation with an expert from a company hired by the KNRM to advise on the replacement of the tractor under scrutiny in the testcase and with the the CTO of the KNRM[1]. Then, the set was confirmed by the CEO during the initial part of the third interview[2]

The participant was asked to individually score the performance of each variant in respect to the selected criteria. These scores were collected using the accumulation table, detailed in appendix M. The criteria were scored using the scale shown in figure 6.1. The nature of this scale naturally integrates a comparison with the current situation or solution for the problem, if any, as this is used as a benchmark.

[1]This conversation took place on the 4^{th} of February and was held virtually due to COVID19 restrictions.
[2]As held on the 24^{th} of April and detailed in appendix N.

E.g., any variants with a synthesizing criterion with a value under 5 is a worse-of solution for the KNRM in comparison to the current situation[3].

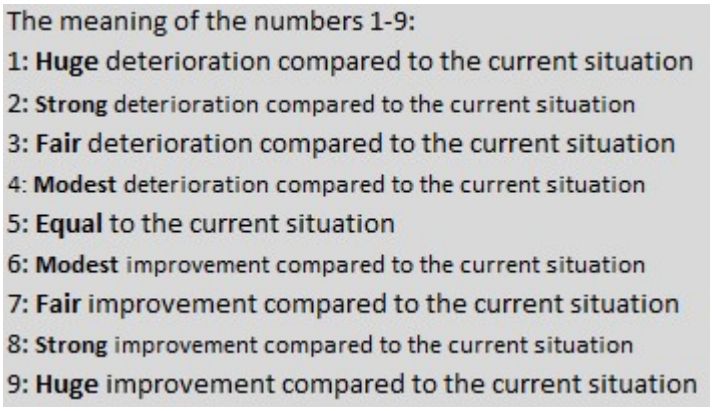


Figure 6.1: The scale used for scoring the performance of the variants.

The outcome and the preference were presented to the interviewee and evaluated, in particular if the outcome didn't match the variant initially preferred by the interviewee. The analysis of the outcome was presented to the interviewee and evaluated with the interviewee. This analysis that was conducted and presented to the interviewee is described in more detail in the appendix for each respective interviewee. A reference for these appendices can be found in table 6.1.

The interview concluded with asking each interviewee his opinion on future use and considerations on how the use should be implemented in order to support both the uptake and the usefulness of the outcome. In the next sections of this chapter the usability of the model will be evaluated based on the outcome of the prior question; the latter question will be evaluated both in chapter

Summarised, the interview followed a number of steps:

1. Evaluate the case and the variants therein using the normal process of decision making and reflect on the cases as they would normally.
2. Score the variants on the criteria identified for the model
3. Evaluate the variants based on the scores from the model
4. Compare the outcome of the model with the original choice and reflect on potential differences.
5. Evaluate insights from the analysis of the model outcome and compare this to the current decision making process.
6. Evaluate lessons learned for the implementation of the model in the decision making process.

Since all these evaluations were integrated into a single effect to reduce the burden on the interviewees (interviews in general lasted over three hours), some order effect may occur. This is due to people being asked for their initial preference first and scoring the variants thereafter. People may be prone to verify or replicate their initial choice in the second part of the interview. This effect couldn't be eliminated, any other than mitigating it by collecting the relative preferences in between asking their initial preference in relation to the variants and scoring the performance of the variants. Stating relative preferences generally took interviewees over 90 minutes to complete, thus some time elapsed before being asked to score the variants. Whether or not this aided in overcoming the effect, or to what extend the effect occurred, unfortunately couldn't be measured.

Yet, this is deemed to have resulted in a thorough evaluation of the usability of the model, how much the interviewee is reflected by the model and considerations for future usage of the model.

[3]Once again, one should take the distance into account. One can safely assume any variant scoring a synthesizing criterion around 3 can be recommended to be discarded. On the other hand, when a variant scores 4,8 or 4,9, things may be more complicated and one should generally be more careful discarding such variants.

6.2. Analysis of results

For the evaluation of the usability of the model, the main data used is the way in which model generated an outcome similar to the original preference by the interviewee. This data is summarised in table 6.2. This table shows the interviewee in the first column. The second column shows the variant originally preferred by the interviewee, the third column shows the variant with the highest synthesizing criterion, which is part of the model outcome[4].

	Initial choice	Model outcome
CEO	4	5
CTO	3	3
COO	2 (3)	3
Policy advisor	3	5
Fund raising specialist	5	5
Financial expert	5	5
Project engineer	5	5

Table 6.2: Comparing the initial choice to the model outcome for all interviewees.

Analysing table 6.2 in more depth, the model returned the original preference as model outcome in four out of seven instances. In the remainder of the instances, the outcome was analysed in more depth. In two instances, the interviewees changed their initial opinion based on the model outcome. Both stated that they learned from the analysis a given criterion played a decisive role in the model outcome, which they initially didn't consider, or which didn't play enough of a role in their initial consideration. They also stated the usage of the DSS forced them to analyse the variants in more detail than they initially did. Therefore, they were convinced, in particular by the analysis on the model outcome (which presented to them which criteria played a decisive role in the model outcome and were distinctive in the model outcome). The last interviewee had a more in-depth vision on the outcome, stating that his ideal solution to the problem was rather a combination of some of the cases, rather than either proposal from the test case. Therefore, he struggled to make an initial choice. And even with the final outcome, he still struggled to accept either solution as a viable solution. Instead, he mentioned the model provided him with many insights usable for a final selection in the future, or, rather, the limitations to include in the original *plan van eisen*[5]. The interviewee thus struggled with the choice as such, rather than with the method of decision making, which he also confirmed during the interview.

An analysis also has been conducted to see how sustainability criteria contributed to the outcome. An example is shows in figure 6.2. The figure shows the contribution on the vertical axis, with all sustainability criteria on the horizontal axis. Note that these criteria also include the criteria from the set *Return on investment*. Thereby, the set includes both environmental, social and economic criteria, thus following a triple bottom line approach (Elkington, 1997; Hubbard, 2009). This structure was also recognised by the KNRM, which makes the use of this approach both theoretical and practical sound.

The example shown in figure 6.2 is taken from a random interviewee. It shows a significant impact of the criteria *life cycle costs* and *emissions* to be the most influential criteria, followed by *safety for the user* and *sustainability over the entire supply chain*. It also shows the criteria *emissions* to be the most decisive criterion from this (sub)set. After integration of the model, these kind of analyses are to be conducted for the organisation-wide outcome, rather than for an individual DM.

This is an example of the analyses made possible by the model. What analyses are of value to the KNRM, the organisation is to decide for itself. Although the analyses conducted during this research are based upon the information deemed relevant to the organisation based on the initial interviews (see also chapter 2, one could also envision for instance an evaluation of all the impact criteria, to obtain a

[4] Other than just the highest value, the model also shows whether the aggregated scores are close together or further apart, which has implications for the changes required to change the order of the outcome. Therefore, presenting only the highest value is a major simplification of the outcome.

[5] Translated to read *set of requirements*, which a document handed to the industry to state the expected minimal performance of any product to be considered by the organisation for acquiring.

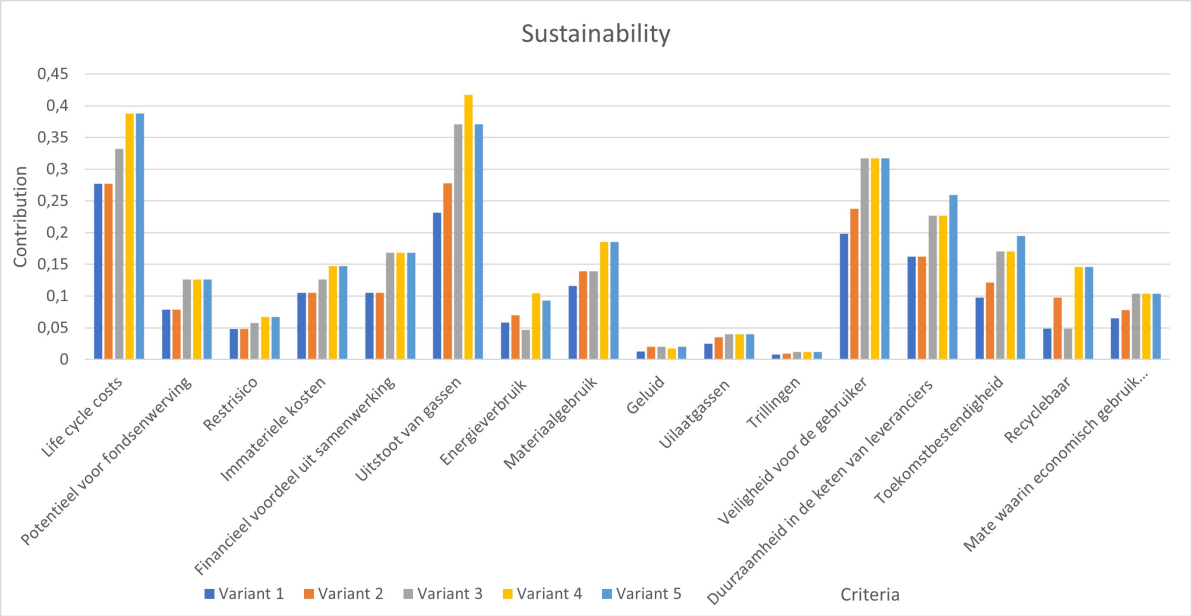


Figure 6.2: An example of the contribution of sustainability criteria in the outcome for a random interviewee.

balance of pain and gain. Possibilities are seemingly endless and depend on the preferences of the Board of Executives (BOE).

In all instances, the interviewees underlined the insights the model provided them and mentioned the model to have additional value in the decision making process, although the opinion on how to use the model, differed slightly amongst interviewees. An example of the analysis that contributed most to the insights gained is shown in figure 6.3. This figure shows the contribution to the synthesizing criterion for the criteria, sorted to their decisiveness. The figure presents the outcome filtering out variants recommended to discard for the decision[6]. In this figure, it was recommended to discard variants one and four. These analysis showed clearly what criteria eventually contributed to the outcome and formed the foundation for a decision. In this case, *Impact on the volunteers* was a strong promoter with the most influence, promoting variant three. On the other hand, *Makes us proud* influenced the outcome, but only to a minor extend. If DMs disagree on the performance scoring in relation to this criterion, this is unlikely to change the outcome order. The scoring for the criteria on the left thus has the most influence on the outcome, and therefore it is important for the DMs to agree to these scores and confirm this. This then substantiates the outcome of the model and underlines the argumentation set out in the analysis. In the example, such an argumentation may be: ”We have chosen variant three for its excellence in the impact its implementation has on volunteers and because it aligns with our core values. We then accept the variant scores lower on its reliability and we will seek to mitigate this effect to improve the performance of this variant.” It could also be a basis for a discussion focussed on arguments and their (numerical) effect on the outcome. And these discussions are not to be limited to the performance scores, but could also include the criteria weights, as they are also reflected in this analysis.

All interviewees agreed the model is to be used for decisions on a board level and should be used to support the decision making process, rather than making the decision. But most profoundly, all interviewees mentioned the added value of the analysis both for understanding of the outcome and the insights in the decisiveness of criteria and which criteria make a distinction amongst variants. This clearly proves the added value of the model and underlines its usage for practical decision making.

[6]For each interviewee is individually chosen what variants are to be taken into account and which are recommended to be discarded. This is elaborated on in the appendix for each interview, as per table 6.1.

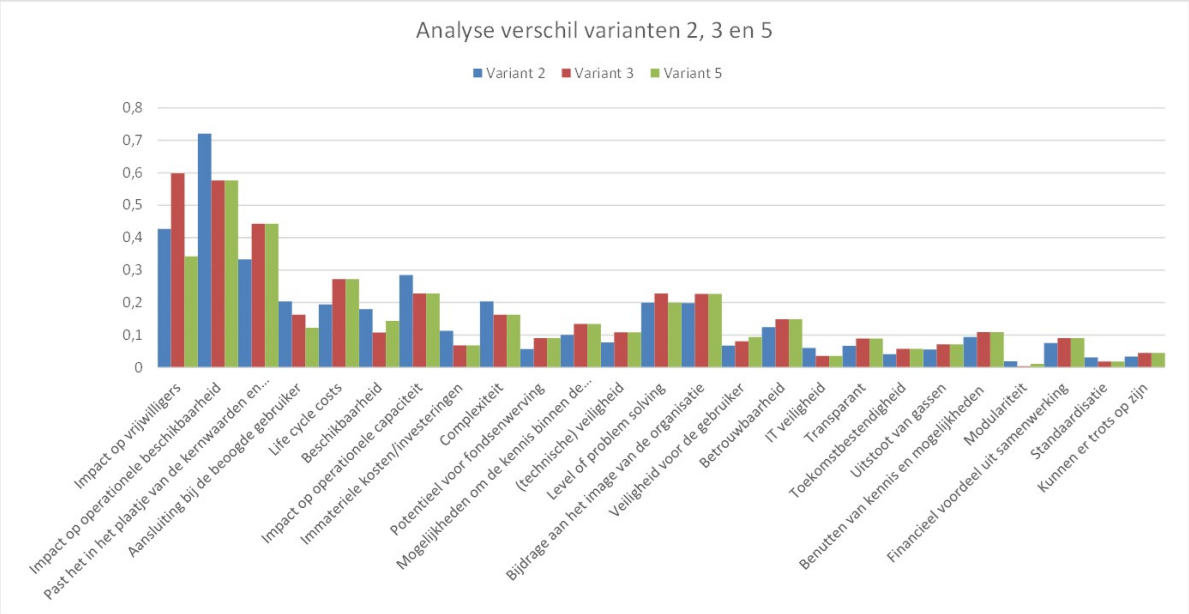


Figure 6.3: Example of an analysis showing the criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

6.3. Sensitivity analysis

A sensitivity analysis was conducted to test the model resilience against changes of single values, having the potential to have a significant, and potentially unwanted, influence on the outcome. If such sensitivity would exist, it would require extra care from the decision maker when evaluating the performance of variants specifically on these criteria.

The sensitivity analysis used both the synthesizing criteria found for the variants during the interviews, comparing these against the maximum criterion weight found, both for each individual interviewee and for the weights found for the organisation. The latter are presented in table 5.3.

It is noted the maximum weight for the organisation set of weights was found to be close to 0.1, while the maximum value for any individual weight was around 0.17. When this is compared to the difference in the synthesizing criteria, it can be observed that a single point difference in the scoring could revert the outcome of the system. Neither wrong nor a failure of some kind, care needs to be taken when scoring the performance of a variant against this criterion, as it determines approximately 10% of the synthesizing criterion[7].

In most of the outcomes, a single point of difference in scoring on the most important criterion or criteria would have changed the ranking of the outcome. In all instances, a change of two point in the score on the most important criteria would have changed the ranking of the outcome. On the other hand, in most interviews, half of the variants scored significantly lower than the others, requiring significant changes in the scores of multiple criteria to change the order of the outcome. Therefore, the DM can be recommended to discard these variants. Instead, the other half of the variants scored relatively close to the highest scoring variant. Therefore, the impact of changing scores for the most decisive criteria could change the order of the outcome. Therefore, DMs are recommended to go over these criteria in detail to confirm the relative scores as presented in the analysis from the model.

The criterion with this high weight is the criterion *Contribution to the mission and vision*. This is hardly a surprise, as this criteria is the core and essence of why the organisation exists and therefore of key importance to the organisation. It matches the individual weights, as three out of seven interviewees mentioned this criterion to be the most important one, while another two out of seven had it as second most important criterion. This underlines the fundamental role of this criterion.

[7]The actual percentage depends on the performance score in any particular case.

Having such an influential criterion also poses a risk. Those seeking a particular outcome could manipulate the scoring in respect to this criterion to achieve maximum influence on the output. While one should be aware of the sensitivity of this criterion in order to take extra care when scoring the performance in relation to this criterion, it also introduces a risk of bias or allowing the pursuit of a personal agenda. How such a sensitive criterion is best handled is also an interesting topic for further research, to substantiate the advice on how to deal with this situation.

As mentioned in the previous chapter, section 5.3, the model could also provide insights in the relation between safety. The model could even be used to test the assumed and hypothetical relation (see also hypothesis H.2) between safety and costs. This has been executed graphically for the test case. This holds no scientific value, as the case is partially based on fiction. It is rather a proof of method, than an statement in relation to the hypothesis. The analysis is shown in figure 6.4, with life cycle costs along the horizontal axis and safety along the vertical axis.

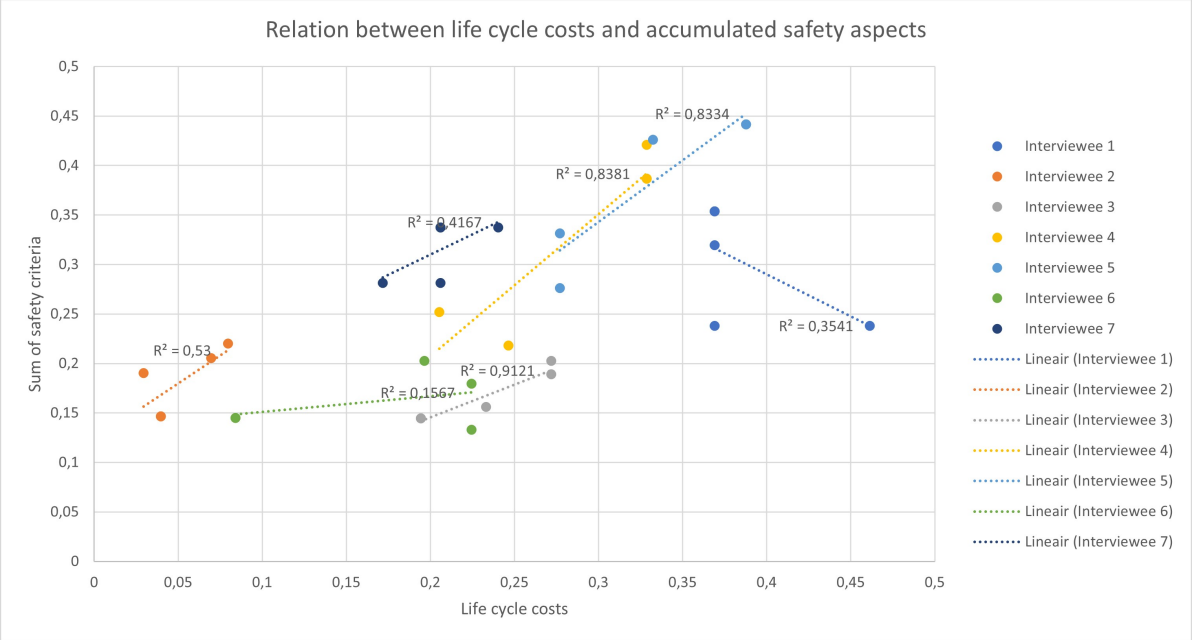


Figure 6.4: An analysis of the relation between safety and costs for all interviewees. Note that the case is partially based upon fiction.

This figure shows a linear relationship seems to exist between these criteria. This could point towards an existing relationship between the criteria involved and could trigger a statistical analysis. Once again, it should be emphasized the test case is partially based on fiction, this analysis therefore as of now holds no value for assessing hypothesis H.2. Furthermore, both axis do not have a dimension to them. Therefore, the relationship in the current implementation cannot establish something like 'the worth of one unit of safety'[8]. However, the example shows the DSS is capable of these kinds of analyses and provides the insights it promises for the DMs. Yet, if such a relation is found, it is unlikely such a relation to be generalisable to every Decision Making Problem (DMP). However, more research is needed to be able to ascertain this claim.

The sensitivity analysis shows both additional analysis opportunities, as well as providing a critical note to the user of the model. The model allows establishing relations and dependencies from within the set of criteria. Yet, it also brings to light the impact of change and the sensitivity for certain criteria, and one criterion in particular. The criterion *Contribution to mission and vision* has by far the highest weight, double the weight of the second most important weight. This has therefore the potential to play a decisive role in the outcome of the model. Although the argumentation for the high weight for this

[8]And even if this would have been achieved, there is much to say as to its usefulness, which goes beyond the scope of this research.

criterion is clear, its significant impact requires extra care when scoring the performance of variants in respect to this criterion.

6.4. Conclusion

This chapter aimed to assess the usability of the DSS using a test case. This showed the usage of the DSS was well received by the interviewees participating in the research.

Although the outcome of the model did not always reflect the original choice of the interviewee. Some interviewees changed their minds based upon the analysis of the model outcome presented to them. They stated the usage of the model forced them to analyse the variants in more depth than they originally did. Thereby, the model contributed to the rigour of the decision making process. Then, the interviewees also stated the analysis of the outcome showed them the impact of certain criteria, which they underwrote. Thereby, the DSS, along with a further familiarisation with the variants, made the interviewees changed their initial opinion to match the DSS outcome.

All interviewees underlined the analysis of the relative contribution and decisiveness as most important outcome and most valuable as a support to their overall decision. They also underlined the model should be used in a supporting role, providing additional insights to its user. Furthermore, it was shown the model could provide a basis for the relation of criteria. Then it was also shown that particular phenomena or combinations of criteria could also be analysed to reach a better understanding of the appreciation of variants and the origin of preference.

As these outcomes did not alone provide insights, but were appreciated by their potential users as well, the DSS underlined its added value to the organisation and within the decision making process.

7

Model implementation

Having established the model and proven its usefulness and added value for both the Decision Maker (DM) and the decision making process, this chapter aims to integrate the model in the current process of decision making.

The current process of decision making has been established with the initial interviews, and has been described in chapter 2. During this assessment, it was found the current decision making process was rather ad-hoc and not formalised. This was confirmed later in the research, as no standard set of evaluation criteria was used by the organisation. Therefore, integrating the model entails more than integrating the model alone; it effectively transforms the process from an unstructured to a structured method of decision making.

The first two sections contain a small recap both of the current decision making process and the characteristics of the model, describing its relevant factors for its integration. The next chapters describe the decision making process in a stepwise manner, accentuating the structured manner of decision making.

Although many conclusions were drawn during the research, not all questions could be answered and the process may be refined after implementation, building on the insights presented here. The learning shouldn't stop with the conclusion of this research, yet it should present a significant leap forward in the rigour and the quality of decision making in the first place.

7.1. Decision making process

Any implementation of an improved decision making process can not be oblivious to the existing structures within the organisation. Change is known to come difficult to people by nature and therefore a narrative is needed to support this change. In this case, this may be integrated into a single endeavour, when recalling from chapter 2 the Koninklijke Nederlandse Reddingmaatschappij (KNRM) recently executed one strategic innovation process and completed the decision making on a second process (the replacement of the lifeboat classes Arie Visser class by the NH1816 and the replacement of the Valentijn class by the Van Wijk class). The chapter presented some lessons identified, that can serve as the foundation for the change.

An evaluation of the NH1816 process showed for instance a lack of structure, rules and guidelines, decisions made based on conservative beliefs and (strong) personal opinions and beliefs, rather than a well balanced and fact-based decision. And even although the process aimed to include many internal knowledge and viewpoints, eventually people felt not heard, which resulted in a limited support of the outcome of the process. The assistance of a Decision Support System (DSS) has shown to support the KNRM in particular with these issues. It is found to be stepwise and structured by nature.

During the various interviews held, interviewees mentioned the change from an unstructured to a structured process of decision making would involve building support amongst the users as well. It was assessed this could be achieved through a plenary session explaining the DSS and the decision making process.

The DSS has also shown it can contribute to the transparency of the decision making through the in-depth analysis of the contributions of criteria to the outcome. This could form the basis for an argumentation as to why a decision was made. While decisions were previously made based on a gut feeling and a strong preference towards existing and proven solutions. The usage of the DSS doesn't disqualify these feelings, but tends to force the DM to substantiate his claim, while at the same time force him to evaluate other criteria as well. Both effects may support the accountability of the organisation towards its stakeholders, while at the same time contributing to the internal support of a decision.

The difference in preferences that was shown to exist amongst DMs, originates from different perspectives on the organisation and its values. These different perspectives are likely related to the difference in role and discipline of the participants in the research. In order for the DMs to make decisions in consensus, alignment in the frame of values and preferences is key. Its absence may contribute to misunderstanding and the process becoming unstructured. And this effect may strengthened when decisions become increasingly complex. In this respect, the research showed it would be beneficial to address the values and preferences amongst DMs on a regular basis. The model may then steer the discussion and provide a tool express the values. As these differences in perspectives may contribute to the decision making process becoming unstructured, addressing the perspectives will likely support any attempt to structure the process.

All in all, the evaluation of recent processes shows an opportunity for the DSS to be a fruitful and valuable addition to the organisation and its decision making process. Although the current process doesn't show a clear step in the process in which the use of the DSS could be implemented, an attempt will be undertaken in the remainder of this chapter to carve out a rough decision making process which may serve as an initial guide for the organisation. In the end, both familiarisation with the DSS, experimentation and learning by doing will improve the implementation. Furthermore, the rough process allows some tailoring to the case at hand and the accommodation of change of the organisation, its values and preferences over time.

7.2. Proposal of a structured decision making process

Now that the lessons identified from original decision making process have been described, a short revisit to the structure of this research (shown in figure 7.1, the current step highlighted in red) highlights how this chapter aims to tie in the outcomes of the research within the current decision making process to achieve a more structured, rigorous and robust decision making process. It is noted the actual implementation and the accomplishment of change is a field of research in itself and this research only scratches the surface of this topic in the final section.

The recommended structures follows the *value-focused thinking* method (Keeney, 1996), which prescribes to focus on the values of the organisation prior to the definition of alternatives, in order to have more control over the decision making situation. This method was proven to be applicable in practise as well (Finnerty et al., 2017).

The recommended structure also evaluates the framework proposed by Belton and Pictet (1997), who compare three different processes for both obtain weights and evaluate variants. First of all, *sharing* is defined to use facilitated group discussion to obtain a commonly shared set of either weights or evaluations. Then, *aggregating* refers to a mathematical procedure to integrate different viewpoints into a single set of outcomes, with minimal group discussion. Finally, *comparing* refers to reaching an eventual consensus based on negotiation of independent individual results. This way, individual differences are acknowledged, without necessarily trying to reduce them (Belton & Pictet, 1997, pp. 287).

A choice between these different methods to obtain a group consensus is suggested in this part to obtain a balance between the required time and effort of strained DMs and optimal representation of individual contributions. Yet, the organisation can adjust these suggestions as required based on their findings when implementing the procedure.

Yet,Belton and Pictet (1997) also show that, as the decision making progresses, it is possible to move from *sharing* to *aggregation* to *comparing*, but not backwards. This may stem from offering the

possibility to initially express and then anchor the individual expression. Once offered the option to express and include the individual opinion, it is hard to undo this. And Belton and Pictet (1997) observe that the costs of sharing is high in terms of the time which needs to be committed to the process and the demand for facilitator expertise, but the expectation of a consensual outcome is also higher. These are important considerations to take into account when choosing what procedure to use, even though there is no definite right or wrong choice here.

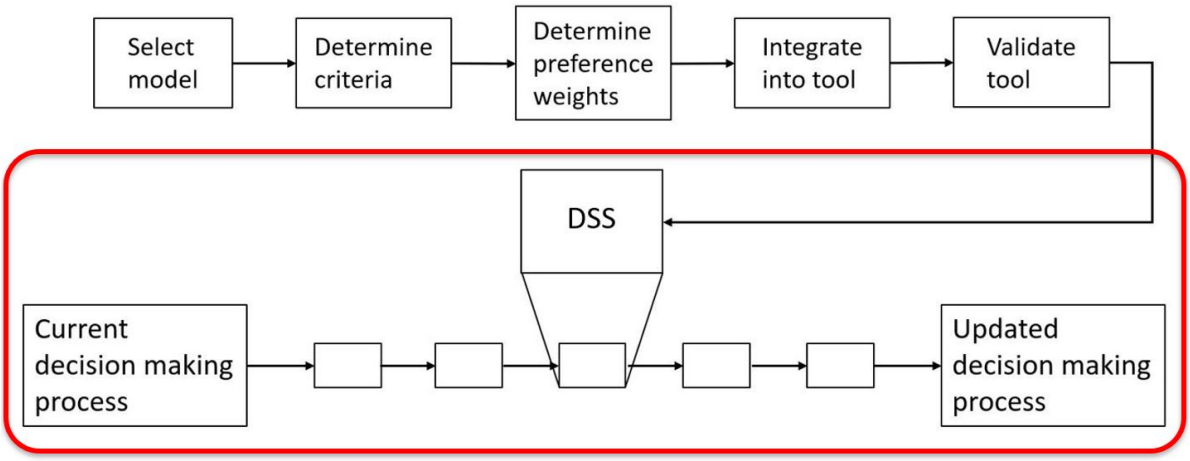


Figure 7.1: The integration of the implementation of the DSS in the decision making process.

It is suggested to follow a systematic process for the decision making process when including the DSS. And although not necessarily strictly adhered to, a stepwise representation also contributes to a common frame of reference amongst DMs. The suggested process is visualised in figure 7.2. The steps are detailed later in this section.

The stepwise process could also be executed over multiple round or iterations, each iterations building upon the decision from the previous step, with the level of detail increasing as the steps progress. For instance, first of all, five problems are identified that may have a claim to the same strategic resources. In that case, the process is followed first to order these in priority or order for addressing them. Having established which problem to address first, the process is revisited in order to do a more detailed analysis for a single problem. For instance, whether to build a new class of boats could be compared to investing in solar panels for all lifeboat stations and so on. Lets say the lifeboats are to be addressed first, then a rough estimate could be decided on, based on a propulsion technique, approximate length and displacement. Then, a third iteration could decide amongst different detailed designs and contractors. This process may continue for instance until the make and model are selected, or even what additional options are to be acquired.

Step 1: Strategic direction

According to Rumelt (2017), a strategy always aims to use corporate means to address a certain problem. Identifying these problems and deciding to direct corporate means to address these problems, is the start of the decision making process, as there are likely to be multiple solutions to the problem, each with their own characteristics, pro's and con's. The identification of problems is a strategic task and should therefore require support from the Board of Executives (BOE). Therefore, the identification of problems and start of a decision making process can be best decided upon in a board meeting. Then, the decision making process also needs a sponsor or someone responsible to complete the process and take the role of driver of the process. Since ownership combines these aspects, this person shall be the problem owner.

Step 2: Problem definition and requirements for a viable solution

Then, the problem is defined in more detail and the nature and context are analysed. Then, the conditions for success solving the problem are identified. It then basically revolves around the question what a solution should achieve. This should also be translated in the minimal requirements a solution

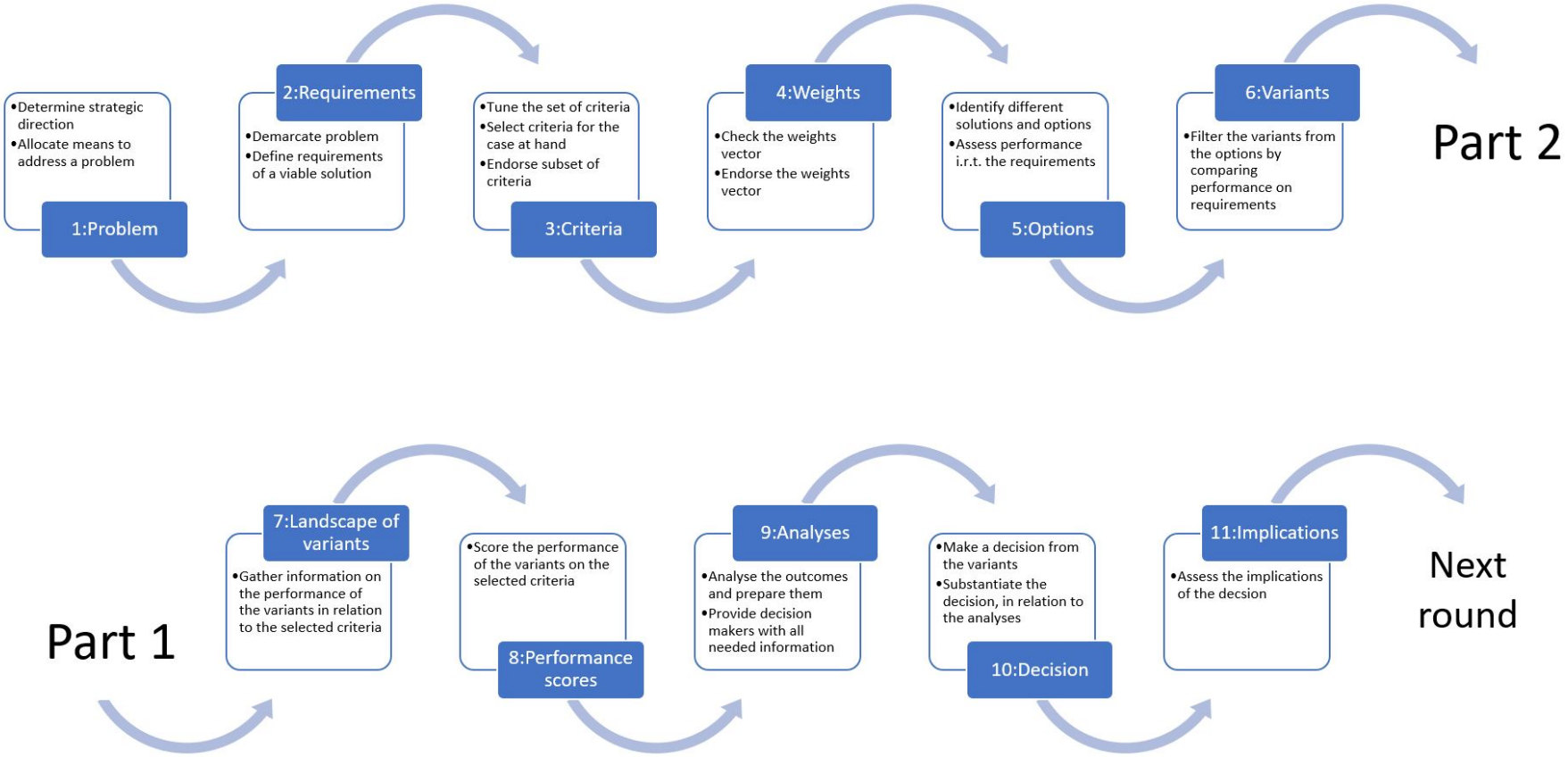


Figure 7.2: The proposed structured decision making process, tailored for the KNRM.

should adhere to in order to achieve the desired outcome by the KNRM. The level of depth in which the current set of requirements is formulated aligns with the level of depth of the problem at hand. The DSS can be used for a quick scan to discern amongst fundamental problems to address, to a choice amongst detailed quotations from shipyards offering a specific ship. In the latter case, requirements could be translated from the *plan van eisen* or vice versa. The set of requirements should result in the filtering of any undesirable alternatives.

Step 3: Verify and confirm the (sub)set of criteria
Then, the criteria should be selected. Since the initial two steps also determined the level of detail involved in the DMS at hand and the nature of the problem itself, the nature of the decision and the Decision Problem (DP) are being set out. This forms the basis to select criteria. During the research, some argued the problem owner should be able to define a set of criteria freely and from scratch. This would require a significant amount of work, in particular as a full weights vector needs to be generated in the next step. Instead it is recommended to select a subset from the full set of criteria established in section 5.2.3. This subset allows tailoring, albeit to some extend, of the DSS to the DP at hand.

Depending on the group preference, the subset of criteria can also be determined by the group as a whole, rather than by the problem owner individually. This would however require additional time by all decision makers. Yet, this would contribute to the ownership of the problem and support of the DSS outcome. A shared decision on the criteria to be used also contributes to the understanding of the DP. Even more so, failing to agree upon a common set of criteria implies a lack of motivation to reach a shared understanding of the problem, as differing priorities can always be expressed through the weights (Belton & Pictet, 1997, p. 290). In any case, this procedure is to result in a single common (sub)set of criteria to be used in the remainder of the process.

Other than selecting criteria from the subset, the main set is likely to change over time, as the values of the organisation and the environment the organisation operates in, changes. This requires a frequent update of the set of criteria. It is estimated that a two or five year frequency should suffice, while recognising special circumstances can always call for an additional update. And although this research aims to identify the current set of criteria, as was described in sections 5.2.2 and 5.2.3, during the second round of interviewees an interviewee was added representing one of the major departments within the KNRM. He already mentioned some improvements could be made to the set in regards to the criteria chosen to represent his expertise.

Furthermore, it has been identified earlier in this research (see section 2.3 definitions of for instance 'sustainability' differed amongst Board of Executives (BOE) members. An initial review could address this issue, while at the same time address the layering within the current set. Then it would also benefit the support and endorsement of the DSS by contributing to the feeling of ownership of the model.

Each time a revision is executed, also the definitions of the criteria are to be reviewed. This research showed some interviewees, in particular if they weren't part of the round of interviewees defining the criteria, lacked a shared understanding of what the criteria entail exactly. Therefore, it would be recommended to agree upon a set of frames and decisions ensuring a common understanding of the criteria. This confirms a conclusion by Belton and Pictet (1997) that an detailed and accurate description and demarcation of the criteria is in particularly relevant if aggregation and comparing methods are used to establish weights and evaluate variants. Same as above, this would also contribute to the ownership, support of the model and its endorsement amongst DMs. Some examples are presented below:

Life cycle costs
Life cycle costs concern of all expected costs during the entire life cycle of the offering. This includes procurement, maintenance, risk mitigation costs, such as insurance policies and technological measures to reduce risk, and expected costs of disposal (or benefits from selling on). The costs of maintenance are estimated as accurate as possible within the level of detail of the DP, including an annual inflation estimation equal for all options. The risk mitigation measures taken into account when estimating their costs should align with the remainder of the risk estimations part of the of the other criteria, so a risk is either (partially) mitigated, or deemed an acceptable risk. Finally, the sum of all costs is then divided over the expected life of the offering.

Use of raw materials
Similarly, the materials are also assessed over the expected life of the offering. Materials that can be recovered, re-used or recycled are deemed not to be consumed and therefore not taken into account. Therefore, the impact of the usage of rubber hoses is much larger that the effect of metal hoses on the overall materials use. The usage of materials is also not expressed in any scale, it is to be a relative scale. This is, for example, as different sorts of materials are hard to compare to one another. Also a financial scale wouldn't work, as this would have the DM assessing the financial aspect of the material, in stead of the environmental impact.

Impact on operational capacity
During the interviews, some discussion was held on the meaning of this criterion, therefore a suggested explanation is in place. The impact on the operational capacity refers to the types of missions that can be executed, or the capacity to conduct these missions. For instance, if a lifeboat can transfer more power to the water at any time, it can tow heavier vessels in distress. A larger sized vessel may carry more casualties or may carry additional equipment, allowing it to execute additional tasks as well, such as additional stretchers, medical equipment or a heavy hydraulics toolkit. This sets it apart from operational availability (in Dutch *operationele inzetbaarheid*), which assess the impact on the overall availability, for instance of a lifeboat station to undertake its operations when called upon.

Contribution to mission and vision
This criterion was often discussed during the interviews, as it seems clear, but yet discussion arises on its exact meaning. The mission of the KNRM is clearly defined. The mission of the organisation is to rescue and assist people (and animals) at sea or on the open waters, around the clock, in a professional way and free of charge. Furthermore, the KNRM assists in the prevention of incidents. The KNRM is an independent organisation, funded by charity and donors. This mission is supported by four strategic themes, safety, quality, sustainability and people. To the alert observer, it is immediately clear that many, if not most of the criteria in the set of criteria for the organisation is directly or indirectly linked to these themes. Once again, this makes sense as these themes represent the values of the organisation, while the criteria aid in highlighting specific aspects to be evaluated for the decision making. The strategy is visualised in figure 7.3. To conclude, one could follow the outlines for the strategy as defined in the internal strategy document for the strategy 2018-2024[1].

When it comes to the financial aspects of affordability of solutions, this is always deemed to be an important criterion in any decision. Yet, as was pointed out by one of the interviews[2], financial criteria, or life cycle costs, shouldn't necessarily be part of any stage of the decision making. While it is likely to play a role in the more detailed and in-depth decisions, it could be left out of initial phases of decision making, in order too widen the scope of the solutions possible and allow for the opportunity to identify ambitious and out-of-the-box solutions that may qualify for extensive co-funding solutions, thus reducing the financial burden on the KNRM. Although counter intuitive, it has the potential to bring interesting solutions to light.

This step should result in a subset of criteria tailored to the DP at hand.

Step 4: Verify and confirm weights
In order to complete the framework capturing the values of the organisation, tailored to the DP, all DMs are to agree on the set of weights. Although there is likely to be a general set (for which the weights vector found in this research is likely to be a viable starting point), the weights vector is likely to change over time, as new insights emerge, the composition of the BOE changes, or society evolves. Also, the weights vector of course needs updating when the set of criteria has changed.

Furthermore, as found in this research, the weights vector would need to change as the layering of the set of criteria is being addressed. Then, research is needed to see if normalisation can be used to negate an effect on the weights caused by the number of weights in a subset. Therefore, first of all, an initial review of the weights is recommended.

[1] This document is publicly available as part of the annual report over 2018, see also Jaarverslag 2018.
[2] See also appendix A.

Figure 7.3: The strategy of the KNRM in one glance, as per the strategy for 2020 - 2024. *Source: KNRM internal documentation.*

In this part it is recommended to harvest the knowledge shared amongst the decision makers by using a *comparing* method. This may be executed by aggregating the individual weights, similar to the method used in this research. Then, the group of decision makers may reflect on the outcome using a facilitator, where the facilitator can benefit from analyses on the aggregation, showing agreement and differences amongst decision makers (Belton & Pictet, 1997).

However, *comparing* deals less well with situations in which not all the DMs are experts on all aspects of the DP (Belton & Pictet, 1997). A solution may be found in evaluating all criteria subsets by a limited number of DMs. This may be achieved by dividing the subsets over the DMs, assigning each subset to other DMs. One option could be, having both the Chief Executive Officer (CEO) and a policy advisor determine the weights of the main categories, the link to strategy and impact criteria, the Chief Technology Officer (CTO) address the technical criteria, project criteria and operational criteria, the Chief Operations Officer (COO) address operational criteria and technical criteria, the Chief Financial Officer (CFO) address the return on investment and project criteria, the head of fund raising department address the reputation, return on investment and sustainability criteria. The DMs addressing the same subset should then compare outcomes and achieve a shared outcome for each subset. Finally, the problem owner should aggregate each subset into a full set.

This effort could be integrated with addressing the layering of the criteria, which is likely to result in a different implementation of the social safety, also known as the safety to the user. This is then assessed in a lower tier, which is in turn likely to effect its overall weight.

The DSS also offers possibilities to analyse relations amongst criteria. This can provide additional tools and insights that may assist in this tuning, as was shown with the analyses provided in this research. There are of course many more possibilities in this line, based on the questions relevant for the organisation.

This again stipulates the DSS should be a living object, changing along with the organisation. It truly aims to reflect the organisation as well as possible and follow its changes over time. When implemented well and used frequently, this should go seamlessly and workload is limited. This would require an initial effort from the DMs, familiarising them with the DSS and its working mechanisms.

This then completes capturing the values of the organisation and tuning the model to include the latest developments in the organisation and its internal and external environment, while also tailoring it to the DP under scrutiny. The next steps then focus on the generation and evaluation of the alternatives.

Step 5: Define options
If a problem is identified that needs addressing, different options to solve the problem are likely to be present to the DM. It is important that the owner of the problem invests in the creation of alternatives, as most organisations take this task lightly (Keeney, 1994). It is also important to identify alternatives, in order to present a complete landscape of solutions to a DM. This background is essential for the evaluation of any option, variant or solution. And not presenting it to the DM and effectively narrowing a choice down to a go/no-go decision, is prone to error making as it is open to known shortcuts also known as the heuristics of system 1 decision making (Kahneman, 2011). Examples of such heuristics are social desirability of any outcome, deciding based on a limited number of criteria, or criteria with a strong social desirability, which result in traditional biases. Furthermore, other psychological phenomena may also contribute to a narrow vision for other alternatives, such as being invested in a specific outcome of the decision making process.

If, and only if too many alternatives emerge, this may be narrowed down, but transparency then demands an explanation of how and why this was done. But even then, it is better to wait until after step 5, as this step already entails filtering the set of options in respect to the requirements. In any case, the generation of alternatives is an important process in order to position the DM for making a sound and deliberate decision.

In this phase, the problem owner is mainly interested in the performance of the alternatives in relation to the requirements of the minimal viable solution. An able DM may combine steps 5, 6 and 7 into a continuous process or single step, but this isn't free of risks. Discarding options should be done prudently, as it is generally done by one person alone and one could discard a valuable solution without putting it up for scrutiny.

Thus having established all options, the landscape of all solutions is set and ready for a further evaluation.

Step 6: Select variants from the set of options
Now, the solutions are checked against the requirements, thus ascertain all variants have been separated from the options and only variants are taken into account that may actually present a solution that matches the requirements of the KNRM and is within the boundaries of acceptance for the organisation.

One has to take into account and appreciate that the filtering aligns with the level of depth of the DP. Therefore, solutions may still be filtered out in a later stage, when the requirements for a minimal viable solution are defined in more detail. The process of decision making as set out here also works for more generalised and less detailed DPs. Therefore it is still possible to reject options in the next rounds of the decision making process, even as these options perform well in earlier rounds of the process, simply because additional details were found hampering the viability of the solution.

Having filtered out options that to not meet the requirements for a minimally viable solution, this step should result in identifying a rudimentary set of variants.

Step 7: Complete information on variants
Now that the variants have been filtered from the options, the problem owner should acquire more details about the variants. And since the criteria relevant for the decision are also known, the alternatives should be evaluated in respect to these criteria. Initially, this is done by the problem owner. However, when the process enters into a more detailed phase, the selected criteria can also be shared with potential contractors or parties offering solutions taken up as alternatives. For this purpose, the set of criteria may be shared with these parties in order to allow them to answer to, or elaborate on how these criteria are reflected in their offerings.

This information is gathered by the problem owner and presented to the BOE in an objective and equal format/manner, thus setting out the landscape of alternatives and variants. This puts the DMs in the position to take decisions.

Step 8: Performance evaluation
Then, the performance of the variants is to be evaluated against the selected criteria. In this regards, it was found the nine point scale worked well in this respect.

There are multiple options to obtain the performance scores. For instance, all board members could score the variants. This may take the most time of the members of the BOE, but may also lead to the best representation of the group of decision makers. It would also allow to benefit the most from innovative and different ideas and viewpoints that exist within the group, that may lead to the generation of creative new solutions (Belton & Pictet, 1997). It is noted here that the sole mathematical *aggregation* of the evaluation scores for alternatives may lead to a representative outcome that pleases none of the DMs (Belton & Pictet, 1997).

On the other hand, one could also choose to lean more on the expertise present within the organisation. This may be achieved through a combined effort, dividing the criteria over a selection of experts within the organisation. This can reduce the burden on individual member of the BOE, while championing the expertise within the organisation. The pitfall then is that it allows people to channel their personal opinions into the decision making process.

Therefore it is recommended to middle these extremes in an hybrid solution. This may be achieved by having the performance assessed by at least two decision makers. This thus entails a *comparing* procedure similar to the one suggested for establishing the weights, described in step 4 of this process. Major differences between the scoring should then be posed as a point of discussion amongst all DMs. During the interviews, some participants stated they found it difficult to appreciate criteria outside their own specialism. In the latter two options, this issue is also provided for.

Either way, the chosen method should result in filled out evaluation of the performance scoring table, cumulating in the values for the synthesizing criteria.

Step 9: Analyse results
The problem owner then aggregates the data and prepares the analysis of the outcome for the board meeting. This goes beyond presenting the single synthesizing criterion for variant. This research clearly showed the added value of the DSS originates mainly from the analyses. And in particular the analysis of the relative contribution to the outcome was valued by the participants. Therefore, it is recommended to include at least this analysis for all DPs. Other analyses may be dependent on the DP and be selected accordingly. In this, it is the task and duty of the problem owner to position the members of the BOE to make an informed decision.

In addition to providing the outcome of the analyses themselves, the problem owner should show how the analysis came about, what data was used and how it was used. Although this may seem a daunting task, generally, some straight forward analyses are able to provide valuable insights aiding the decision making. Yet, this transparency and attention to this support the building of trust and confidence in using the model.

By doing so, the problem owner should try to harvest the maximum analysis power of the DSS to support the BOE in making an optimal, deliberate and informed decision.

Step 10: Board level evaluation of the analysis and decision making
The board is to have a group discussion on the DSS outcome, along with the analysis that comes along with the outcome. As one of the interviewees stipulated, this process could be further strengthened if all DMs would fill out the full performance scoring sheet altogether, allowing them to signal major differences with the expert. This would then be a starting point for discussion and allowing for the signalling of out-of-the-box ideas or potential 'red monkeys', as referred to by Steas (2008).

It must be emphasized once again, the decision does not necessarily match the outcome of the DSS; instead the analyses generated in the previous step are to provide insights empowering the BOE to take the optimal decision, rather than doing that for them. The DSS provides insights, not ready-made decisions.

The group process should contribute to the common understanding of the decision and the criteria and arguments for the outcome of the process. The DSS should support the informed decision making, deliberate considerations and a thorough evaluation of a large number of criteria.

This should result in a widely accepted choice amongst the variants. It may also result in a better understanding of what a solution may look like if a more general decision has been assessed in this stage.

Step 11: Determine consequences and direction
Assess if more detailed rounds of decision making are required to improve the depth of decision making.

Now that this process has been completed, the choice can be implemented, or a new round of decision making can be started, now that more is known about the problem and the general direction the solution is taking.

For example, in this research one of the participants remarked he would prefer to have a variant combining design aspects from the different variants. This allows the problem owner to return to the market place and initiate a more detailed tendering process. In this case, the process doesn't necessarily result in choosing a variant, but still generates valuable insights that aids the decision maker in the follow up addressing the initial problem.

This way, the DSS should assist the organisation in achieving a more rigorous, structured and effective decision making method.

7.3. Implementation

The change of organisational behaviour doesn't come naturally. People are subconsciously resistant to change, as learned behaviour requires less effort (Tiggelaar, 2018). Therefore, change requires action by those who want to achieve change.

Accepting that change doesn't come naturally, one would have to introduce the process step-by-step and accept that initial interpretation cannot pretend to be a final solution. Interviewees also referred to this, mentioning uptake of change required quite some effort within the organisation. But just as important, is just to start. Therefore, it is recommended to introduce the model in a pilot phase, potentially assisted, in order to get used to working with the model. During the pilot phase, the use of the DSS and the decision making may exist next to each other, allowing to compare the model outcome and analysis to provide insights in how choices were substantiated, while on the other hand the model is tuned to better reflect the values of the organisation and its DMs. This pilot may achieve several objectives:

1. Familiarisation of the DMs with the DSS and the analyses.
2. Experimentation and learning by doing.
3. Build support for the implementation of the DSS amongst DMs, by showing its contribution and value.
4. Tuning of the model to increase its alignment with organisational values.
5. Tuning of the decision making preferences to align with DMs preferences.
6. Familiarisation with the analyses to substantiate choices and provide transparency.
7. Familiarisation and tuning of a stepwise and structured process of decision making within the organisation.
8. Professionalising the decision making process and optimising the process. This way, the change of the decision making process may contribute to the implementation of the actions set out in the strategic memorandum for 2018-2024.

With the aim of implementing a structured, rigorous and deliberate decision making process, a pilot may be a viable first step to achieve this aim. For this pilot a stepwise plan can be proposed as well, aimed at dividing the change in smaller and feasible steps. A suggestion is presented below:

Step 1: Update the set of values and preferences Initially, the set of values and preferences needs to be reviewed as described earlier, as it is essential to start off with a set endorsed by the DMs.

In this pilot stage, it is recommended to address the set of values in a guided group session. This should result in a maximum uptake of the lessons identified in this research and a valid starting point for the pilot. And, initially, the process is to be used in a single forum or group of DMs. This should require a single iteration at this point in the process.

Step 2: Basic implementation Based on the set of values achieved in step 1, it is recommended to use the model in its most basic form. That is, in step three and four, no changes are made in respect to the criteria and weights, other then selecting criteria from the set created in step one of this process, using the check boxes. This way, the DMs can focus upon understanding the analyses and their usage in aiding the decision making. Thisshould be continued until the DMs are familiar with the analyses and can easily use them to build argumentations.

Step 3: Update weights Now that the decision makers are comfortable using the model outcome, they should focus on improving the alignment of the outcome with their values and preferences. This part is divided in two steps, starting with the adjustment of the weights. This has less impact when it comes to workload or understanding of the workfile. Therefore, manipulating the weights is easier to execute than changing the criteria, which would result in changing the weights anyhow. Once the DMs feel comfortable changing the weights, the pilot can progress towards the next step.

Step 4: Implementation of the full DSS Now, the group should use the full model, including tuning the full set of values and preferences to the need of the organisation by updating both the set of criteria and the weights vector. Therewith, the KNRM gains full control over the model. This should empower the organisation to take ownership of the model and be in control of the set of values and preferences used as a starting point. The pilot should then progress to the next step when this empowerment and control is also experiences by the DMs or problem owners operating the workfile.

In this sense, this step provides the most complex operations, which is at odds with the requirement of a model that is simple to operate. Therefore, it is paramount to have some sponsors willing to learn how to operate the model and invest in its implementation.

Step 5: Diversify amongst fora and groups of DMs. Up until now, the model should be used by a single group of DMs only. Now that the organisation is in control of the model, the initial group of DMs are likely to become sponsors of using the model in other fora or groups of DMs. Herewith, the model can be used widely across the organisation.

This stepwise pilot to aid the implementation and uptake of the model is also visualised in figure 7.4.

These processes aren't linear or fixed in time. Instead they may be iterative and repetitive. It requires learning, developing and changing behaviour. These are processes that need to grow and generally require sponsorship in order to become successful.
A pilot process would be a viable step to achieve both a period to experiment with and evaluate the use of the DSS, as well as facilitating making a start with implementing change.

7.4. Conclusion

The culmination of this research is the integration of the DSS into the decision making process, taking into account as much as possible the lessons identified both from the current decision making process, as well as from the experiments with the support system itself.

This came together in the formulation of a structured and stepwise process, adhering to the *value-focused thinking* principles set out by Keeney (1996). This entails, after having defined the DP to be assessed, focusing on the values of the organisation, before proceeding with defining alternatives and the evaluation of the DP itself.

The values of the organisation are transformed in a set of requirements for a minimally viable solution, a set of criteria to evaluate the performance of a variant, and the relative weights. The latter establish

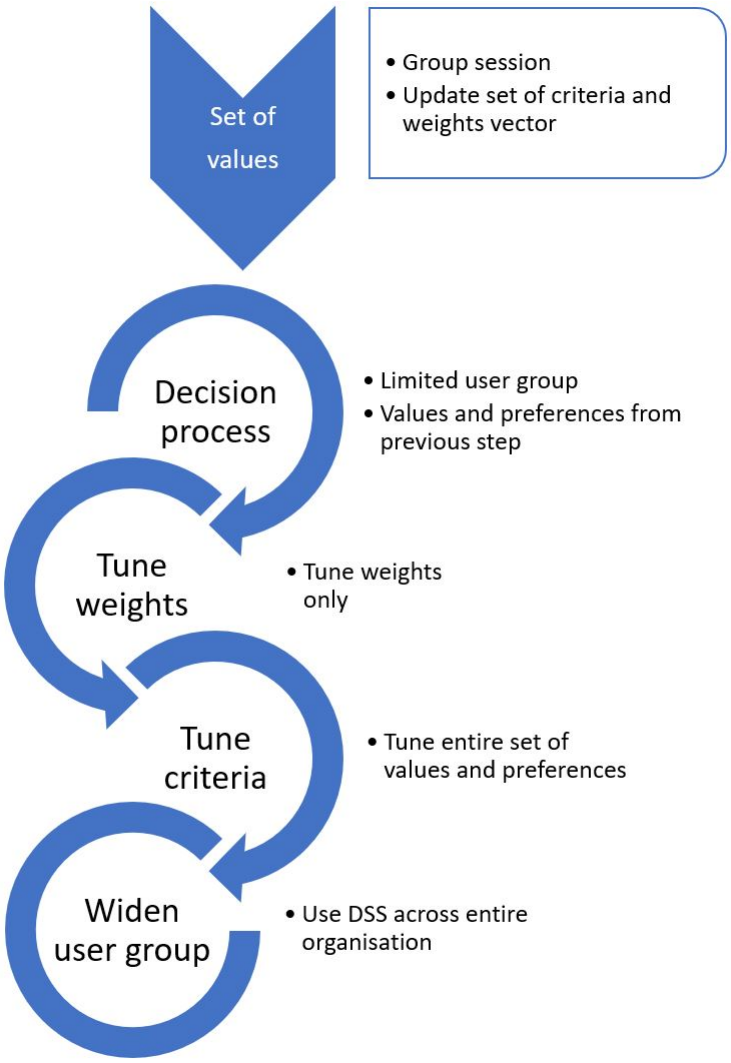


Figure 7.4: A visualisation of the stepwise pilot process suggested to support adaptation of the decision making process to adopt the decision support tool.

the relationships of relative importance of the weights amongst each other. This capture of the values changes over time and follows the organisation, the perspectives its employees and DMs and the societal embedding amongst its stakeholders, over time. This requires regular updates and adaptations from the set of values and their implementation in the DSS.

Then, the DP is studied in more detail. First of all, the level of detail is to be agreed. Then, alternatives are generated, charting the full landscape of solutions that may address the problem. This process is generally undervalued and this is stipulated as a point of attention.

Now that the values and the full landscape of solutions has been set out, one can start narrowing down to reach a conclusion and an optimal choice amongst options. First of all, options that do not meet the requirements for the minimally viable solution. Care must be taken that this is done conscientiously and substantiated, in order to be able to provide full transparency and accountability.

Then, in order to establish a single synthesizing criterion, the performance of variants in relation to the criteria are to be determined. Different implementations have been discussed, recommending an hybrid implementation in which criteria are scored by two DMs independently from one another. This mitigates both workload pressure as well as the pitfall of personal beliefs and opinions, albeit to some extend.

Now that the single synthesizing criteria have been established, the problem owner is to aggregate all DSS outcomes and analyses required by the DMs, thus positioning them to take a deliberate and well evaluated decision.

The decision process set out in this structured procedure can be used both singular and using multiple iterations or rounds, each time filtering out a number of solutions, while differentiating solutions on a higher level of detail. The latter applies if many solutions to a problem exist. In this case, one can start off with categorising the solutions and choosing amongst categories. These iterations may then continue until a make, model and manufacturer are selected.

This is an implementation of a DSS into a structured process, tailored to address the issues and lessons identified by the KNRM. Although the implementation of the process is likely to require some time for familiarisation and some tuning of the model to improve both the usability, user friendliness and organisational fit, it is expected to aid the KNRM in achieving more deliberate, and therefore, better decisions.

8

Conclusions

This research aimed to investigate the contribution of structured decision making methods, in particular related to the problem of integrating sustainability criteria into the decision making process, while at the same time ensure decisions are made in line with the set of values of the organisation. These topics were point of struggle for the Koninklijke Nederlandse Reddingmaatschappij (KNRM). Therefore, this research started off with charting the current method of decision making and issues the organisation ran into in recent innovation projects. This forms the basis for what method may be applied to achieve an optimal result.

In this research, a main research question was formulated accordingly:

> How can a structured decision making method aid a sea rescue institute in evaluating the sustainability of a set of multiple investment options and selecting the option best aligning with corporate values and preferences?

The research concluded a structured method can indeed contribute to the decision making process. In particular, the method provides means for analyses, contributing to a better understanding of the decision making, transparency and accountability. The analysis of the decision turned out to be appreciated most by the participants in the research. The participants also stipulated the model helped them to evaluate many additional criteria to take the decision, more than they would normally evaluate or take into account. This is a known shortcut in the human brain to simplify complicated decisions. However, for the type of decisions under scrutiny here, it is important to review and integrate the whole scope of criteria into a single evaluation, allowing for the weighing of all criteria against one another.

In order better understand and answer this question, this research followed a stepwise process. During a number of initial interviews with persons involved in the decision making process, observations, lessons identified and requirements were collected for the selection of a suitable Multi-criteria Decision Making (MCDM) method for this case. Then, a literature study was used to select the Best-Worst method (BWM) to be used in the remainder of this research. Then, a round of interviews was used to collect the criteria relevant in the decision making process. A next round of interviews determined the weights of the criteria. These were mathematically integrated into the Decision Support System (DSS). The model was validated using a partly fictional test case written for this purpose. Finally, the integration of the model in the decision making process is evaluated. This entire process is visualised in figure 8.1.

Current decision making process

In the initial phase, the evaluation of the current decision making process resulted in the identification of the need for a more formal and structured decision making process. This would align with the efforts currently being employed by the Chief Technology Officer (CTO) to define such a structured process, partially based on a stage-gate formulated step-by-step process incorporating formal go/no-go decision

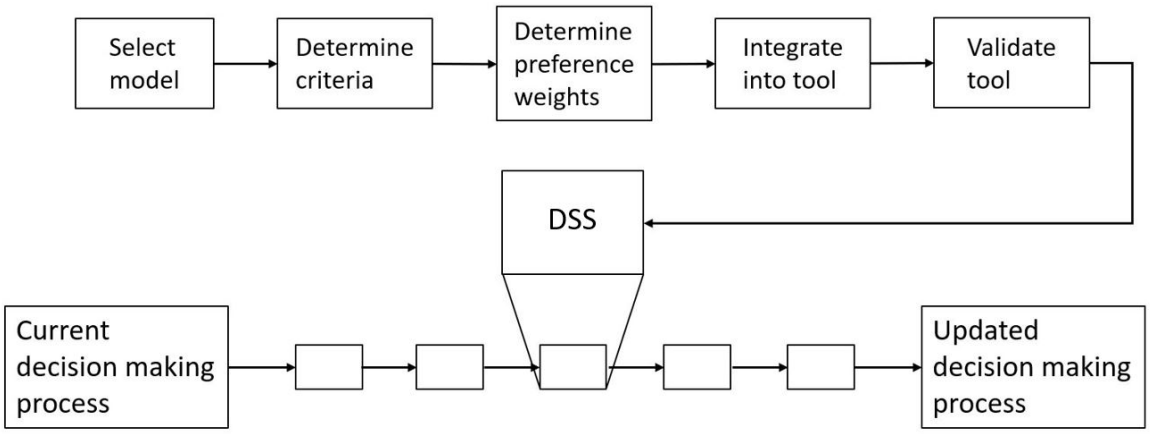


Figure 8.1: Overview of the steps involved in this research.

moments. Structuring the decision making process was also a lesson identified from the NH1816 procurement process.

In this phase, the definition of 'sustainability' was discussed, as well as the meaning of sustainability in the context of a sea rescue institute. During the interviews came to light that the organisation values both environment related topics, but, most of all, values the safety for its volunteers as a key part of sustainability. Effort is needed to align opinions across the Board of Executives (BOE), which may be achieved using the model as a context and guideline for the discussion, which could centre around the criteria that make up 'sustainability' in the context of a sea rescue institute. This research included this topic in the remainder of the interviews, but didn't allow for a proper discussion amongst Decision Maker (DM)s. In this light, it is recommended to hold a group discussion with the entire BOE to fine tune the current implementation of the model, its set of criteria and the weights. This would further strengthen support and endorsement for the model and its implementation. And it may also address the layered structure of the set of the criteria.

This evaluation culminated in formulating a number of requirements a Decision Support System (DSS) should fulfil in order to maximize the usefulness for the KNRM. When it comes to the model, participants support the benefit of using a MCDM-based DSS. The following requirements were discussed as a guidance for identifying the optimal model for this specific case:

1. The model shouldn't be a black box; the calculations used should be both understandable and traceable. There should be a clear relation between in- and output.
2. The model should be transparent. It should show input and foundations for the outcome and present it in an understandable manner.
3. The model should be easy to operate. This is to be understood both in a practical sense (not requiring complex actions) and in the sense of effort. Using it should require as little effort as possible.
4. Can cope with the input and viewpoints of multiple persons, experts or groups, providing their input on a single decision problem.
5. Should present an overview of the full problem, without isolating criteria beforehand.
6. Albeit designing the model to present a full description of the decision making, the model should preferably also work with a selection of the full set of criteria to assist in a segmented decision making process.
7. The model should be able to tap into the tacit knowledge of experienced employees and crew members into the comparison.

These formed the foundation for the model selection, which, in turn, formed the foundation for the DSS. To that end, these requirements were 'translated' into the jargon used amongst MCDM scholars, in order to link these requirements to the common grid of reference in the literature published on the

topic. This process was done in two steps, resulting in these required model properties:

1. The model should use discrete variants or options to choose from.
2. The model should be able to handle a relatively large number of criteria (>10).
3. The model should use pairwise comparisons.
4. The model should avoid using binary preference relation **S**.

This resulted in the choice for a single synthesizing criterion-model to be implemented.

Two selection frameworks were used to the select the optimal model. The outcome of these frameworks both pointed towards the Analytical Hierarchy Process (AHP) method. This model stands out as it is easy to operate and to comprehend. There is a clear relation between the input by the user and the DSS output. This was also observed during the interviews. Thus, it was assessed the aim of traceability was achieved.

However, instead of using the AHP model, the Best-Worst method (BWM) was used, which is based on the AHP methodology. The BWM has a number of the advantages over the AHP, such as a significant reduction in the number of pairwise comparisons needed and a higher consistency.

Criteria relevant in the decision making process

Having established the model to be used, a full round of interviews was held to establish all criteria relevant in the decision making process of the KNRM. These interviews were held with six respondents and resulted in an individual set of criteria for each interviewee. These sets were then integrated, resulting in a set of 89 criteria, divided over 19 subsets and a maximum of four tiers, as visualised in figure 5.1. These tiers were used to overcome the limitation of the model and the DM using the model, the consistency of the decisions and thereby the effectiveness of the model significantly decreases when more than eight criteria are within a single (sub)set. However, in a later stage, the research showed some downsides to this tiered structure and it is recommended to review it for the future. It is recommended in the first place to reduce the number to tiers to have three tiers only. Furthermore, it is recommended to balance out the number of criteria within each subset. And more research could show if normalisation methods may be applied here to support both internal understanding and comparison of individual weights.

The number of criteria involved in the model remained a point of discussion. With the introduction of each criterion, the number of pairwise comparisons increases, even although the tiered approach somewhat limits the extend. Therefore, the amount of criteria also impacts the workload for the DM to use the model. And although the addition of criteria adds to the level of detail, it may hamper the consistency and therefore the truthful and meaningful comparison of criteria and weights in relation to one another. Although the model and the resulting DSS were proven to be valuable to the users, further tuning may increase the value.

Relative importance

A second round of interviews was used to determine the relative importance of the criteria. In these interviews, the BWM proved its worth in limiting the amount of pairwise comparisons. Even so, most interviews in this round lasted well over three hours to evaluate weights and evaluate the validation case. For the integration, the geometric mean was used in order to achieve an equal representation of interviewees while retaining the reciprocal property of the set.

Some observations were done in relation to the scale used for determining the weights. Although a standard scale used in these situations, the hyperbolic relation between the relative preference and the resulting weight led to issues when interviewees thought criteria weights should have been closer together, but not equal. In this respect, two potential solutions are posed for further review. First of all, some scholars use a mathematical translation of the relative preference score into a preference relation. A second and highly unconventional solution may be found in researching if the Multicriterion Aggregation Process (MCAP) can be rewritten to express a linear relation between the relative preference and the weight.

The weights show a clear preference towards the category *link with the strategy*, as this is deemed the most important category and the criteria in the subset also represent the two highest nett weights. Furthermore, criteria related to safety, reliability and availability are often cited and marked as being important. This makes sense, as this represents the core *raison d'être* of the organisation, as well as its core values.

The weights vector also showed effects originating in the layering structure thereof. Criteria in lower tiers scored significant lower weights than higher tiered criteria. Albeit to be expected, this needs to be evaluated when tuning the set of criteria, in order to improve the set on this point.

A further analysis of the weights integration shows where opinions amongst DMs differ. This is likely to be contributed to the different background of the participants in the research. As opinions differ on how to view outliers and differences in opinion, it is reckoned this is a reflection of (sub)groups within the organisation that is to be cherished. The group should respect these differences and they should be the start of discussions amongst DMs. Yet, the group of decision makers is to endorse a set of values and preferences that represents the KNRM as an organisation. In this research, the opinion of all participants was reflected both in the (mathematical) integration of the criteria and of the weights. This presents the most objective aggregation method. On the other hand, it may feel more natural to create the set of preferences using a group discussion, as has been suggested for the implementation pilot. The outcome should in any case be a common ground and reference frame shared amongst decision makers. The model and the analysis of the weights integration sheet can therein serve as a discussion starter.

As many of the characteristics mentioned earlier in the research characterising the KNRM as an organisation are reflected both in the criteria and in the weights, this was deemed sufficient to continue the research and assess whether this also holds in a validation case.

Safety and sustainability

The outcomes of the criteria and weights was then analysed in more details in order to gain insight in the representation of some phenomena within the model. Amongst others, the initial question was to reflect on the balance between safety and sustainability.

First of all, the research showed that in the current implementation, the comparison of weights cannot be done without the utmost caution. Different factors play a role in the resulting weights, that need more research, amongst others the layering structure and the different number of criteria in the subsets.

Yet, some conclusions may be drawn in this respect. First of all, the triple bottom line was reflected in all definitions of the criteria. This entails that social aspects are part of sustainability, rather than opposing it. This is also reflected in the integrated set of criteria for the organisation. Furthermore, the importance of safety was reflected in the designation of two criteria side by side, with each focusing on a different aspect of safety.

Another angle to research was posed by the organisation, stating a deep-rooted bias towards proven technology, as this was mentioned in relation to safety and trustworthiness. In the evaluation of the weights, the weight of *proven technology* was found to be marginal, both within the subset of *technological criteria* and globally (in the entire set). So, either this premiss doesn't hold, or the interviewees have scored this element as being unimportant as the associated criteria, such as *quality*, *reliability* and *safety*[1] were also to be judged on their own merits.

To assess the coupling or statistical relation amongst criteria, the model needs to be applied to a real-life case. Any conclusions on the current validation case would be preliminary, as the case is partly fictional.

Albeit analysed partially, the analysis lead to some interesting results. For instance, it was shown that *proven technology*, on its own merits, is hardly validated as an important aspect in the decision making. In stead, associated criteria were valued much higher, such as *reliability* and *quality*. But foremost,

[1] In this capacity it is not necessary to discern between technical and social/human safety.

safety was found not to be at odds with sustainability, rather, it is assessed to be an important part thereof.

Representation of the organisation

During this research, the effects of group discussion and influencing has been excluded as much as possible by interviewing all participants individually. This allowed being able to observe opinions differed strongly amongst DMs. This was also underlined in the evaluation of single contributions in the overall outcome. The evaluation of a single contribution showed an individual can have a significant impact on the integrated weight.

Therefore, an equal representation method was used, to value opinions of DMs equally. Furthermore, participants were chosen selectively to achieve an equal contribution, representing all departments within the organisation equally. It that respect, only one department was represented by two participants. The effect thereof has been established to be quite significant. Whether or not this interferes with the overall aim of obtaining a representation for the group is for the organisation to decide. It has been established that any set of criteria and weights is only a snapshot of the organisations preferences. To keep it current requires constant tuning and frequent updating of the set. Therefore, the set of criteria and weights is to be viewed as a starting point from where the organisation can start adopting the method and further tune it to increase the fit, usability and value for the KNRM.

Then, the characteristics of the organisation and its preferences as discussed in the preliminary interviews were reflected in the set of criteria and its weights. This is another confirmation the set and the associated weights present a viable reflection of the organisational preferences and values.

Validation of the model

The model and associated DSS were validated using a partly fictional test case. In this case, DMs were presented information on five options to replace the tractor used for launching and recovering lifeboats. Although much effort was put in generating realistic options, some fictional elements had to be used to overcome lacking publicly available data (most commercially valuable).

Interviewees were asked to assess the options individually and make a decision, using their traditional method of individual decision making. Then, the interviewees were asked to score the performance of the options in relation to the criteria. Then, the outcome of the model and the analysis from the model were evaluated with the interviewee. Then it was assessed if the interviewee potentially changed his opinion. And if so, why this was the case.

The validation showed all participants valued the use of the DSS, most of them stating the model aided them in incorporating many additional criteria in their decision then they would normally have. The eventual choice by the DMs was found to match the initial choice in four out of seven cases, the model thus reflecting the opinion of the DM accordingly. In the remaining cases, DMs either changed their opinion based on the model analysis, or, in one instance, couldn't come to a choice altogether. In one case the decision was more complicated, the DM having a more sophisticated and detailed opinion on the options. Also in this case, the DM underlined the added value of the DSS and the analysis obtained, stating it provided him with additional insights aiding in the decision. Therefore, the model was assessed to have both provided an accurate representation of the opinions of the DMs, as well as being an asset to the decision making process.

User appreciation

As stipulated earlier, all participants in the review underlined the added value of the DSS, in particular the analysis of the decision, which substantiated the outcome and generated insights, rather than pointing towards either option. This lead them to the conclusion the model was of added value to the organisation and would benefit the decision making process.

The participants further stipulated the tool was to be used as an aid to the decision making process, rather than providing a solution to abide by. The participants also commented the model should be used on board level, for strategic decision making. Furthermore, the interviewees mentioned the model aided them in the incorporation and evaluation of many more criteria to base their decision upon than they

would normally have.

The use of the DSS even achieved some DMs updating their choice, as the use of the model required them to study the variants in more detail then they would otherwise have, where the participants attributed this merit to the use of the DSS, which asked them to judge the variants on criteria they would otherwise have overlooked.

Overall, participants valued the contribution of the model to the decision making rigour and supported its future usage.

Implications for the decision making process

In line with the observations from the interviewees and the findings from the evaluation of prior innovation projects, the KNRM would benefit from a more structured process, in order to support deliberate and rigorous decision making.

A rough stepwise process has been defined based on the *value-focused thinking* method. This entails focussing on the values of the organisation and setting the requirements for a successful solution to a given problem, prior to defining possible solutions. The process is designed to function in multiple iterations, increasing the level of detail in every round, the next round building upon the choice of the previous one.

It is expected both the DSS as well as the structured process will benefit from tuning to the DMs preferences and needs. Therefore, implementation may start of with a pilot. This allows both the tuning of model and process, as well as familiarisation and the building of support of the system usage.

It is also recognised it may be necessary to revisit the set of criteria and their weights in order to address the layering issues and scale issues found in this research. This may also increase the alignment over the criteria and their weights and their confirmation by the members of the BOE. In all of these processes, the outcome of this research is likely to present a good starting point to start these processes, as was confirmed during the validation case used to evaluate the current implementation.

During the initial phase, when selecting the model, two risks were discerned with respect to the model adoption within the organisation. First of all, the some more complex mathematics were used to derive the weights from the relative preferences. Although most participants didn't understand the mathematics used, they did see the relation between the input and output. Therefore, the aim of an understandable and traceable model are assumed to be achieved. The second risk lies with the amount of work involved in the usage of the model. This risk still exists. It is somewhat mitigated through the stepwise implementation of the pilot. Furthermore, the KNRM is recommended not the change the set of values and preferences every time the model is used. Instead, the model should be revisited periodically to keep the alignment with societal and organisational changes. A sponsorship and ownership of the model also support the uptake, but cannot be enforced or implemented. Rather, they need to grow instead.

The suggested process is likely to have not only internal advantages, but external benefits as well. The transparency aids in clarifying decision towards donors and other important stakeholders. The model also helps clarifying requirements, needs and values of the organisation, which may assist contractors in tailoring quotes and offerings to the need of the KNRM, in this case in the role as customer. But most significantly, the model should have a positive contribution to the quality of decision making. This originates from a structured approach, combined with the rigour of the possibility to evaluate many weighted criteria and support through a focused analysis on the decisive elements in the decision.

8.1. Bottom line

Overall, the use of a structured DSS based on a MCDM is expected to aid the organisation in the deliberate and rigorous decision making. Therefore, this is expected to result in better decisions, as has been observed in similar research, as well as contributing to the strategic aims of the organisation.

Other than the quality of decision making, a DSS based structured decision making process has a number of other advantages to the organisation, as listed below:

1. The process is transparent and understandable by other stakeholders. This may be reflected in a more detailed explanation thereof towards for instance the donors. It may also be used to ratify decisions with sponsors involved in a project.
2. The process supports incorporating tacit knowledge present within the organisation.
3. The DSS supports communicating a set of values to potential suppliers.
4. Analyses allow better understanding and substantiating of decision.
5. More criteria are evaluated in the decision making process and their relative importance judged independently prior to evaluating options. This may also support more detailed inquiries with potential suppliers to better understand offerings.
6. Reduce the costs of wrong decisions, albeit near impossible to quantify.

Of course, no improvement comes without costs. To name a few:

1. Decision making may take more time to complete.
2. The implementation requires overcoming the natural resistance to change.
3. The system needs maintenance to maintain the alignment with the value of the organisation.

Although the final choice for the implementation rests with the organisation, this research clearly showed a number of benefits, addressing of lessons learned and the alignment with the strategic objectives, in favour of implementation.

9

Discussion

Albeit the ideal outcome, this research cannot claim to produce a final, tailored and perfected Decision Support System (DSS) and perfect decision making process solving all problems for years to come. Instead the research aimed to achieve a humble first step contributing to this goal.

Although a general direction has been set out throughout this research, some shortfalls, pitfalls and considerations for the implementation are accumulated and presented here. First and foremost, albeit a viable starting point for implementation, the DSS and its underlying model require some tuning.

First of all, the Best-Worst method (BWM) was selected because of its apparent fit with the requirements of the organisation, thus assumed to address the most prominent needs of the organisation. This is not to say that other models may not provide other insights that are also valuable for the decision making. For instance, Decision Making Trial and Evaluation Laboratory (DEMATEL) may be used to provide additional insights in dependencies amongst criteria. These are likely to exist in abundance, as some criteria overlap with others, which in turn require specific details on a specific part of another criterion. Within this research it has not been possible to observe these relations.

An improvement in the model may be the use of fuzzy logic. Fuzzy logic proves its strength in case of uncertainty, which is most certain the case in this situation. As of now, this research refrained from its implementation, as its complexity would hamper the transparency defined as one of the characteristics sought for this implementation.

The layering of the criteria in tiers led to some issues, in particular for comparing weights. The layered design of the criteria was used to accommodate a large number of criteria, while research shows a DM can evaluate only a limited amount of criteria within a (sub)set. However, the layering also resulted in difficulties evaluation relative importance of criteria in relation to each other. This was as lower tiered criteria have significantly lower weights due to the additional multiplications done to obtain them. Initially, the user is recommended to restructure the set of criteria to reduce the number of tiers with one, retaining three tiers only. This addresses the problem only to a limited extend.

An associated problem is weights are lower when there are more weights within any (sub)set. This is reflected in the average weight, which is, as per condition, $\frac{1}{n}$, with n being the number of criteria in the (sub)set. Thus, the effect increases when incorporating smaller sets of criteria. Therefore, this effect is present within this context and needs addressing, for instance using normalisation techniques. More research is needed in this respect in order to see if this is of added value in this case.

In order to assemble the weights, participants were asked to define their relative preference of one criterion over another. Although a standard scale was used, participants often mentioned the scale was misleading and they couldn't get weights close enough to one another to reflect their preferences. Two avenues of approach were posed for further research. The first and unconventional option would be to research the implications of working with a linear and stepwise Multicriterion Aggregation Process (MCAP) within the BWM. Much easier to pursue would be to find a mathematical relation between the

stated preference and the preference ration used in the MCAP equation. Common examples of this approach are present within the literature.

When asked for their relative preference in the pairwise comparisons, some interviewees stated having difficulties scoring performance in relation to criteria that were outside of the scope of their expertise. A solution was posed in dividing the criteria to be scored amongst DMs, having two DMs score the performance of variants in relation to each criterion. This was aimed at both overcoming DMs scoring criteria outside the comfort zone, not being dependent on the judgement of one individual only and minimising the workload for the already strained DMs. Once again, other solutions are possible here as well, and any solution is a balance of the presented criteria playing a role.

Then, because of the pressure on the agenda's of the DMs involved in this research, some parts of the research were covered in the same interview. During the evaluation of the validation case, participants were asked to state and substantiate their initial preference. Then, interviewees were asked to provide their relative preferences. And then, people were asked to score the performance of the variants in relation to the criteria. Being again asked for their preference amongst the variants may trigger an order effect, having people scoring to achieve the same outcome as their initial choice. As this effect couldn't be measured, it is not known to what extend it may have occurred.

Not all interviewees had the opportunity to endorse the set of weights before continuing with filling out the remainder of the weights. Although all interviewees stated they endorsed the set after all, some stated they would prefer to make minor adjustments to their set were it to be implemented as the set for the organisation. Although it is unlikely to result in major changes to the set, the perfect fit of the set is of critical importance for the value of the model as a whole. Therefore, the organisation is recommended to discuss the set within the group of DMs to ensure implementation of all minor changes desired by the group of decision makers before implementing the model. Thereby, the group of DMs should work towards a set of criteria and associated weights confirming and endorsing the representation of their values in the model.

The current integration of the weights has been according to a mathematical method. This should therefore be put up for the scrutiny of the group of DMs, as they are required to confirm and endorse the set of weights before it can be used in a practical implementation. This should be an essential starting condition before using the model.

This remains an issue throughout any implementation of a DSS; any such representation is a reflection of the reality and therefore requires continuous updating. In this respect, it is recommended to frequently revisit the set of criteria and weights, for instance at least every other year, or when major changes occur. This couldn't be more relevant as it is today. Shocks in the environment and within the society at large (which is part of the environment surrounding the organisation, wherein the organisation is active) such as the COVID disease, showed their marks everywhere. In this light, the criterion *collegiality* may have gotten a complete new meaning. This may then be reflected in the weighting and scoring of this criterion when using the model.

This research culminated in the formulation of a structured decision making method. Its implementation is for the organisation to orchestrate. Some of the DMs were already involved in the decision making and are aware of how the DSS is to be used. The package handed over to the organisation contains the sheet for calculation of the weights using the relative preferences stated by the DMs. Furthermore, the package contains the sheet to score the preference of alternatives, given the criteria and the weights to be used. In this sheet, criteria can be selected using checkboxes with each criterion. The sheet then automatically calculated the synthesizing criterion. The package also contains a file for initial analysis of the outcome. This is only the visualising of the contributions of criteria in the outcome and relative decisiveness. Any other analyses couldn't be foreseen and may also be case dependent. The package comes with a manual and the offer to accompany a number of decision making processes. This may aid the implementation, understanding and uptake of the model and it allows the organisation to evolve the model together.

In the end, the DSS is a tool that should reflect the opinion of the organisation as a whole. Within the model, there are only few opportunities to confirm the correct working of the model. If such an opportunity occurs, for instance through using checksums, this is implemented. The cells for which this

applies, use a traffic light protocol, being green means all is in order and red signals an error.

There are two main signals the model is not working correct. First of all, the output-based consistency is measured through the Consistency Index (CI). This research found the input-based consistency (both global and local) to present a valuable indicator of the consistency. Yet, the output-based consistency provides a more detailed review of the overall consistency and an advanced DSS operator is recommended to use the latter. One should note that this is one of the strengths of the BWM as well. By including the OW-vector in the model, the DSS allows to check the consistency in the first place, which is a major argument for its use over more basic MCDM-implementations.

Second of all, common sense is to be applied too. One should never forget the model is just a representation of the opinion of the group of DMs as a whole or individually, depending on how the DSS is used. Therefore, the group of DMs should recognise themselves, their opinions and input in the outcome as well. Although not a very advanced method, it is a very important one and should never be overlooked.

The opportunities for checking the correct working of the model thus are limited, but nonetheless extremely important. Therefore, additional research is needed focussing on this area to further support the DM here. This is important for a small charity such as the KNRM, with limited resources to deepen out all details involved.

This is also why the BWM is deemed to be a better choice for the KNRM than more basic implementations of simple additive weighting methods. The BWM presents the DM with pairwise comparisons, which a cognitive aid to the DM. This helps him to evaluate the weights of a large set of criteria, the latter providing a more detailed reflection of the values and preferences of the organisation. Then again, the BWM also limits the amount of pairwise comparisons needed to obtain a full matrix of relative preferences, while still being able to measure the consistency of the DM. The consistency is also expected to score better than it would have in more basic model implementations. Again, foremost, the amount of criteria involved in capturing the values and preferences of the KNRM in a holistic model, requires the use of a more sophisticated method to offset loss in consistency. During the interviews, the need for a holistic method balancing all criteria involved was emphasized. And later during the research, the set of criteria has been confirmed, reaffirming the initial choice of the model.

The DSS created in this research was tailored to the case at hand. Yet, it is presumed to have value beyond its original aimed purpose as well, and on multiple levels. The set of criteria and weights are tailored in particular to the KNRM. Yet, even then, the set of criteria may provide a viable starting point for similar charities, in particular when relying on volunteers. It would then also require these organisation to use the criteria as a discussion starter and a starting point to create a set of criteria tailored to their own needs. For that, the discussion on aggregation and the aggregation methods used in this research may provide a good starting point. It is however important to note that the body of literature on this topic is still evolving, which may result in new insights.

Then, the model selection was done on a number of arguments that may apply equally to similar sized organisations, which is likely to have a much wider application. Both the method and its implementation may prove valuable to any similar-sized organisation aiming to implement a structured and holistic DSS and the process of using it in practise. In this sense, this family of models takes decision making back to its essence by objectively representing the decision problem at hand. At the same time, the

While small organisations likely lack the capacity to achieve this depth in decision making details, larger organisations on the other hand would probably require additional depth and insights for their decision making processes.

Overall, although the implementation of the model has its flaws, the model presents a viable starting point for implementation, in particular when taking into account tuning of the model is part of the implementation process. This once again stipulates the importance of the DMs confirming and endorsing the set of preferences before using the DSS in practise. And most of the issues discussed have also been translated into recommendations to overcome them in the future and achieve an improved implementation.

10

Recommendations

First and foremost, this research resulted in an initial structured and rigorous decision making process. Its implementation would mean a significant step in improving the decision making process. In order to implement the structured decision making process, the organisation is recommended to initiate a pilot to test and tune the Decision Support System (DSS) to the needs and values of the Koninklijke Nederlandse Reddingmaatschappij (KNRM).

One of the initial observations was that the KNRM would benefit from implementing a structured decision making process. Whether or not this entails implementing a Multi-criteria Decision Making (MCDM)-based DSS, is a next question.

This research focused on the question if a MCDM-based model were to be used, what model would be suitable for this case and how could an implementation look like. It was found that the Best-Worst method (BWM) matched the case and it is recommended to base any implementation upon this model. The model is an advanced implementation of the well-known Analytical Hierarchy Process (AHP) with some beneficial properties, related to a reduction in the workload for the Decision Maker (DM), as well as an improved consistency.

In the sense of decision making, a model is no more than a tool to compare potential solutions to any problem with values and preferences of the organisation in a methodical and structural way. In this light, the implementation of an MCDM-based DSS is an aid to the decision making, rather than a black box spitting out what decision is to be taken. Furthermore, the main advantage of the model isn't to be found in the visualisation of the optimal outcome, it is to be found in the analysis of the outcome, which shows what criteria contributed in discerning amongst variants. This should form the core of a substantiation of the decision. So, rather than taking the decision, the structured decision making process focusses on empowering the Board of Executives (BOE) or the group of DMs to take the final decision.

And in order to further aid the DM, more research is needed in order to check the usability of the model outcome and a correct working of the model. This is necessary to support the decision makers in the use of the model, as the resources of a small charity such as the KNRM in this respect are limited. It would thus be highly beneficial to have more traffic light based indicators showing the user the model is working properly, possibly for every step in using it.

In order to achieve this, a structured and deliberate decision making process has been posed in chapter 7, following the *value-based thinking* methodology. It is recommended to implement this procedure in a pilot, which could be used to familiarise with the model, tune the model and gain support and endorsement of the DSS.

Before the initial implementation of the DSS, it is recommended to undertake an initial tuning of the model in a group session with all DMs. This will require a number of dedicated sessions. First of all, the set of criteria needs to be improved. In this light, first of the layering needs to be addressed. It is recommended to eliminate the fourth tier. Furthermore, it is recommended to look into the subsets with

only two or three criteria. If possible, these may be integrated in the subset one tier higher; this is then to be reflected in the weighting.

During this initial session, effort should be invested in the demarcation of the criteria. This may be done for future reference and to align understanding of what is meant with each criterion.

Before the second session, the data sheet for the relative preference scoring needs to be altered accordingly. Then, in a second session, the relative preferences are to be gathered. In this phase, methodologies may be implemented to experiment with a mathematical relation between the preference judgement and the ratio between the weights. This may aid in overcoming the issues found with the scale and is easy to implement.

For establishing the weights, one can either opt for a group session, which is the most effective in terms of time required, as the endorsement is part of the outcome of the session. On the other hand, opting for the weights to be evaluated individually and accumulated afterwards, allows analysing differences of opinion, identification of outliers and general differences of opinion. Either should be put up for discussion. Outliers may originate from bright ideas or revolutionary new insights. A general difference of opinion may for instance originate from an unclear definition or demarcation of the criteria. In either case, a discussion is needed to align DMs behind a single point of view representing the organisation as a whole.

The result of these sessions is an updated set of criteria and associated weights, proposed to the group of DMs for their support and endorsement. This may then be used as a starting point for the proposed pilot, in which the decision makers experiment with the process and the DSS itself, potentially further enriching the analyses presented to the DMs.

Eventually, when the decision process is implemented with the KNRM, the set of the criteria and the associated weights still requires a frequent update, approximately every two or five years, or when mayor changes occur. This way the model stays aligned with the values of the organisation and the preferences of the DMs.

The proposed decision making process is an iterative process, each iteration building upon the decision in the preceding stop, increasing the level of detail with every step. This allows the DMs to split a decision in comprehensible parts and avoid going in too many details in an early stage.

The sensitivity analysis found the system could potentially be sensitive to a single point in the performance scoring of alternatives. Therefore, the analysis should point DMs to the criteria which have the most influence on the outcome and therefore must be evaluated with extra care. When it comes to the analysis showing the DMs what criteria were decisive in the outcome, care should also be taken to see if any criterion is missing that was expected to influence the outcome. If so, there is either a misalignment in the representation of the preferences by the model, or equal performance scores were given to any variant, where different scores should have been given.

Given that the use of a DSS and a structured decision making process both address some lessons identified in prior innovation projects and reflects a practical implementation of themes addressed in the stratefy of the KNRM, its implementation is expected to present a step forward for the organisation. And as well as making better decisions, the DSS should first and foremost result in making better informed decisions.

Further research

This research has shown once again MCDM is an interesting field of research, with many developments ongoing, and many more avenues for further research. Some of these were encountered in this research, and will be elaborated upon in this section.

As of now, little is known about the group size and its influence on the outcome when integrating the personal preferences of multiple DMs into a single set of preferences. It is posed this reduces the error margin, e.g. the difference between an abstract such as the *corporate preferences* and their representation by a model.

When it comes to the model used and sensitivity analyses, the DEMATEL method may provide valuable insight as to how criteria influence each other. If such phenomena exist (and given the overlap in criteria, it is expected to exist in abundance), this may provide opportunity for interesting analyses. For instance, suppliers or contenders can significantly improve their option if they know where to exert the most influence on the system by investing in and improving the performance score in relation to a limited number of phenomena or criteria. Or how the KNRM may seek to cooperate with a supplier to tailor a solution to the needs of the organisation. Given that change is achievable, the expected performance may then be used as a basis for the performance scoring. If this method could be applied for other scenario's involving (predicted or expected) future change, would also provide an interesting angle for future research.

In the literature there are a lot of progression on the development and usage of hybrid models or integrated models. Further research could show if there are benefits in this rather new development in the research on MCDM. This may offer the opportunity to combine the strengths of different models, while at the same times negating, at least some of the negative effects. Although there are likely to be additional complications, in particular due to transparency issues, this may be a game changer for the use of MCDM models.

Furthermore, more research is needed to address the issues observed related to the scale of the relative preference scoring. Should the solution be found in a mathematical relation between the score and the weight ratio? Or could a linear Multicriterion Aggregation Process (MCAP) function lead to a new model implementation?

More research is also needed to clarify the effects of layering on the comparison of weights. Such research may also look into the effects of the number of criteria within any (sub)set. An avenue of approach for the latter part could be the use of normalisation techniques to overcome this effect. If weights could be compared to one another, this would open up another world of opportunities for analysing the data set and provide DMs with additional insights.

More research may also show whether or not it is beneficiary to extract financial and risk related criteria from the initial evaluation. This way, the DM would, in a second step be confronted to chose amongst a cumulative value or gain, the associated costs and risks. This wasn't under scrutiny in this research, as interviewees stated in the initial interviews that a comparison should be holistic, in order to be able to relate all criteria to one another.

All in all, this research brought to light some additional angles for future research. Some of them could be valuable to the KNRM as well, in particular those having the potential to provide the organisation with additional insights that may support the quality of decision making.

A

Initial interview with the CEO

This transcript denotes what was being said during the interview between the author (A) and mr. Jacob Tas (T), Chief Executive Officer (CEO) of the KNRM on the 1^{st} of July 2020, which lasted approximately one hour.

A: ... [Introduced the background of the study] A: First of all, sustainability is a very wide notion, what does the term mean to you?

T: I also regard this as a very wide term. Within the KNRM we have defined the memorandum on strategy, which we have translated into a strategic plan for the next three years. One of the strategic themes in this plan is sustainability. That means, in a as wide as possible sense. What I mean this, ranging from energy neutral, or even negative in energy consumption to circularity, both in recycling as well as acquiring reusable products. Thus, in a wide spectrum, going well beyond waste separation and acquiring some solar panels ... We are evaluating many options, such as alternative fuels for the rescue crafts. However, for our organisation we are looking for proven technology, ensuring safety of our crews at all times, which is an operational constraint. But this doesn't limit us from putting solar panels on the roofs of the boathouses, even if this would cost us money. Also in the materials we use, our buying decisions. For instance, we operate aluminium rescue crafts. And I have been told that aluminium is well recyclable. This is also an aspect we can look at.

A: Circularity and re-usability.

T: Yes, exactly.

A: Do you use - or have - certain criteria that you use to establish or determine weather a proposal is sustainable to you?

T: No. The stadium we are in is that we have recognised and acknowledged that this is something we have to pursue. I just answered how I define sustainability. Within the strategy, we also established priorities, stating that we will shape this more detailed next year. So, by mid 2021, we aim to develop policy, as well as define the means we will make available for implementation. Furthermore, we will seek to identify specific funds that may support this push towards sustainability in particular.

A: Yes.

T: What we currently run into - as we were discussing Hydrotreated Vegetable Oil (HVO) fuels and additives in the board yesterday - it costs money. Both to acquire, as well as to distribute. So it is better, less grime and carbon dioxide, healthier, but we must also assure balance in costs and benefits, which currently isn't the case as we have more costs than income. Therefore, on the one hand, we have to establish what the costs are in more detail, including transportation, but on the other hand, we have also asked our fundraising department to see if there are specific funds, which are currently not sponsoring us, we could reach out to, mobilising them for supporting this. Then, it may no longer cost money, which I am hoping for.

A: We've spoken about the strategy, the strategic plan and theme and, relating to that, what does the KNRM aim to achieve with its push for sustainability?

T: As we operate in nature reserves, we operate at sea, we are involved in nature, [...] this is a fundamental choice we've made and thereby we're including the full spectrum. And by naming it as a strategic theme, we force ourselves, with every decision we make, to evaluate the sustainability. Or to evaluate if there aren't any more sustainable alternatives. We want to turn this into policy. But

even now, as we are about to invest in a new class of rescue craft, the ”van Wijk”-class, to succeed the ”Valentijn”-class, we are actively investigating what we can do to reduce noise, reduce emissions, reduce vibrations, and so on. However, for operational reasons, we are limited to stick to a certain power-to-weight ratio when it comes to the engines we can choose, as well as the capabilities of the vessel itself. Yet, we aim to live up the IMO Tier 3 standards. Therefore, we're confronted with fuel additives, such as Urea-like fluids for post-processing of exhaust fumes. This would require the engine to operate at high temperature, rather than in short bursts of power demand. Furthermore, this is a dangerous substance. So, if you're operating in high seas, or even if a vessel would capsize, you wouldn't want the fluid to chemically poison the crew. This forces us to drop this for operational reasons. But our starting point is to see what we CAN do, trying to tap into the developments around us and not be the last one to join.

A: So, sustainability would be implemented from mostly from a societal perspective, societal involvement and limited by operational conditions?

T: If you'd put it like this, its good emphasise that it is also from a safety interest, and the health of the crews. You, as a crew member are aware, with regards to health and safety regulations, the vibrations of the vessel, as well as the noise and emissions from the engines are worrisome for the organisation. So we're not only doing this from the perspective of joining a societal trend. No, it is in the first place from my responsibility for the safety and well-being of all our volunteers, I feel obliged to make much more progress than has been done in the past. So, its not nice to have, instead its need to have. It assumes that these norms are leading, unless it can't be done. Do you understand what I mean?

A: Yes.

T: This is important notion, as some people think that we are doing this to satisfy our donors, who tend to think that we should operate sustainable. Which they do indeed, more and more so, are they questioning our behaviour as societal charity. But, in the first place from a personal perspective, for my people, but also as an organisation, what you are contributing to an improvement or decline of the environment. So, there are three main objectives. First of all, the crew, then, our own role as an organisation and in third place, our money-raising activities and reputation within society

A: Yes.

T: And it may also be interesting to mention that there is also a cultural perspective to this. Just as with vegetarianism, I lead an organisation with both volunteers and employees, and there are many opinions. Some people may find everything about climate change nonsense, they think they'll survive the raising of the sea-level, and others may be very passionate about climate change. That's why it's very important for me to say safety and health are most important to me, they are number 1. And we have to take steps here, because we all have nice survival gear and we have nice ships, but what are we doing about stress measurements? Also regarding my crews, who are operating in difficult circumstances ... Why, you know? Everybody is wearing a Fitbit nowadays, if he goes cycling he knows exactly what is happening to him. But if you're stepping on a rescue craft, it's ”Good luck!”, you know ...

A: Yes. But the Fitbit goes along on the rescue craft ...

T: Yes, yes, with you maybe ... But it is a trend, of which in the strategy, of which I say we should act upon. Because, in stead of acting tough and saying that we don't need any of that, no, if I can already measure somebodies heart-rate and blood saturation and other indicators signalling hey, this guy is not going well. I'd rather know about that before he gets a heart attack ...

A: ... To take action before it happens instead of afterwards ...

T: ... Or so you can say: ”You should take it easy, you're not doing well.”, so to speak. But these are developments that we haven't really responded to. So for me, it's relevant, also with respect to sustainability - because otherwise we'll be only addressing health - it is an important impact, in particular when you're constantly operating in a high noise environment with exhaust fumes, whilst standing. Yes, then I consider it a corporate responsibility to [act upon it], primarily. And secondary, our own role within the ecosystem we're part of. And third, indeed, is our reputation and fundraising activities, which more and more ... [pay attention to this subject]. Take for instance the postcodeloterij[1], which doesn't donate to organisations that don't take action on this.

A: Yes.

T: So I consider this three nice reasons. Is this is, or did I miss out on one, in your opinion?

A: No, definitely not, it's not like I ehm ....

[1] A lottery organisation in the Netherlands that (is obliged under the law to) donate a significant amount of its revenue to charity.

T: ... think, why isn't he mentioning this ...

A: I more or less identified the same, which is also interesting to see. Then, the third question, which has also been addressed a little, which type of sustainability, or sustainable projects would fit the KNRM?

T: Well, yes, we are working on a number of things. We sit, we will look into a tractor - and it may be less relevant for Harlingen[2] - but we do a lot of beach launches and other stations have a launching vehicle. This used to be a transformed Caterpillar, in order for it to be at least half submersible. But all of that is vulnerable, it is equipped with a heavy diesel engine for pulling power, but why can't it be electric? Because that thing doesn't have to go far, or for a long time. It should work, and work in every circumstance, but let's see if it can be done another way.

A: Torque is of course one of the strong characteristics of an electric engine. So, in that sense, it matches the operational profile.

Yes, yes, that is something else. You couls also consider the Beach Assistance Vehicle (BAV). They are often involved in long searches, but maybe you'd need some sort of hybrid, or perhaps a hydrogen solution exists, [which is what] we'll find out. [That] all costs a lot of money, also such a conversion, but these are the examples. In the case of the tractor, we are active. we have an organisation in place that has evaluated whether its possible. They say it can be done, only as of now, its a costly affair. And beyond that, during the development of new rescue craft, we have been actively looking alternative propulsion. But we consider that fool proof, the hydrogen propulsion. Klaas Visser[3], who is a member of our supervisory board, is also saying all the time: "Shouldn't you act on this?".

A: Yes.

T: … But he also understands that that isn't yet ... he ... There's a difference between operating a tug with it, or a rescue craft. And here we want ... My biggest interest is safety, so yes, I am not going to experiment with this. So it should really be proven technology, and then perhaps, under all weather circumstances.

A: It will also require a training effort to have the people operate it.

T: Yes. So, we, well, yes. These are some examples. Other than that, we of course know about solar panels on rooftops, we all use electricity to keep the engines on temperature, but we don't pay taxes or we have a special rate, so that doesn't earn us money.

A: No energy tax, as I understood from Hans.

T: I'm not exactly sure, but you've probably heard more about it.

A: Yes.

T: But I'm saying, yes, but to me, it's not about saving money. To me, there is a difference whether I consume electricity from the network, or from my own solar panels, and with that, add energy to the net. This isn't a financial issue to begin with, it's a sustainability issue. And we've even had stations that said: 'Well, we aren't waiting for IJmuiden[4], we are installing, we currently have a donation from someone involved in solar panels, we'll put them on the roof and that's that." And so that ... You can also take initiatives with your local rescue station, to find a local sponsor for solar panels who is willing to say: "Hey, I'll buy those, I'll install them."

A: Yes. And there was also the suggestion to ... there are also many of those energy cooperatives, which rent roof space and who then invest in solar panels ...

T: Yes

A: ... and they would profit from ... they get more for the electricity, they aren't hampered by the VAT and energy tax issue and then you can ...

T: Yes. You'd get money for renting out your roof space

A: Indeed, you'd get money for that and you'd also benefit from the image, the image in that people see ...

T: That we have, that we do something. But that is where we currently stand. Here, the KNRM wasn't exactly the first, so to say, because, for instance, I took a full electric car. Well, the response from my employees, they are all like: "Hey, would you then need a trailer to carry your battery pack?" Things like that. People are laughing about it, because we are petrol heads, as it is called in English, we are like, we love engines, you know, and also when they go fast, and if they are durable, in the

[2]The rescue station for which the author is a crew member.

[3]Ir. Klaas Visser is an assistant professor on the faculty of 3ME faculty at the TU Delft, where is is part of the ship design, production and operations department. He is also a member of the supervisory board of the KNRM.

[4]A common phrase to address the main office, which is located there.

sense that they continue running. Currently, I don't have, due to circumstances, my electric car, but my own old car with me, which is a diesel, and immediately, I hear one of the operational inspectors who said yesterday: "Oh, I hear you have a diesel!" You know. So there is a tradition regarding engines, which are nice.

A: Yes

T: ... and all those novelties, well, hmm, it may just break something, or it'll probably not work, or it'll ... You see, on this point we also have to go through a cultural development and to make in order to ...

A: Yes

T: ... to take them along to change. As in, when it work too, it can be done. And, on my behalf, our responsibility, which you can extend as far as - which may be interesting to mention - as to include, as you may be aware, we own a significant capital, people have inherited bequests for future rescue craft we will build, or support the KNRM in general. We have invested this money, but shouldn't we do this more sustainable? Not just socially responsible, we are already doing that, not in arms manufacturers, tobacco and so on. But shouldn't we, why are we not investing our capital in the United Nations Sustainable Development Goal (SDG)s? And, as an example, there are some marine life ... Yes, well, there are some SDGs that would fit our image very well. And then we can also be proud on doing good things with that money.

A: Yes.

T: That is interesting.

A: It seems a very logical win-win, yes.

T: Yes! And it would be much more than just ...

A: Yes, there seem to be only advantages to it.

T: ... well, we have capital growth or we have return on equity. That is all nice and well, the returns are fine. I mean, not from bad companies, it's not carbon-related returns. But you can go even further by saying, I am going to actively support marine life as an SDG. Which companies are currently involved in ocean cleanups, sustainable fishing and so on.

A: Yes.

T: Well, and you could even, in the reddingboot-magazine[5], or in the stopzak[6], say, look, this is what we do with your money. So feel free to donate, because we do not only use it to save lives at sea, but also the sea itself, so to speak.

A: Yes.

T: We can add that to the list as well.

A: Even use the investment strategy to contribute to the mission. Yes.

T: And with that, interpret the mission in a wider sense than just rescue people ...

A: ... and operate a fleet of rescue craft ...

T: ... and sail as fast as possible because we have to get people out of the water, resuscitate them and bring them back. No, we are part of an eco-system.

A: Yes, I would say that this is a modern and progressive line of thinking, in my opinion, if you would compare it within Europe or within the IMRF, or with similar organisations in this matter.

T: Yes, I think we can set ourselves apart, but also benefit with regards to our reputation and fundraising ... See, it would also be great if volunteers would say: "I am not just volunteering to do incredibly good work for our society, I am also part of an organisation that I am proud of." Not just proud on the work that we do, because everybody is already extremely proud of, I think,

A: Yes.

T: And the way we organise that, for 195 years, but also the way the organisation has shaped this, so to say, when it comes to sustainability. That we reduced as far as possible, our contribution to the damages. And in Dordrecht, for instance, we are, and operate with the rescue craft in the Biesbosch, well, that is a nature reserve. Yes, there you are, so to say, with those nice Yamaha's, two stroke, which should have a particulate filter ...

A: ... with a black trail of smoke ...

T: ... fitted, yes, so to say, in fact. Indeed, they are very reliable, under all circumstances, even if they almost capsize and go through the sea, they'll still run. Great, but not so great on the other part. So, we should be able to find something that is still great ... Well, we were quite far along on that account, with Evinrudes, I don't know if you've heard about that, it is another project.

[5] A magazine that is distributed amongst donors of the KNRM.

[6] A magazine that is distributed amongst staff and volunteers of the KNRM.

A: Yes, yes, yes.

T: Also a two stroke, but almost as clean as a four stroke, but with the power-to-weight and with a long ... Well, for the Atlantics, and eh... But now Evinrudes said, we're to ...

A: ... Stop the production ....

T: ... won't do it any longer.

A: Yes.

T: After 110 years ...

A: What a waste ...

T: Yes, it really is an eternal waste.

A: Yes, indeed. I had a nice conversation with one of the mechanics in the workshop, who told me, well, yes, Evinrude is now producing only complete jet propulsion trains ...

T: Yes.

A: ... nd only supplyt them to their own wharfs. And maybe it would be ...

T: Yes.

A: ... nice to have a way in. Maybe, from a sustainability perspective, say: "I would like to have those propulsion trains, would I be allowed to install them to my rescue craft myself?"

T: I don't know yet how they compare to Hamilton, but we still have those Yamaha's. But, first of all, the Yamaha's are phasing out and second of all, they are very polluting and very ... Yes, very reliable, great for rescue work, but not great with respect to the environment.

A: No.

T: So I considered ... these Evinrudes had twice the endurance with the same amount of fuel.

A: It's really amazing that ...

T: I was just thinking it's a win-win-win ...

A: When I heard that, I was thinking, how is that even possible?

T: Where should I sign? And then it was all gone ...

A: Yes.

T: But well, that was another project we were quite far along, also with the height of the Atlantic. We plan of course to develop a new Atlantic, or a 9 metre RHIB, right, so we may have to equip them with four stroke engines. See what that would ... as the Royal National Lifeboat Institution (RNLI) is also using them, I think, and perhaps with an aluminium hull, well. So there sustainability will surely, as that is your question ...

A: Yes, that is why the English craft has been extended with one metre, yes, indeed.

T: ... play a significant role, because, ok, we want maximum sustainability, but also maximum safety. So we'll always choose safety over maximum sustainability. Because of the characteristics of the work that we do. You know, it's hard to explain to your wife, well, Wouter didn't return, but it was an extremely sustainable ride.

A: Right. But then, safety of course isn't one or zero, it isn't a black-and-white. So [for example], you'd have a small change in safety, compared to an enormous change in sustainability. How would you balance ... ?

T: Well, safety awareness, right? I've recently learnt from an expert in the field of safety who says: "It's not about safety awareness, it's about risk awareness." So, it'll involve considering sustainability, costs and risks. And thereof, we hold, and me in particular, time and time again: "Yes, we have a [financial] shortage, but I'm not here to reduce spending. Then I have to increase the revenue." There is potential for that, so I'm pushing the element of costs onwards. That can't continue forever, I'm not able to provide a golden propeller behind an engine and expect to get away with it.

A: No.

T: ... just because it seems to be a good idea. But I expect that safety always prevails over ... and look, if safety means we can still operate with gale force 10 [bft] winds, and else op to gale force 9 [bft], but then extremely sustainable, then I'd have to check with the crew of that station, can you assure me that you will not operate when the wind is stronger than force 9 [bft], because otherwise I'd again have to explain that someone was in distress and they went regardless, you see? It's sustainable but unsafe.

A: Yes.

T: So it's more subtle than say, if I would achieve 20% increase in sustainability at the cost of 1% increase in risk, I'd choose sustainability. I don't have concepts like that in my mind right now.

A: I can imagine they wouldn't exist at all, I'd say. I'll explain later why I posed the question like that anyway. Yes, let's address that later.

T: So for now, I'd automatically answer that I wouldn't do any concessions to safety, neither for sustainability purposes.

A: Yes.

T: Because then you might say, with regards to this ureum, this afterburning effect right, to sail yet more efficient and environmentally friendly with those Volvo D6 enginges, yes, what is the this risk that this fluid escapes from its safe container? I wouldn't know. I didn't even ask the question! Because I think well, I don't want to take the risk anyhow, to have someone return with ammonia well ....

A: Yes.

T: Do you see what I mean? Of course, if I'd pushed harder for sustainability, I might say, well, go out and test it.

A: But it's ... Yes.

T: Go to MARIN[7] Or, eh, Delft, to a towing tank[8], roll over it 20 times and, I don't know, real-life testing, everybody wearing survival suits, with masks and I don't know what, and see if it stays, with wind force 12, still remains intact. But when it comes to that, I tend to say indeed, I am not taking any risks.

A: No.

T: The task of my volunteers in those rescue operations is full of risks already, under some extreme conditions, ...

A: Yes.

T: You're probably familiar with the story of the Arie Visser-class that capsized near Ameland or something like that, with the door still open, and is able to return home nonetheless.

A: Yes, it's incredible, yes,

T: It may be incredible, but it's also, it gives my volunteers a feeling of comfort, this is a good ship, I am gonna be OK. Or on a Valentijn-class, that people in fact say, well, we can do everything with this ship.

A: Yes.

T: That, to me, is more valuable than a 10% sustainability improvement.

A: I see. Do you think that in the end, a trade-off exists where you will compare alternatives on arguments or criteria, or would you recon you'd evaluate the safety element separately, establishing beforehand that an option is safe and continue only if this criterion has been met? With regards to the safety aspect of a given proposal, before going ahead and compare it with other viable options?

T: Well, the difficulty is, as I have been saying, safety is number one, so I'm not doing compromising there. But what also is going on, is that people, for the sake of safety, use it as ab argument. The facts are unknown [to me] but I'll claim that it is unsafe and then, well, Jacob will drop it, so to speak. Thereof I am of course saying, well, then you'll have to explain to me why that is unsafe, because otherwise there'll never arise any ...

A: ... progress ...

T: ... change, progress. That's also why, like with such an Evinrude, that is to be tested. Then people can say, well, that Yamaha, is so great, because I know that one! Yes, but we'll be testing this anyway, because we think this Evinrude is great too. Yes, but if you reverse, it stops running. Yes, well, if you'll reverse when at full speed ... But when will you actually be doing that? I mean ... Yes, but if the sea conditions are like this and this... Well, and how often ... ? And what about that Yamaha? Well, that would also stop running ... Well, then it's not really an issue, is it? But it shows you, progress requires change. People aren't fond of changing and will, well, I used to work for a children charity in the UK, and in the charity, well, there it's like ... Children will die. There I had fostering, adoption, all kinds of things, people with disabled children and so on. And there I had an organisational change and people would argue, if you'd do that, then children will die. And I would ask, why? Please explain? Well, yes, children will die! Yes, I understand, I hear what you say, but can you explain to me why that is? You see, that is how safety should not be used, to kill conversations, for well, if we use that, we can stop all change in its tracks. And that is where the challenge lies. Because in my example of the electric car, everybody here thought that to be really awkward. And that really felt like a kick in the guts.

[7] The Maritime Research Institute, which researches ship related behaviour.

[8] A marine testing facility for testing hull designs and ship dynamic behaviour.

A new CEO and then we'll have to go with an electric car .. What is this? This guy's weird. An engine is cool, right? No, but ...

A: Yes ...

T: So, that is all very well, I should decide that for myself, they understand that, but I did it on purpose.

A: Yes.

T: To show that things are about to change.

A: So, start with yourself, leading by example ...

T: Indeed!

A: ... and live the message ...

T: Yes! ...

A: ... Turn it into the first domino to ...

T: ... Hoping that from there, [people start to see like] oh, oh, right, so it can be done, you can ... drive from IJmuiden to Eemshaven without having to stop en route, oh, we didn't know that.

A: Yes

T: I really get a lot of questions about it, so I, well yes, you are able to drive 400 kilometres with it, you can recharge along the road, that's all possible, it works fine! It's not like I am saying that you should use an electric vehicle for saving people, but it transfers the message that it can also be done in another way.

A: Yes.

T: But well,

A: Yes, that slowly leads us ... leads us to projects, investment and strategic choice questions. The first question I have is a straight forward one, but it entails many aspects. What does the decision process look like when it comes to innovation processes? Who initiates the process? Which, if any, are the steps you take in the process?

T: Yes, yes, so, well, we have a new chief engineer, who is also in on this theme. So, that is important, as culturally, we are aligned with the ambition to do things more sustainable. And for the projects, I already made some remarks on this, is our starting point to aim at maximised sustainability. Maximised safety and then maximised sustainability. So we start with the highest standard in sustainability, so to say, and then we go down step by step if an option turns out to be unsafe. But we start with ... Do you see what I mean? So we try to ...

A: Not quite I'm afraid

T: No, so we try to say, for instance with these engines ...

A: Yes.

T: We want them to be as efficient, fuel efficient and with minimal exhaust, we want to identify, for the propulsion.

A: Yes.

T: Well, that would be hydrogen. So you can dive into that and then we find that this isn't proven technology yet. So, we rule that option out. And so on, we peel off layers. You start off with the highest achievable option and from there you'll say, no, this isn't possible, it's not proven technology under all conditions. Then we say, ok, and later on that Volvo-engine has a good power-to-weight ratio, we have good experiences with it, they are equipped with an afterburning-device making it more efficient, better, less noisy and exhausts less carbon dioxide or black smoke, right, that is what we want. Oh, but that is impossible, as we consider it too dangerous, when it comes to the circumstances we operate in. So you'll be ...

A: So, from the maximum achievable and from there step by step back ...

T: Only if it turns out to be infeasible, why not, and then step by step back.

A: So there is a set of fixed criteria you use to ..

T: Well, as I was saying, that is the challenge of course, how rigid are those criteria? If somebody says, it's not proven. How come, not proven technology? Perhaps not in a rescue vessel, but did we ask Volvo if they are being used in fast RHIBs of intervention teams of the SAS or SBS or I don't know what Navy, right, are being launched from a submarine, with this specific engine and then, I'd say, the Navy and the Marines are allowed to, yes, then you'd think they are ... those lives are worth something too ... Lets assume that for now ...

A: From my experience in a governmental organisation I can say that in many cases the lowest bidder ...

T: Well, that is of course a challenge as well, but there the sustainability criterion will also play increasingly important part ... But lets say that the lowest bidder is both sustainable and operates in those circumstances, why would we then say that it is impossible? So there should be a challenge to such claims.

A: A challenge, yes, for a argumentation and a sound substantiation.

T: You see, because else, we'd return too fast to what we already had and well, then you're not making any progress. Yes, with Hamilton we would, as they are saying they have a more efficient, lighter, a little more expensive but newer version. Yes, it's not very difficult to acquire it, you just say, do we have the money to do it, does it fit in the budget? Yes, okay, then we include the latest version, than also spare parts will be available longer and so on.

A: Yes.

T: Do you see what I mean? In this way, it is being peeled of.

A: Ok.

T: Or so it is supposed to be peeled of.

A: Yes, ok, yes.

T: Next to that, we are also involved in different projects, innovative projects, by saying well, ok, go and check out such an electrical tractor, what would be involved with something like that? Without having prior considerations on having the required funds, is it exactly what we want? Have someone, for not too much money, make a plan. Would it turn out to be lighter, cheaper ... Well, if that is the case, perhaps without a special overhaul, as these cells, these battery cells, can we place them somewhere watertight, with a proper linkage, than that may turn out to be much more attractive, all of a sudden.

A: Yes.

T: And with a good vantage point, allowing you to see properly over the vessel, as that is often the issue with these tractors. Well, in that way. So, how can we meet the set of requirements, or perhaps even improve performance with a more sustainable solution? But as I am saying, this is not a peeling-of process, we are developing a new tractor, this is just go and check it out. Just try it, see what happens.

A: Yes.

T: And from there, based on that guidance, the next time we are working on it, then take it up.

A: Experiment, investigate feasibility ...

T: Yes. This is always very important to us, as I am keen to refrain from including the financial element at this stage. There are of course all kinds of grants, for innovative people who are into all kinds of things, but in our case, also there are many funds and foundations that may be specifically interested if we are to develop something like that. So there we also have an opportunity.

A: Yes.

T: So that is why I keep this funding element as secondary. So I'm not saying, like a commercial organisation would just say, I've heard about that hydrogen-propelled tug that is just laying there, it sails on common fuel again. Because the grant - so to speak - period has ran out. It's all working, but it's way too expensive for this tug owner to just continue like that. So yes, the entire experiment has been set up, paid, and so on, it works. But economically it doesn't work yet, apparently. Or it was a hybrid solution, or I don't know what, how they did it, and then it's just, yes, as they have to earn money. I of course don't have to earn money, right, I just have to make sure that I don't loose more money.

A: And spend money in a smart way too.

T: Yes. I have a different scope. Yes.

A: Some investments repay themselves only in a longer term of course.

T: Yes. But for me, sustainability comes down to a core of three arguments, safety, health, effectiveness and then there is also reputation. Reputation is also relevant of course, right?

A: Yes.

T: The middle part is, what is my contribution as an organisation to the deterioration or improvement, or limiting our impact on the living environment.

A: Yes.

T: And the truth is, we haven't addressed that at all as an organisation yet.

A: No.

T: That we use that as a ground for decisions. Right? Because for many people, and you may know this better than I do, in Harlingen, why are people with the KNRM? Not because how sustainable we are, because if so, they would have joined Greenpeace, or the Wadden sea, or you name it.

A: Yes.

T: Right?

A: Yes indeed. Yes.

T: They want to rescue people, that is what drives them. And comradeship, and with good equipment. When I was in Den Helder, with some Navy personnel on board, who were saying, look, here things do work. Who'd tell me, with this vessel, everything works! If I press a button, it works. In the Navy, half of the times, it doesn't work. So that is a story I share everywhere of course!

A: Yes.

T: In particular in company of senior Navy officers when with the Raad voor de Kustwacht[9].

A: Yes, I am familiar with the story and I often tell it myself.

[Intermezzo]

If we focus on the peeling process, I understand that discarding options is always based on hard criteria, based on which you are saying the projects are rejected.

T: Yes, so the exciting thing is, you start of with a large ambition and then, because of the safety, and there is no computer software package that can establish that, it has to be done by people.

A: Yes.

T: So that is where the challenge has to take place, so, no. But we want sustainable. Don't just say no, right. For example, with those HVO additives, 30% or something like that, from Good Fuels, well, yes, the pilot service successfully operates with it, for quite some years, and they intend to further expand this too. While half my technology coordinators say hohohoho, no, I'm not so sure. Engines, ho, and the gaskets may ... and oh no, and yes, has that all been tested? And is it going to stay OK? It has been tested for years! There is a full report on it! So, don't give me the story, give me the facts! You see, so there the leader, the management comes in, to say, no, this is what we want. You need to bring more arguments to the table, than just worries.

A: Asking critical questions when appropriate.

T: Yes, and also substantiated

A: Yes.

T: And don't just argue like, I don't want to change and this ... The KNRM with all its qualities, is still a rather conservative organisation.

A: Yes.

T: Change is ... Ehww .. we don't know .. we like what we have!

A: Yes.

T: That may be nice and all, that it's like that. It's just, like this, there isn't much progression.

A: No.

T: So.

A: Yes.

T: But you'll probably recognise it, this character.

A: Yes indeed, Yes. In Harlingen, there is always discussion about reducing speed when there is no need to be fast. That would save significantly in the costs ...

T: Enormously.

A: ... But they just don't want to.

T: No.

A: You would think ... They responded to me, like, what are you talking about?

T: Yes, it's like rocking the boat.

A: Yes. And in Den Helder we weren't particularly good at it, but at least, if you'd bring it up, people would respond positively. In Harlingen, they just don't want to do it.

T: No, and with respect to the experience, you know, whether you'd sail 25 kts or 32, with respect to ship handling, that doesn't make a huge difference, it's still fast.

A: Yes.

T: And it would save enormously, as we have already communicated, a very good point, very much communicated ...

A: Yes.

T: ... with graphs that showed you ... The only thing we're currently not doing, and I intend to go there in the future, is to provide crews with additional insight. And when I'll be showing 45 stations their respective consumption, it might spark some competition, as hey, this station does this many miles with

[9]The Coastguard board, entailing representation from the involved ministries, who are responsible for the strategic decisions involving the Coastguard.

this consumption. How can that be? And that this would stir some kind of sustainability competition, motivating people to say: ”Hey guys, when we’re exercising we don’t always need to go this fast, if that saves us so much.” But that is of course eh ... We do have these insights in the costs, but it is still challenging to create accountability and ownership among the crews. It still is a little like, we get the vessel from IJmuiden, so to speak, and they continue going on about all kind of thing we have or don’t have to do half of the time, and hey, that’s fine and all, we get that, but then there isn’t any great accountability to say, hey, this can’t really make ends meet, ...

A: No.

T: This all does cost a lot more money than it, eh, costs, eh, than the gains that are achieved.

A: Yes.

T: He, and we’d also like to see some more activities, also at the rescue stations, when it comes to fundraising. And that should be possible, on many accounts. And eh, on that topic, people are saying: ”Hey, but you never asked! So eh, well, I really like to do what I do, but I could also start a shipping community in the area, asking local small and medium sized enterprises like 1000 euro’s or something, say in exchange for a trip with the management team and using the station facilities for a meeting. Very well, I’d like to do that!” And if there’s like ten or twenty of them, we’d generate let’s say, €20.000,-. And a better understanding with the local community.

A: Yes.

T: Who would also enjoy its presence, saying, well, I wouldn’t call it, in any case, I wouldn’t reject it. Times 45 rescue stations, I’d have collected something close to 1 million ...

A: In that way, the gap would be closed in no time!

T: Well yes, as a matter of speaking.

A: I thought it would be something like that.

T: But of course I’d have to ... yes, it’s somewhat around €2,5m, depending on many factors, but let’s say it’s €3m, for practical purposes which I have to, which I am short. But with that, I will have to get out there with these plans. Announce that this will be the direction of travel. And see with the crews. I mean it’s not that if you don’t want to raise funds, you all of a sudden have to do it, no. But amongst the 25 people there, and a local commission, chances are that there is someone who’ll say: ”Sure, I’d love to!” But well ...

A: To trigger the right person, ...

T: Yes.

A: And the local commission that is there ... , yes.

T: And there may be stations that absolutely don’t want to do it, while others will raise €50k instead. Well, that would also compensate it.

A: Yes.

T: So it doesn’t need to be real strict. But well, also when it comes to sustainability, this is a theme. You may say, well, we’ll not sail as fast any more, because that is not sustainable, it consumes a lot of fuel, a lot of issues, black smoke, carbondioxide, noise and so on ...

A: ... And you’re not really that much earlier. No.

T: And that much earlier, no, but if you could say, well yes, it leads to a totally different ships handling, we really have to exercise at this speed, for ships handling. But nobody told me it’s like that.

A: Well, I can imagine you’d have to do so occasionally, but surely not always and under every circumstance.

T: With call-outs, you would of course, because time is, risk of survival.

A: Yes.

T: But you’d have experience with that as well. But well.

A: Yes.

T: We’d quickly agree that that would reduce ...

A: Yes, well, we have been discussing objectivity in decision making earlier ...

T: Yes.

A: ... and for you, that’d entail asking critical questions and demanding thorough srgumentations ...

T: Yes.

A: ... as to why one holds a certain opinion. Then there is also objectivity in, in the sense of weighting arguments, in determining what the relative importance of certain criteria is.

T: Yes, very well.

A: ... And not saying this aspect is so important, as with safety, I understand, let's put that aside for now ...

T: Yes. Say with money, costs.

A: Yes, costs versus sustainability.

T: Yes.

A: How are you going to determine that on one occasion, you'd let one argument weigh in heavier, while in another occasion, it would be the other way around?

T: Yes, so my opt-out, but I, I would say, ehm, I would try to compensate the increase in costs by raising additional funds, specifically to achieve this aim. So I won't go to the Dorus Rijkersfund and say, every year you're donating me €250k, would you like to support our sustainability aims this year? Because then I wouldn't be able to use it for other things. That doesn't gain me anything and the additional costs remain, ehm, so, that is my opt-out. Where I am saying, no, we are, we need to raise additional funds anyway, try to find sources that are specifically aimed at that goal. Or family offices, wealthy people that have earned a lot of money, who wouldn't even notice it. But currently we don't have them. It may sound easy, but if we'd do it together, within our own network, we'd stand a chance. Which would cancel part of the costs, which would allow me to do it! Because I want to, for the sake of safety, health, and for our own contribution and reputation as an organisation.

A: Yes.

T: And I named it as one of the four strategic themes. So, when I'll communicate this - as I haven't done yet - it will be impossible to misunderstand for anyone. When I'll communicate that sustainability is amongst the this we consider to be important. So, the next time you mention in Harlingen, hey guys, can we slow down a little, haven't you seen the KNRMs presentation on the four strategic themes? It's all about people, safety, quality of the process and it's about sustainability.

A: Yes.

T: So, in my opinion, on these three items, it's all good, but when it comes to sustainability, there's a lot of room for improvement, when you always go full speed.

A: Yes.

T: Then you'll at least have an angle, it's not like ...

A: Then you'll have some sort of back-up at hand ...

T: It allows you to say, well, we agreed on that right? And if they would totally disagree ... Ok, so it doesn't matter that those trees are dying and the sea level is rising, that is all conspiracy. You'll always have some Trumpian Boris Johnson-characters remaining who'd all that ... But hopefully there's also a majority who'd ...

A: Who would support it, yes.

T: Yes, that are is a group who'd say, well, yes, no, perhaps when it's not really necessary ...

A: It tends to be the silent majority who'd indeed ...

T: Yes.

A: But aside from that, eh ...

T: You see, it's what you get with Corona[10], Doeksen[11] is also about to operate Liquified Natural Gas (LNG) catamarans.

A: That seems to be a totally different story, they could write a book on that too ..

T: Really? I wouldn't know. I only heard they are about to start operating it.

A: This friday [3rd of July] they have planned the first departure [with passengers on board] and we have some Doeksen employees in our crew ...

T: Yes.

A: And some of them avoid to be on duty this friday.

T: No? Because?

A: Because of the trouble they had leading up to this, which leads to doubts on the trustworthiness of the propulsion.

T: Yes.

A: They already had to shut down half way, drop anchor and await tugs and they are saying, what if this would happen with all these guests on board, they would be terrified.

T: But this is supposed to be proven technology right? Or isn't it? Would you say well, it's a little more complicated than they thought?

[10] The COVID-19 virus disease.

[11] The firm operating the ferry service between Harlingen and the islands of Vlieland and Terschelling.

A: Ehm, It's proven technology alright, I would say so. It's just, it was constructed by the lowest bidder, which resulted in a poor build quality.

T: Yes, so I've heard.

A: They cut some corners to save money, which resulted ...

T: Yes, there has been conflict with Vietnam, I've heard that too, through Gerard.

A: Ok.

T: One of the captains there, who supervises the project. He also mentioned problems with the responsibilities, in who was responsible for what.

A: Yes, that, and the building quality was so poor, that during transportation ...

T: ... it sustains damage.

A: Yes, which resulted in an additional year of repairs before ...

T: Right.

A: Yes, ehm. Ok. So financial aspects could be isolated, by the opt-out.

T: Yes, given that that ...

A: Yes. but I still have yet another ... To really achieve this objective balance, for instance, eh, there is a project that is very sustainable, really contributes to those sustainability principles, but which would require all volunteers to undergo additional education, of which we know, would cost a lot of time, they don't want to, they even dread it, as the subject doesn't interest them, eh, yeah, so there is a balance, a trade-off. How ...

T: Yes, that I learned with the KNRM, I have to pay attention to that, because otherwise I'd get so much resistance, I can't overcome. So, when it comes to that, I'd say it's voluntary, but not without obligation. But I'd also have to, choose my battles. I'd rather have people to consider this a good development along with me ...

A: Yes.

T: ... rather than enforce it.

A: Yes.

T: That wouldn't do me any good. It would cost me much more teime ...

A: Yes.

T: ... and in the end, my effectiveness would be hampered. That doesn't mean that if volunteers would organise themselves will, nothing would happen. Because I wouldn't quit just like that, of course. But, that they, small steps at a time.

A: Yes.

T: So, that is in respect to the fleet plan, that is in respect to the integration of two stations that may merge, which would make sense, but the people so badly oppose it, from many historical battlegrounds, that, well, let it be. It doesn't benefit me that much. While in a profit maximising organisation you would say yes. I saw that at Shell, with refineries, in Denmark one had to be shut down, which was profitable ever since its inception. So, they'd ask, why should I shut down? Well, it's in the interest of Shell at large. And such an outlier, even although it makes money, eh well, induces additional costs. Yes, so that isn't fun for those who'd lose their job ...

A: No, no.

T: ... and don't understand they contribute. Well, as you with Tata, there the same battles are likely to take place. I'm not in such an environment, eh. I'm may be short on money, but I didn't get assigned to, well, solve that within three years. I did say that I intend to solve it. And that is why I choode to increase fundraising and control spending. Do you see what I mean? So, ehm, choose my battles.

A: Choose your battles, yes.

T: Would apply in this case.

A: Yes. So, its really depending on what criteria you compare. And in this case we consciously take two criteria apart for comparison, with two criteria on the sideline.

T: Yes.

A: How would you judge the increasing complexity in ...

T: Yes.

A: ... there being ever more criteria that one way or the other have an influence on ...

T: Well yes, that is what we are going to change, what we will, so to say, modernise. So ehm, I can imagine that I'd have to row upstream when it comes to sustainability, if I think like, yes, there is some resistance, but yes, this is baseless. But if you analyse the Doeksen case, it does have a foundation. Yes, I do have to pay attention not enforcing something that doesn't work.

A: No.

T: Just for the sake of enforcing. Eh, but, also in respect to, so to say, the alternative case, the commercial salvage case, the quarrels on the water, yes, I try to say, in conversation with the Coastguard Netherlands and some of the salvage companies, ok, we are not there for someone who has engine trouble and is completely safe otherwise. That isn't my job. I'm here to save people, and to rescue in order to prevent worse. Ehm, so, I'm not for mere assistance.

A: No.

T: And if I would provide assistance, it needs to be payed, for instance. Well, there will be many volunteers having an opinion on that, depending on which crew they belong to, Hindeloopen, Harlingen or Lelystad ... I don't know how much you know about this case, but I now know far more than I ever wanted to know ...

[Laughter]

T: Eh, so, not everybody will applaud it, if we introduce policy on that. But well, we have to continue on one or another. We have to chose a course in this matter ...

A: Yes.

T: ... so, eh, that is why, if I'd also enforce this engine and the flashing light is also inside out and upside down, than, at a given point people will say, not so much, handing in their pager and quitting, but it's more like that they can't keep up. They don't enjoy it any longer, so to say.

A: That's right.

T: So, I have to keep an eye on that.

A: Yes.

T: And of course, I could say well, old generation out, new generation in. That could be done, I believe it is, but do I want ...

A: Would I want that? Yes ...

T: ... for which benefit, you know? In the end?

A: Why would you do that to people ...

T: Well, yes, indeed. In that case, it'd be better to ...

A: ... who have gradually ... yes ...

T: ... start driving an electric car and in my strategy address sustainability. To show people in what direction we're heading.

A: Yes.

T: You understand?

A: Yes, I get it. And in order to, all those criteria aligned. But them , I still have a feeling that in many cases you are arguing from a certain narrative and in every plan, try to identify where the issues are. Without ...

T: Yes. So I clearly state the flag on the horizon, the destination, what do we try to achieve. All agreed? Yes? Ok, then we can, all together, start moving in that direction.

A: Yes.

T: Because we already know where we're heading.

A: Yes.

T: And from there, we'll take on the individual battles, depending on the potential benefits, eh.

A: The benefits, and the expected costs [resistance].

T: If the benefits in terms of sustainability is huge, yes, then I think I should be convincing. In the directing of the volunteers, saying eh, this truly is a good plan!

A: Yes. So the costs should be viewed in a much broader sense than just money, it also involves volunteers' motivation and ... or ...

T: Yes. But if people say that it's unsafe, then I'm directly 0-1 down. If I then say I can counter that argument, it is safe. Yes,s but it doesn't go as fast. Ok, so lets take the example of reducing speed. Well, I think, I should be able to achieve that, that can't be ...

A: No.

T: ... people just don't do it.

A: Yes.

T: There just isn't a single argument, other than, occasionally we all need to train at full speed. Well, once you've done that. And then back to normal, during training situations. And that entails, up to 25 ... and then we'd save half of the fuel expenses. On a yearly basis. That would be €30k. Just a number.

Or in Harlingen only €5k. That's a huge amount of money. Or are you going to chip in the additional money individually ...

A: Look at this ...

T: ... here in Harlingen we can go full speed all year, as here is €5k. Then you can still say, ok, that is financially settled. But all those ducks that have died because of the pollution, or I'd know what. That's still a shame.

A: Should you have to raise that in additional donors who all donate €60,- a year, eh ...

T: Indeed, see, but then you'd still only have compensated it financially. But then you'd only have my last argument, then there is also reputation and that we as an organisation want to be sustainable. We don't consciously want to create dirty exhaust fumes and noise? And then we still have the safety and health of our own crews who are standing outside on deck and are breathing in these fumes, for the sake of the speed. Then you can still argue, well, what a bullshit, I'm not breathing in anything, because there is all fresh air around me and those fumes are coming out behind me. Fine, then that is not much of argument. But then remains, what is my contribution as an organisation.

A: Yes.

T: Yes, but what does it achieve compared to that other guy who is doing this and that, still running on fuel oil ...

A: You can always find examples who ... who do far worse than you.

T: Yes. And then I can even say, we are going to look for sustainability champions, in every lifeboat station I'm going to solicit a number of people who are going to support me with that. Who'd say, hey, shut up for a minute, let's close the windows when the heater is on full capacity. Well, and like that, shouldn't we go a little slower and like that ... you see ...

A: Yes.

T: ... we are trying to head in s certain direction without having to resort to writing it all down in rules, regulations and instructions.

A: Yes, on that we can also ...

T: I think we're slowly running out of time.

A: Eh ... Eh, yes, I have a rather more specific question, what is your take on on the usage of aids or tools to balance criteria against each other? Eh, a specific example we use at the university, is the usage of decision matrices in which you detail what criteria you will use for assay, and their respective weights, lets say because I think ...

T: Important.

A: ... the safety criterion far more important than any other weight. And then I'll see how ...

T: Yes.

A: ... a specific project scores on each criterion, allowing me to say, well, if I'd be able to improve the score of this project on this criterion, this would clearly be the best option to go for. Or, I expect this score to develop in a certain direction in the near future. How would you reflect on the usage ...

T: Well, positive. I think it can be useful, as long as it's a keep-it-simple-stupid ...

A: Yes.

T: ... kind of way, so it doesn't induce a discussion on the matrix itself.

A: Yes.

T: That you know, the matrix produces a certain outcome, but then we are going to discuss the matrix, arguing it isn't right in the first place.

A: Ok.

T: So, as a tool, as support, as an aid ...

A: Yes.

T: ... very good, I think it'll help. Because ... but, again, the condition is that it is understandable.

A: Yes, I am indeed looking at a very simple and transparent model I'd like to show ...

T: Yes.

A: ... in a later stage of this research. But, eh, speaking of discussion, ... discussion is of course, can also be useful, to identify certain issues.

T: Yes.

A: Or to invoke some discussion ... if the matrix produces a certain value which is contrary to ones gut feeling or beliefs ...

T: No.

A: ... to use the matrix to identify where this comes from.

T: How does that came to be? Yes, absolutely. But, as I mentioned earlier, we were to have an Atlantic 85 from the RNLI to practise with, to assay. Well, that would have to be transported to different stations and the technological department was only saying they were too busy, we have far too much work. Well, I hear what you are saying, in that case we'd have to prioritise. So, well, let me help you with that, make me a list ... Yes, no, good idea. But I say, the first thing to drop is the Atlantic 85. Because it is, as I already mentioned, what are you going to practise? What are you going to test? If it goes fast enough? If it capsizes? You'd require a testing protocol, right? You're not going to just say, eh, this is nice! Great! In relation to what? In relation to the 75? Or in relation to a speed requirement, turning requirement, towing requirement, vibration limitations and so on. Well, they'd look at me like, oh, testing protocol? Why would we need that? So to speak ... While for me that is ... and I am not an engineer at all ...

A: No.

T: But that is some sort of a minimal requirement.

A: Yes.

T: So that if you are to test something ... And that you are going to prioritise, you are going to say, well, this is nice to have, and we don't have time for this at the moment. First of all, we need to make sure the lifeboats we have are serviced and that entails we are not going to test the Atlantic 85 right now.

A: But if you see that the effort required for upkeep of these lifeboats is increasing exponentially in time ...

T: Yes.

A: Yes, if you then never take the step to search for something new and innovative ...

T: ... innovate ... No, I absolutely agree.

A: You get stuck on the curve

T: And then you never get ... Its the same with computers. If you never learn how to do it, you never get over the hurdle to invest. That is another argument. What I was about to say, a matrix or a test protocol, neither comes naturally to this organisation, you see, to ... because it feels like a rigid thing, enforcing something on you. It doesn't allow you to say neh .. I just don't like it.

A: Yes.

T: That is, as of now ... And maybe even, that gut feeling, may be very well developed here, as there are many people here who have worked with rescue vessels for many years, with volunteers and all of that. But I would like to see that translated into some kind of data.

A: Yes, that, and you can of course also say, I include it, can you attach a number to it, would you consider it an eight or a nine ...

T: Yes.

A: ... and then we put it ...

T: Yes

A: ... in context with other criteria.

T: Exactly.

A: And then ...

T: And then ... But there .. That is a hurdle. For many people, what a rubbish. And then I'd have to fill out another list ... I'm telling you, its good or no good. Yes, so you are saying good or no good, and somebody else is saying good or no good, and he saying ... Like that, I won't be able to decide.

A: No.

T: And then I'm not able to move forward. Eh, like that, there never will be a new rescue vessel design, because it just doesn't work. Someone wants it this way, somebody else that. Somebody wants it enclosed, the other open. And a stretcher, a lifting installation for drowning people and so many opinions and stories. It must have this displacement, this length, this width ... Yes, then I can't accommodate it all. And then we're also going to ask the volunteers for their opinion. And they're also saying, hey, I told you what I want? And now something totally different emerges? ... Yes, but it isn't like that. I'm not asking you what should happen, I'm asking you for your opinion. And, well ...

A: You're looking for smart things people have experienced, learnt, that have much more value to incorporate in the design ...

T: Yes.

A: ... rather than an all inclusive design.

T: Yes.

A: Originating from many people ...
T: Yes, and in the end I have to built a vessel.
A: Yes.
T: So yes, it won't match everybodies vision. Ok, I put my hand up. But is it better? Yes ...
A: Yes.
T: ... yes. Well, great, another step forward. Nice.
A: Yes.
T: Very good. Well done.
A: That were the questions I had. Yes, so I'd like to finish with a small recap. So the strategy is built on three [pillars] ... eh ... Sustainability in a strategic perspective, first of all for the crews ...
T: Yes.
A: Safety and health of the crews. And secondly, because of the role of the organisation within society and within the Maritime ecosystem.
T: The ecosystem, very good.
A: And finally towards the donors and the society at large, the image of ...
T: Yes.
A: ... the organisation.
T: The reputation, and also as it is a trend, more and more people expect you to be sustainable ... eh .. Yes, that is ...
A: Yes.
T: Yes, very well.
A: Eh, and then in the end we briefly discussed the usage of tools. Ehm, I would like to ask one additional question. If the tool can also contribute to transparency and accountability ...
T: Yes.
A: ... Showing how a certain choice came to be, ...
T: Yes.
A: ... as it has ...
T: Yes.
A: Do you see added value in that?
T: Yes, absolutely, no, absolutly.
A: Yes.
T: As long as it isn't a black box.
A: No, ...
T: It should be comprehensible what the matrix says.
A: Yes. Otherwise, it wouldn't be transparent.
T: Yes, so I would hand it over to Wouter and out-of-the-blue a score appears.
A: Yes. But if you don't understand what the matrix says ...
T: Exactly, and very complicated.
A: ... it wouldn't be transparent. No.
T: No. So, explainable, just like with investments and things like that, it should be comprehensible.
A: Yes.
T: Not like hedgefunds, with I know what ...
A: Derivatives ...
T: Yes. Obscure structures, resulting in not knowing what mortgage you have invested in in the end. And as it turns out you invested in a small home for someone in Mississippi, while you reckoned to have invested in a mortgage in the Netherlands. Then, yes, that is not clever.
A: No.
T: We wouldn't want that
A: Clear.
T: Good.
A: Yes. Thank you very much for your time!

B

Initial interview with the CTO

This transcript denotes what was being said during the interview between the author (A) and mr. Gert-Jan Wijker (W), Chief Technology Officer (CTO) of the KNRM on the 23^{rd} of July 2020, which lasted approximately three hours, of which one hour has been recorded. The interview was held in Dutch, a translation can be made available by the author upon request.

A: De voorbeelden illustreerden het al hoor, maar wat, wat, hoe zie jij het strategisch belang om te verduurzamen? Wat brengt het de KNRM, wat we nu nog niet hebben? Of hoe kunnen we er beter van worden? Het is dus als thema aangegeven van de KNRM wil verduurzamen. Wat gaat het de KNRM opleveren als je het doet, ja

W: Nou, ten eerste is het natuurlijk wel het KNRM brand print markering, dat we een groene uitstraling krijgen … ehm … Tevens levert het ook, wat ik net al zei, is dat het de mindset dat het naar groen overgaat, is een hele andere uitstraling naar de buitenwereld. Dus de toekomstige sponsors of donateurs kunnen daar, eh, ja, kunnen zich daarin zich mee verenigen met die gedachtegoed. Wat ik al zei, van de nieuwe generaties denken groen en gaan ook groen doen en ik denk dat het, eh, ook mensen stimuleert als organisaties als de KNRM zich ook eh milieutechnisch of ja, hoe noem je dat, eh, milieubewuster met het equipment omgaan. Dus dat is eigenlijk, eh …

A: Dus het zit in de mindset intern en het zit in de uitstraling naar donateurs, naar de buitenwereld toe?

W: Ja, precies ja, dat wat ik al zei, is dat de hele nieuwe generaties die nu opkomen die zijn al met duurzaamheid bezig en groen en om dat ook te stimuleren, gaat die groep groeien. He, wat betekent dat wij meer aanhang krijgen met de groene gedachte hierachter zit. En de mindset bedoel ik eigenlijk de mindset die zich binnen de KNRM, dat mensen zich moeten bewust worden dat we naar groen moeten overschakelen. En niet nu, het liefst gisteren eigenlijk …

A: Ja.

W: En dat is het een gedachtegoed dat heel veel aandacht nodig heeft. Ja … Het even goed formuleren … ehm … In de mindset en het draagvlak vanuit de mensen … ehm … Hoe denk je, wat kan daarin helpen om dat tot stand te brengen? Nou wat ik net, wat ik net al aangaf ben heel bezig met die, met die alternatieve brandstoffen …

A: Ja.

W: … Is mensen bekend maken met presentaties wat alternatieve brandstoffen zijn, wat doen, wat is de impact van de alternatieve brandstoffen he. Want er zitten heel veel vooroordelen aan alternatieve brandstoffen, van het is verkeerd, dat geeft slijtage, het werkt niet mee, eh, ik denk dat we de mindset die bij de mensen gecreëerd wordt, door de bewustwording groter te maken is dat het wel hetzelfde effect heeft als de oude minerale brandstoffen. En misschien zijn ze wel beter.

A: Dus het uitleggen, en wegnemen van vooroordelen?

W: Ja, aannames, vooroordelen. He, ik ben nu bezig met die alternatieve brandstoffen en het eerste wat ik dus, als ik zeg in de technische dienst van, he, jongens we gaan naar HVO, het eerst wat wordt gezegd, is dat weet ik niet, de motoren stop, gaan stuk, eh, alleen maar problemen. Dus mensen zien heel veel problemen erop, in plaats van de oplossingen ervoor. De mindset moet eigenlijk zo zijn, dat is goed, hoe kunnen we de problemen die voor kunnen komen, ja, ons voorbereiden, he, om die

problemen weg te nemen en hoe gaan we die , eh, eh, hoe gaan we dat opvangen dat aanpakken, in plaats van defensief …

A: Ja.

W: He, kijk, je hebt natuurlijk in de denkwijze, dat is hier wel grappig, is dat, je hebt een DAD denkwijze, of een triple D denkwijze, is dat decide, announce, defend, he, dat is dus een werkwijze. In projectmanagement ook he, het is meer van, je moet meer naar develop, distill, discuss omgeving gaan, dat mensen dus meer vooruit kijken en de problemen identificeren en dan de vraag stellen van hé hoe gaan we die problemen oplossen, in plaats van, ik ga niet zeggen hakken in het zand. Ja, eigenlijk wel, het is hakken in het zand en laten zoals het is. Want zo kom je niet met ontwikkeling, verder.

A: Nee, nee, nee …

W: En dat speelt heel erg, die ontwikkeling, he, dus ja, Daarom ben ik dus ook met die brandstof, de brandstofleverancier gevraagd van he, heb je meer documentatie, een keer een presentatie geven. Dus alleen maar om die vooroordelen weg te nemen en de mensen zo te beïnvloedden, dat ze dat gaan dragen en dat ze dus soort ambassadeur zijn om dat binnen de organisatie te dragen, maar ook buiten de organisatie te dragen. Die milieubewustheid

A: Dus ja, develop distill en …

W: Discuss.

A: Discuss. Ja, zodat mensen uiteindelijk ambassadeur worden van van de oplossing.

W: Ja, ja, en dat je dus meer draagkracht creëert en meer mensen creëert in een creatieve mindset om alternatieve brandstoffen te omarmen of milieutechnisch te gaan denken. En meer, veel meer, de mindset krijgen van dat we daar mee bezig moeten zijn.

A: Ja.

W: Dat is dat is wat ik al zei, van, het defend, hakken in het zand geven, ja, is een manier van coaching zeg maar, dus eh, maar goed dat is eh, dat is een uitdaging …

A: Dat gaat niet van de ene dag op de andere dag …

W: Nee, nee, dat eh, dat eh, dat is dat is de grootste uitdaging, ja.

A: Een understatement. Ja.

W: Je hebt hier niet een groep mensen die zeggen van, goh, wat leuk, zeg he, daar gaan we ons op inleven, en daar gaan we mee aan de gang om te kijken of we het kunnen realiseren. En dat is natuurlijk het grappige met, wat ik al zei, met die Ruud Bakker, ja, als je daar iets hebt, dan zie je het enthousiasme, en die ziet, ja, de toekomst, of eh, die ziet, die ziet er toekomst in om op alternatieve manieren, eh, producten te ontwikkelen, zodat wij het milieu minder belasten. En, en, en, dat is ook mindset.

A: Ja.

W: En dat het niet allemaal lukt, dat geeft niet. Maar als er, als we er wel naartoe willen streven, dan vind je op een gegeven ogenblik wel een manier om daar naartoe te komen, of een oplossing komt er naar buiten. Want ja, dat is de, de, de ontwikkeling die je moet hebben …

A: Ja.

W: … binnen de organisatie. Dat is een eh, leuke uitdaging.

A: Ja. Eh, tweede vraag die ik heb. Wat verstaat u onder duurzaamheid? En dan, ja, duurzaamheid is in de wetenschap natuurlijk heel veel over eh gesproken, ook heel veel definities van, maar, ja, wat wat betekent het voor jou specifiek?

W: Een goeie vraag is dat. En wel een moeilijke vraag, geen moeilijke vraag. Duurzaamheid eh, wat ik net al persoonlijk zei eh, is dat wij, eh, de producten en de manier hoe wij leven, zo moeten inrichten dat het minder belastend is voor het milieu, omdat er een betere balans is in die omgeving.

A: Specifiek het milieu-element wat jij er …

W: Ja.

A: … in terugziet.

W: Ja, dat, als we het milieu sparen, he, en we weten om daar een mode in te vinden om het milieu minder te belasten …

A: Ja.

W: In de route daar naartoe komt men best wel op andere alternatieve duurzame technieken of, om onszelf te beschermen tegen schadelijke invloeden van equipment.

A: Ja.

W: He, trillingen, geluid, he

A: Ja. En dat komt eigenlijk in de zoektocht …

W: Naja, kijk, weet je wat het is … dat is heel grappig dat dat, nu ben ik bezig geweest met die alternatieve brandstoffen te kijken …

A: Ja.

W: Dan nu komt er voor uit dat het minder schadelijk is voor het milieu. En tevens is het ook minder schadelijk voor de mens.

A: Ja.

W: De uitstoot eh, het produceert bij die eh, bij de verbranding van die brandstof, produceert minder geluid en minder trillen. Nou, dat betekent dat het ook voor, ARBO-technisch voor de mensen beter uitkomt.

A: Ja.

W: Dus als we het aantal dB(A) mee kunnen verminderen, is het alleen maar meegenomen.

A: Zeker.

W: Maar goed, dat zijn de studies die nu eh, met de brandstof is nu eh, die tonen dat theoretisch.

A: Ja.

W: En of dat ook werkelijk is, dat zal dan volgend jaar uitkomen. Bij de van Wijk-klasse is het wel zo dat, ehm, we gaan nu bouwen met de nieuwe van Wijk. Er zit een nieuwe dieselmotor in, en ehm, daar ga ik ook geluidsmetingen uitvoeren volgens de normering. Ik heb een specialist op geluid, ga ik inhuren om tijdens de paal proef trekproef het geluid goed vast te leggen, he, in elke bandbreedte, en dat gaan we eerst doen met de conventionele brandstof. En dan gaan wekijken of een HVO blend kijken of we daar ook geluidreductie van krijgen, en kunnen meten.

A: Ja.

W: Want dat is de basis en dat is eigenlijk niet om je gelijk te krijgen, nee, het is alleen te kijken van wat de brandstofleveranciers zeggen of dat ook zo is, of dat ook werkelijk van toepassing is op die boot. Het is een beetje een meetwaarden. En dat kunnen we dus ook weer als promotie geven, als dat zo is, kijk jongens, de originele brandstof geeft zoveel geluid, als we dit toepassen hebben we 5, 4 dB(A) reductie. Ik noem even een dwarsstraat. En, maar dan heb je dat wel aantoonbaar gemaakt.

A: Is het hard, ja.

W: En als je dat eenmaal in die cirkel zit, dan gaan mensen ook wel denken van oh, weet je wat het is, het heeft positieve effecten.

A: Ja.

W: Dat komt weer terug op die mindset.

A: Ja.

W: Dus …

[…]

A: Ehm ja, we hadden het net over de HVO als voorbeeld voor het minder belasten van het milieu, en een betere balans, en de positieve effecten, bij-effecten voor de mens. Ehm, dan wil ik de volgende stap maken, naar de projecten, en we hebben het er in het voorgesprek al een beetje over gehad, welke producten passen bij de KNRM? En waar zit voor de KNRM de grootste impact? Als ik het zo begrijp, zit dat duidelijk op de op de brandstof.

W: Het laaghangend fruit, wat we nu kunnen realiseren met de huidige vloot, is om milieu-technisch aan de norm te voldoen, of te kunnen voldoen, is dat we dus alternatieve brandstoffen kunnen toepassen in de hele vloot. En daarentegen, ehm, voor in de toekomst, moeten we kijken naar andere aandrijftechnieken, zoals ik al aangegeven heb, in dat haalbaarheidsonderzoek, van hoe kunnen we dus het materiaal, het nieuwe materiaal, op een nieuwe manier, transporteren van station naar de kustlijn? En dat gaat dus over de kustvoertuigen, zeg maar. En daar kunnen we zeggen van, we hebben, we delen in naar, de bestaande tractoren om te bouwen naar een elektrische aandrijving, of de trekkers helemaal weg te laten en dat we naar een volledige elektrisch aangedreven trekker gaan.

A: Ja.

W: Wat weer het effect heeft dat we een stuk minder materiaal hebben, dus een kostenbesparing, en ook een milieubesparing erop. En dat houdt in, dat we daar, ja, goed onderzoek naar moeten doen. En dat is dus wat op de lange termijn. Maar eh … Daar zit de grote impact en dat past bij de KNRM. In mijn visie wel …

A: Ja.

W: Maar dat is weer de terugkomen, van past ook in de gedachtegang van de mensen die op de stations zitten. Van, wordt het gedragen en willen we ermee werken. Want …

A: Ja.

W: … de tractor en trailercombinatie zijn ze gewend, en als je dan opeens naar een volledig elektrisch aangedreven bootvoertuig gaat, he, is een andere manier van lanceren, en met een ander gedrag moet daarop ingespeeld worden. En eh, dat is ook een leuke uitdaging.

A: Ja.

W: En we gaan bij de vlootvernieuwing, volgend jaar zal de eerste van Wijk dan te water gaan en daar komt ook een nieuwe trailer bij. En mijn wens is om dan een stand alone bootwagen te hebben op elektrische aandrijving.

A: Ja.

W: Zodat we dan geen tractor meer hoeven aan te schaffen. En eh, dat geeft een ander inzicht, maar goed, dat moet ook gedragen worden door de KNRM zelf. En dat wil ik onderbrengen, dat studietje, bij NCM, wat ik net al, van Ruud Bakker, om te kijken of dat haalbaar is, wat de kosten zijn, [13:30] want we hebben budget, daar lopen we ook tegenop. Want hoeveel geld hebben we geprojecteerd in het vlootvernieuwingsplan. Ik moet wel zeggen dat daar wel budget voor is meegenomen. Maar ik kan nog niet zien of wij hier ook een investeringskostenpost meenemen voor vernieuwing en innovatie.

A: Ok.

W: Dat heb ik nog niet kunnen zien.

A: Hmm.

W: Het is nog gebaseerd op oude brongegevens van de oude conventionele techniek. Maar dat is nu de de transitie waar we ook inzitten.

A: Ja. De transitie is nog in volle gang.

W: Ja. Want ik zal je zometeen, als ik die aanvraag doe. Want ik heb de aanvraag voor die boottrailer nu bij de oude leverancier aangevraagd, Roodberg, en dan krijgen we zometeen een prijs.

A: Ja.

W: En tevens stuur ik ook naar NCM, van moet je eens luisteren, dit is de huidige boottrailer, is het mogelijk om die stand-alone te maken, met een redundant power pack, …

A: Ja.

W: … en die vanaf de boot te bedienen is, maar ook vanaf het strand te bedienen is.

A: Ja.

W: Dus lanceren wordt de master, is dan de boot, de bemanning van de boot, dat ze kunnen lanceren. En terughalen door de bemanning aan de kant. En vice versa.

A: Ja.

W: Dus dat is operationeel dan een vernieuwing, zeg maar.

A: Ja. Ja. Interessant. Ja.

W: Maar goed, dat ga ik nog eventjes, dat zeg ik nu …

A: Ja.

W: … en die aanvraag heb ik nu lopen, die, bij NCM, of ze dat, of ze daar een kostenplaatje voor kunnen maken, van wat het ongeveer gaat zoeken, zo'n studie, en of het ook haalbaar is.

A: Ja.

W: En wat voor risico we daarbij lopen, met die nieuwe technieken. En als dat klaar is, dan wil ik dat wel presenteren naar de … is dit iets voor de nieuwe …

A: Ja. Je zou de gedachte inderdaad eens kunnen laten vallen op de stations en kijken wat voor reactie je krijgt van …

W: Ja, maar wat je krijgt is…

A: … heel voorzichtig natuurlijk te werk gaan.

W: Ja, maar dat is hier bij de KNRM wel zo, dat als je iets doet, moet het wel gevisualiseerd zijn. Mensen die kijken heel veel, zijn visueel ingesteld en of ze een plaatje zien wat de bedoeling is, en wat de kaders zijn van wat ermee bedoelt wordt, dan, dan is dat duidelijk. En meestal wordt een luchtballonnetje opgeblazen en iedereen gaat ermee aan de loop. En dat moeten we niet willen, want dat …

A: Nee. Dan worden de meningen ook niet op feiten gebaseerd.

W: Precies, ja.

A: Ja.

W: Maar goed, dat is een uitdaging, en ik weet niet of we dat gaan redden, maar dat is wel een persoonlijke doelstelling waar ik denk van he, daar kunnen we misschien wel wat mee, …

A: Ja.

W: … maar dat wordt nog niet gedragen binnen de organisatie.

A: Ok. Jammer, ja.

W: Ja, nee dat is zo.

A: Ja, ehm, het tweede deel van het interview wat ik eh, de vragen die ik heb opgeschreven gaan meer over de besluitvorming, over processen rondom de besluitvorming, van wij willen een nieuwe boot, een nieuwe van Wijk klasse, hoe loopt dan het traject? Waar komt de aanzet vandaan? Hoe komen de opties op tafel? Hoe gaan we besluiten over de opties, dat is een voornamelijk voor mij de kern, en ja, dan naar de uitvoering toe, hoe dat in zijn werk gaat? En je zit toch niet zo heel lang bij de KRNM, dus je hebt een verse blik op het proces. Ik ben wel benieuwd hoe jij het proces ziet, hoe jij de stappen daarin ziet.

W: Nou dat is … het grappige is dat we, dat we het hele proces ontwerp voor innovatie bestaat hier niet. En als je mensen gaat vragen, die hebben allemaal wel een mening, een eigen perspectieven erover, maar echt een proces, stappenplan, in een flowschema weergeven, bestaat niet. Hoe we nieuwbouw moeten, of tenminste, hoe we nieuwe projecten, in het leven moeten roepen.

A: Ok.

W: En … dat is, ik weet niet of ik dat mag zeggen, kan zeggen maar het is allemaal van we kijken wel waar het schip strandt mentaliteit hier en dat is schadelijk.

A: Ja.

W: En … dat moet wel komen. Want, wat je wel krijgt, als dat proces niet aanwezig is, hebben we ook geen afspraken gemaakt, hebben we geen kaders geschapen van wanneer pakken over en wanneer accepteren we dit nu. En dan loop ik nu best wel tegenop met een voorbeeld is dat het proces van de realisatie van van Wijk, dat zou dus eigenlijk in het proces flowschema zo beschreven moeten zijn. We gaan de startcondities creëren, de behoeftestelling van de bemanning. Als die behoeftestelling is gedaan, dan moet hij naar de technische dienst toe gaan, van de KNRM, om te zeggen van goh, wat voor techniek kunnen we daar invullen, dat betekent dat we behoefte en techniek redelijk in een raamwerk hebben staan, en dan moeten we eigenlijk extern gaan vragen

A: Mag ik je even onderbreken, sorry, je zegt behoeftestelling van de bemanning, zou je, als ik het zo hoor, de bemanning is vrij conventioneel in hun mening, dus die gaan uit van het bestaande, dus een behoeftestelling zal ook uitgaan van het kader en het bestaande wat ze hebben. Moet je daar al de lat hoger gaan leggen? Om te zeggen, we gaan die ambitie verhogen, of ga je echt zeggen van nee, we houden het eerst bij wat de bemanning vindt en daarna gaan we onder de motorkap …

W: Ja, ja, ja. En wat eigenlijk het proces he … Ik ga even uitleggen wat er nu gebeurd is …

A: Ja.

W: … dus ik heb een evaluatie gemaakt van de NH1816 en van de van Wijk en we gaan ook dus de nieuwe 1816 nieuw gaan bouwen, realiseren, binnen nu en anderhalf jaar. En wat ik nu aan het doen ben, is dat ik dat hele proces van start tot einde uit ga schrijven.

A: Ok, ja.

W: En dat betekent ook, van wat we hebben, is dat … ik moet even nadenken wat ik nu ga zeggen. Bij de van Wijk is dat best wel breed, te breed gedragen. Dus we hebben niet de juiste stakeholders gevraagd om in het proces mee te sturen. We hebben ook geen afspraken gemaakt bij de stakeholders. En wat ik gemerkt heb, is, we lopen allemaal hier te brullen van ik wil dit, ik wil zus, ik wil zo …

A: Ja.

W: En zo werkt dat niet. Je maakt afspraken, je krijgt huiswerk mee, en je geeft gedegen huiswerk terug, ja, en dat wordt beoordeeld. Dus, wat we nu, het plan de campagne, wat nu is opgezet, voor de nieuwe 1816, het proces flowschema zo gaan inrichten, dat we alleen de all weather stations gaan uitnodigen, twee ambassadeurs daarvan, en die krijgen dus duidelijke richtlijnen mee, en kaders, van wat wij nu willen van hun. En wij hebben de behoefte al opgesteld en zij kunnen dus gericht schrijven op de behoefte die wij nu al opgesteld hebben. En ik heb daar ook een procesplannetje voor gemaakt, een proces flowschema, hoe we dat gaan doen.

A: Ja.

W: En dat betekent eigenlijk, als een besluit is genomen over dat stukje, dan gaan we naar de volgende trede. We gaan niet eerder naar de volgende trede, als de eerste trede helemaal voor honderd procent is afgesloten …

A: Ja.

W: En zo bouw je structureel veel beter een case op. Want nu kom ik terug naar de van Wijk, we moeten iedereen meenemen in dat stappenplan maar we moeten ook, bij elke trede, moeten we dus

de achterban goed informeren.

A: Ja.

W: Ja, ik kwam binnen, toen was het bestek al geschreven, vanuit de KNRM, het bouwbestek, we hadden de aanvraag al gedaan, we hebben de offerte is binnengekomen, en opeens ga ik naar de raad van toezicht geef ik mijn rapportage wat onze bevindingen zijn en waar we op uitgekomen zijn. En wat bleek uit de raad van toezicht, van de commissie van veiligheid en techniek, is dat we twee meter voor de finishlijn, ja, de raad van toezicht zegt van ja, ik ben het niet eens met het bouwbestek. Dus ging ik terug naar nummer één, moesten we al die trappetjes weer opnieuw doen.

A: Ja.

W: Wat schadelijk is, in het hele proces, en ook juridisch gezien, is dat niet goed afgedekt. Dus dat is eigenlijk al een vraag van, wat gaat goed, wat gaat fout …

A: Ja.

W: … nou, die procesflow is ver te zoeken. Maar dat geldt dus voor, niet alleen de nieuwbouw, maar ook de innovatie, hoe pak je dat beet, welke afspraken maken we, wanneer is het, hoe gaan we dat aanvliegen, wat is een besluitmoment, van een yes of een no, of terug naar de tekentafel, dat is niet in, dat hebben we nog niet.

A: Ok.

W: Ik heb het wel op papier gezet, nu, maar dat is eh …

A: Nieuw.

W: Voor jou waarschijnlijk niet, voor mij ook niet, maar hier binnen de KNRM is dat eh …

A: Ja.

W: … de procesflow …

A: Ja.

W: … met duidelijke afspraken, decision points, hold points, als ik dat zo mag zeggen, is niet aanwezig.

A: Ok.

W: En dan, daarvoor maakt het ook heel erg moeilijk, als we iets willen hebben, …

A: Daarbij krijg je ook valse verwachtingen bij spelers die een bijdrage gevraagd wordt te leveren.

W: Ja. Maar je weet ook niet waar je staat.

A: Nee.

W: En dat is heel vreemd, als je zeg maar, in je stapjes, als je staat op trede twee en we komen niet naar trede drie om die en die reden, dan begrijpt iedereen dat. En die kan zich dat visualiseren. En nu weten we dat niet. Wat ik net al aangaf, …

A: Ja.

W: Ik denk dat ik alles heb gedaan, de verwachtingen van de raad van toezicht heb ingevuld, en ik stuur de documenten in, en opeens zegt, ik ben het niet eens met de bouwbeschrijving. Dat kan niet. In de grote, in de commerciële wereld daar wordt je kop eraf gehakt, als je doet.

A: Ja.

W: Dat kan niet, dat is schadelijk, dus. Maar dat geeft wel aan dat het onbekend is dat iedereen maar een beetje bekijkt, en op besluit gevoel, en hun mening, hun perspectief. En dat kan niet. En daarvoor moet je die afspraken maken, dat je op operationele gronden besluiten neemt, en beslissingen neemt om naar de volgende stap te nemen.

A: Ja. Dus het proces moet nog ingericht worden.

W: Ja, dat ...

A: En dat moet dus ook met kaders en afspraken …

W: Ja.

A: .. moet dat uiteindelijk beslag gaan krijgen.

W: Ja, vanmiddag heb ik, omdat dat niet bestaat, en wij wel een nieuwe boot moeten maken, wil ik niet dezelfde valkuil creëren, dus wat we nu gedaan hebben, ik heb voorgesteld om een externe man aan te trekken, en dat is dan, die gaat ons begeleiden in het proces, en dat is de methodiek scrum of aikido principe, en hij, tenminste, wat mijn inzicht is, ik heb een bepaald perspectief, en ik zoek eigenlijk iemand waar ik mee kan spiegelen, van he, hoe kunnen we dat het beste, dat proces kaderen …

A: Hmhmm.

W: … dat proces omschrijven, zodat, voordat we dat proces in gaan zetten, dat we eerst zeggen, jongens, dit zijn de stappen die we gaan nemen, en dit is de inrichting van elke stap.

A: Ja.

W: En dan is het duidelijk. En als we dat eenmaal hebben, zo'n processtappen …

A: Ja.

W: … dan kun je ook voor innovatie makkelijker toepassen …

A: Ja.

W: … want dan weten mensen gewoon, als dit iets is, dat het dan geen luchtballonnetje wordt, of misschien wel een luchtballonnetje wordt, maar dan …

A: Dan weten ze het.

W: … als we bij fase drie zitten, dan wordt het een realisatieproject.

A: Ja.

W: Dus dat proces. Dus dat eh …

A: Scrum is juist heel flexibel, en over de hele breedte van het project tegelijk werken. En aan de andere kant, het stapsgewijs werken, is veel meer een stage-gate, dat ga je dan combineren met elkaar.

W: Dat is, omdat we, dat is het hele punt. Kijk, waar ik vandaan kom, jij komt bij de Marine vandaan, ik kom bij de offshore vandaan. In de offshore, stage-gate of staircase, of trapjes is een heel gebruikelijke methodiek.

A: Ja.

W: We gaan pas verder naar de volgende fase als elke stakeholder, of ermee eens is, of klaar is, in de volgende fase te gaan. Nou, …

A: Ja.

W: … eerder ga je niet reageren. Dan moet je wachten, totdat iemand anders klaar is, de superintendent, met zijn werkzaamheden. En dan ga je naar de volgende fase toe in het project.

A: Ja.

W: Gebruik van de methodiek als mensen daaraan gewend zijn dan is dat heel makkelijk. Ook qua meetingen, heel concreet, rationele beslissing te nemen …

A: Ja. Ja zeker, ja.

W: … Management op exceptions, he, want wat gaat niet goed, ok, dat hebben we geïdentificeerd, hoe kunnen we het wel rechttrekken. Nou, dat is een flow. Maar hier hebben we te maken met een combinatie van mensen die heel … scrum willen toepassen, ze willen gehoord worden, ze willen feedback terugkrijgen, althans dat is het bestaande … Dus invloed op het project. En tevens wil ik de stage gate introduceren bij die mensen zodat ze gewend raken dat we, dat we stappen gaan maken in het project.

A: Dat er een streep in het zand staat en hier moeten we eerst gaan checken aan de hand van een aantal criteria voordat we verder gaan.

W: Ja, maar als we behaald hebben en we gaan naar de volgende stage, zeg maar, dat we niet meer terug kunnen naar stage one …

A: Ja.

W: … want die beslissing is genomen. Dan kun je wel zeggen, ok, goed bedankt voor je notitie, bij het volgende project nemen we dat mee als lessons learned, he, om dat te verbeteren. Maar het doosje is al gesloten in de eerste stap.

A: Ja.

W: Want anders verstoort dat, anders blijft je constant maar …

A: Ja. Er zijn ook mensen afhankelijk van de beslissingen die je op een gegeven moment moet nemen, daar zijn de mensen in de volgende fase afhankelijk van, om hun werk voor de volgende fase te kunnen doen.

W: Ja, oh, en ik probeer nu ook de stations te dwingen, dan, samen met scrum en aikido toe te passen, het is niet vrijblijvend, er zitten ook verplichtingen aan om in zo'n team te zitten om te kunnen bouwen naar een bepaald proces wat transparant is, en effectief, en dat we het doel bereiken, dat wij een hele goede Arie Visser of NH1816 op papier hebben staan, wat gedragen wordt door de hele organisatie, waar ook iedereen tevreden mee is, ja?

A: Ja.

W: Ja, en dat in de evaluatie staat, het is een hele goede boot, en de verbeterpunten zijn dit, die neem ik mee in de volgende boot. En niet de, wat ik net al probeerde aan te geven, weer terug te vallen naar bepaalde aspecten om de boot helemaal weer eh …

A: … van nul af aan te moeten beginnen.

W: Ja, nee, maar ook de mindset door te zeggen dit is een slechte boot, he, dat zie je bij de 1816. Als je gaat kijken naar de 1816 ontwikkelingsproces, heel veel stakeholders, heel veel besluitvorming, en niemand is tevreden over die boot. En dan zeg ik, dat vind ik toch vreemd in zo'n heel groot proces, hoe kan dat dan?

A: Ja.

W: He, er is een groep gehoord en er is een groep niet gehoord. Maar hoe krijg je die groepen nou bij elkaar. Nou, dat is dus, dat is mijn perspectief, dat we niet de goede stappen hebben genomen, hebben gesloten, voor we naar de volgende fase zouden gaan.

A: Ja.

W: Er stonden nog veel teveel punten open, die niet beantwoord werden, of opgelost zijn, he, maar wel doorgeschakeld naar de volgende fases. En dat zie je dus ook, dat het ontwerp, of de bijlboeg en andere dingen, is, of doorgedrukt, door autoriteit, dat kan, he, dat iemand zegt, ik wil dat hebben, principekwestie,

A: Ja.

W: … op zich niet verkeerd, want het proces moet gedragen worden door de hele …

A: Ja. Ja.

W: … door alle stakeholders, dat dat de beslissing is geweest, want zo draag je, als hij dan goed is of fout is, kun je wel zeggen van he, moet je eens luisteren, we hebben collectief toen dit besloten. En iedereen is erbij gehoord, en dat is ook ingevuld. En zo krijg je wel de beste, de beste boot. Oh, wacht even, maar zo krijg je wel het proces …

A: … het meeste draagvlak.

W: … het meeste draagvlak, maar ook, resulteert dat tot de boot die de meeste mensen willen hebben.

A: Ja.

W: En eh, nou goed, over het proces.

A: Ja.

W: Dat is een, al een hele interessante, deze, dus eh, met een nieuwe boot, wat ik al zei, vanmiddag gaan we het traject in gang zetten, hoe we dat verder gaan aanpakken.

A: Ja. … combinatie scrum/aikido en stage gate …

W: Ja, of dat allemaal wordt toegepast, dat volgt vanmiddag wel, daar gaan we dus over discussiëren van hoe gaan we nou het raamwerk, de paaltjes neerzetten, het kader, en hoe gaan we inhoudelijk nou het proces goed invullen, zodat wij tevreden zijn en andere mensen ook tevreden zijn.

A: Ja.

W: En dat we niet te veel invloed hebben op de buitenwereld, nee, ik zeg het verkeerd, dat tijdens het proces, dat de buitenstaanders geen invloed hebben op het proces.

A: Ja.

W: En dan bedoel ik de raad van toezicht, andere mensen met bepaalde heel sterke mening, of autoriteit.

A: Doordat je het proces hebt vastgelegd en afgekaderd …

W: Ja. Ja.

A: … dan is dat het proces. En binnen het proces kun je je ding doen, maar het proces is het proces.

W: Ja. Ja. Ja.

A: Ja.

W: Maar, dat is ook weer, eventjes terug dan naar stap een, die eerste stap is natuurlijk heel belangrijk, van, is het duidelijk bij de raad van toezicht, wat we gaan doen? Het kan best zo zijn dat mensen denken van, die 1816, daar gaan we er nog twee van bouwen, snap je? Dus dat moet ook heel duidelijk worden. Dus het perspectief, wat we, hoe we het gaan doen, dat moet in de basis beschreven zijn, en goedgekeurd worden door de raad van toezicht.

A: Ja.

W: Dat is het eerste, dat is eigenlijk stage one. Dat is om te voorkomen van, wat ik net al zei, bij van Wijk, dat ze zeiden van he, hier wist ik niks van af, hier nog eventjes weer ook mijn mening over geven. En dat geeft dan …

A: Bij alle interne spelers, als ik dat opschrijf, is dat dan juist? Het perspectief vooraf duidelijk bij alle interne spelers.

W: Ja.

A: Okee, helder verhaal.

W: Nou ja, ik kan het heel goed verkopen, alleen de uitvoering moet nog. Natuurlijk de executie is altijd wat lastiger.

A: Ja zeker, want je wil bezig met het ontwerpen van 1816 2.0, maar voordat je daaraan kan beginnen moet eerst het proces ingericht en afgekaderd worden, dus eigenlijk heb je nu twee stappen werk in plaats van alleen maar met de boot bezig. Maar uiteindelijk gaat de eerste stap je wel helpen in de tweede stap.

W: Ja. Als je je fundatie goed hebt staan, we hebben, dit is het budget, dit is het ontwerpbudget, dit is de boot die wij gaan ontwerpen, dus dit doet de KNRM alleen, met bepaalde mensen, en in de omgeving, die hebben ook invloed op ons proces, dat staat ook in de evaluatie. Het moet wel helder zijn, bij de raad van toezicht.

A: Ja.

W: Voor hetzelfde geld, is er in de raad van toezicht iemand die weer een linkje heeft met een ander kopstuk binnen de Nederlandse scheepvaart die zegt van ja, eh, weet je wat het is, kun je nog even bij memo'tje Damen, bijlboeg, prachtig, dit en dat, en opeens wordt het proces van de KNRM boot overgenomen door een buitenstaander met een, met iets wat door bobo's wordt …

A: … wordt opgelegd …

W: … wordt opgelegd ja, maar zijn onze eigen doelen uit het zicht geraakt. Want wat het meest belangrijk is, is dat …

[intermezzo]

A: Ja. We hebben het dus gehad over de stage gate proces. Het stage gate proces en de lijn, de lijn die je overgaat. Wil je daarin eigenlijk vooraf criteria vastleggen, nou ja, waarvan je gaat zeggen, als we dit, of ja, we gaan hierop toetsen, wat het beste ontwerp is? En aan de hand daarvan gaan we door. Of, of, hoe zie jij de criteria om door te gaan naar de volgende stap?

W: Ik heb het procesje hier uitgeschreven.

A: Ja.

W: Het is heel simpel, is dat we …

[intermezzo, looking up a file, which is also shown in figure B.1]

W: Dit is de eerste opzet die ik gemaakt heb is dat, we gaan starten met de naam NH1816#2. Dan gaan we eerst de functionele stafeisen opzetten, die is gedaan. Dan doen we een brainstormsessie met all weather stations, OD, TD. Dan gaan we de ideeën die we hebben, gaan we verwerken en afronden, om te kijken van kunnen we dat collectief verzamelen. Met die ideeën gaan we engineering uitbesteden om een prototype op papier te zetten, dus dat is eigenlijk van hoe komt, wat is de vormgeving van die boot, he, want iedereen zegt, ik wil een bijlboeg, of ik wil een Arie Visserboeg, of ik wil een andere romp. Nou, uit die criteria gaan wij zeggen van nou goed, uit de scrumsessie komt wel automatisch naar voren wat voor bodem ze willen hebben, wat voor romp, wat voor een boegtype ze willen hebben. Nou, en dan gaan we dus verschillende, op basis van die informatie gaan we dus modellen maken. Die modellen, die gaan we dan dus weer terugsturen van he, even kijken, is dat goed? Dan gaan we hier naar beneden, dus succesvol prototype all weather stations, dus dan gaan dus eigenlijk weer met een sessie gaan we dus met die mensen dus de dialoog voeren, dus dit zijn de ontwerpen, kunnen jullie hiermee leven? Ja/nee. Nee, nou goed, dan krijg je weer, is het herstelbaar, het probleem, of de discussie?

A: Hmhmm.

W: Ja? Dan gaan we weer verder met het uitwerken van het commentaar van het prototype.

A: Ja.

W: Ja, dan ga je weer die sessie doen.

A: En hierin zouden dus eventueel meerdere prototypes naast elkaar kunnen bestaan?

W: Ja, maar …

A: Dus we hebben oplossing een, oplossing twee, oplossing drie …

W: Ja. Maar op een gegeven ogenblik moet je keuzes maken.

A: Ja.

W: Om het proces te maken, moet je dus …

A: Ja.

W: … zeggen van, en dat is dus het moeilijke in die prototypes …

A: Ja.

W: … waar je dus de hoofdkenmerken van de scrumsessies of van de aikidosessies proberen te verwoorden in tien specifieke kenmerken. Die, want dat is eigenlijk je primaire informatie wat je wil

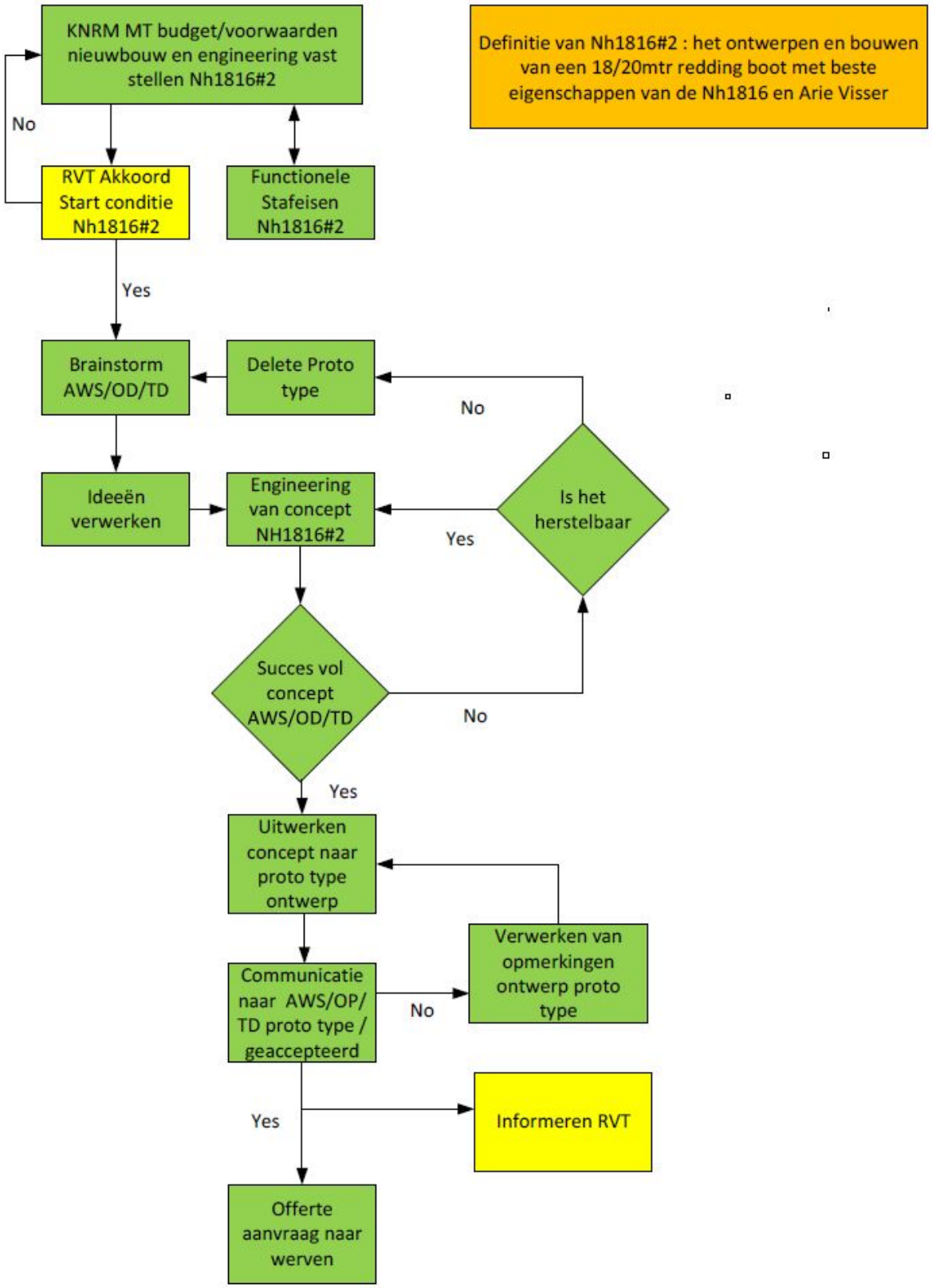


Figure B.1: The concept of the process flow that was discussed during the interview with the CTO.

hebben. Waar moet die boot aan voldoen? Nou, hij moet blijven drijven, hij moet een bumper hebben …

A: Ja.

W: … hij heeft die boeg, ja. En, uit dit proces, uit dit cirkeltje, dus dat van succesvol prototype, …

A: Ja.

W: … gaan we dus besluiten, wordt een besluitvorming gemaakt, van, we kiezen optie B. He, het wordt optie B, met misschien wel een eigenschap van prototype A bijgevoegd.

A: Ja.

W: Dan krijg je dus …

A: Ja.

W: … eigenlijk hier …

A: Ja.

W: … dus de gemeenschappelijke deler van …

A: Dus je wil hier echt al terug naar een prototype, je zegt niet van, we beginnen met tien, en daarvan vinden we zeven inferieur en die laatste drie die liggen redelijk dicht bij elkaar als we het bekijken op de primaire parameters en dan gaan we in stap twee of stap drie gaan we een keer die keuze maken, omdat we daar, de een heeft voordeel een, daar kunnen we misschien, ik noem maar wat, waterstof in toepassen, de andere …

W: Nee, zover zijn we nog niet. Nee, dit is echt, dit stukje, he, TD moeten we even weglaten hier … Het prototype is alleen maar de boot. En het prototype wordt beoordeeld door de all weather stations en operationele dienst …

A: Ja.

W: … op de functionele stafeisen.

A: Maar daar zou uit kunnen komen dat er meerdere oplossingen voldoen aan de behoeftestelling.

W: Ja, ja. Dat kan.

A: Ja.

W: Maar goed, het gaat om de mensen die aan boord zitten, de schippers, die hebben een behoeftestelling om mensen uit het water te halen of werkzaamheden met die boot uit te voeren.

A: Ja.

W: En daar ga ik eerst op sturen. Dus dat we de boot hebben. Want de mensen die erop werken, dat is de primaire klant van ons binnen de organisatie.

A: Ja.

W: Die moeten ermee varen. Ja? Dus als wij de primaire behoeftes hebben ingevuld in een prototype, ja? Dan gaan we naar de volgende stap, eigenlijk, dan gaan we uitwerken van prototype naar definitief ontwerp. En, ik moet hier nog eventjes … voor mij is dit duidelijk dit procesje, maar hier staat uitwerken van het prototype, dat betekent eigenlijk dat wij met de technische dienst, of met technische mensen, dus gaan besluiten van wat voor motor komt erin, wat voor jetaandrijving komt erin, wat is het geluid, he, want dat komt ook uit de behoeftestelling, hiervandaan, maar wat kunnen we doen aan geluidsreductie? Of wat kunnen we doen aan trillingsreductie van de componenten?

A: Hmhmm.

W: Dus als we die behoefte niet hebben, komen we automatisch wel tot componentenkeuze, he, dus dan kan je zeggen van nou, een Hamilton-jet heeft zoveel geluidsdruk en zoveel trillingen, maar een ander merk heeft, misschien wel wat duurder, heeft minder geluidsdruk en minder trillingen. Nou, dat is een keus die je dan kan maken. Maar door de techniek gaan we dat hier invullen. Als het definitieve boot op papier staat, met ook de technische invulling, dan gaan we in communicatie weer terug naar de all weather stations om over het definitieve ontwerp te vertellen, van he jongens, moet je eens luisteren, van, dit is onze insteek, vanuit techniek, ja?

A: Ja.

W: He, heb je nog op- of aanmerkingen? Maar dan stellen we wel de spelregels, niet van ik wil nog een kikkertje hier of daar een scharniertje hebben, nee, het gaat echt op van he, kunnen we erbij? Wat zijn de behoefte ervan? Kunnen we, zijn jullie het ermee eens? Zijn jullie het eens met dit testbord, ja, is er standaardisatie? We moeten ook naar standaardisatie kijken, naar kosten. En dan eigenlijk, zeggen van, uit deze sessie krijg je weer het verwerken van details op het definitieve ontwerp. Nou, dus de opmerkingen uit deze sessie gaan we hiernaartoe, dan verwerken we de details, van om de puntjes op de i te zetten. Dan gaan we terug, dan gaan we nog een keer die sessie doorlopen. En dan krijg je eigenlijk, als we dat eenmaal hebben, dan weten we wat we willen hebben, dan weten we

ongeveer hoe die boot er, tenminste, we weten hoe die boot eruit komt te zien. En dan gaan we een offerteaanvraag doen naar de werven. Want dit is onze scope. Dit is onze aanvraag.

A: Ja.

W: Ja? En dit is een heel ander proces, he, want nu komen we niet meer op het KNRM proces, dat we alles zelf gaan doen, nee, we gaan dus het proces neerleggen bij een werf. Maak maar een technische specificatie. Maak maar een detailontwerp. Eh, …

A: Hmhmm.

W: … wat is jullie innovatie ervan? Wat we nu gedaan hebben, in dit proces, hebben we alles beschreven, naar de werven toe, hoe wij het willen hebben. Dus er is heel weinig ruimte om eh, met andere slimme koppen van de buitenkant …

A: Ja.

W: … mee te denken in het proces hoe we die boot tot stand kunnen krijgen. De besluitvorming van de van Wijk, wij hebben de hele besluit … wij hebben het hele ontwerp zelf gedaan, laten doen, ook besloten, en ik heb daar eigenlijk een streep door gezet van nee, we gaan niet meer verder met bepaalde mensen, we geven een totaal nieuw ontwerpbureau, met mensen ook van de TU, die scheepsbouwers, die innoverend bezig zijn, om innovatie toe te passen. Bijvoorbeeld van geluidsreductie. Hoe kunnen we nou geluidsreductie toepassen?

A: Ja.

W: Ja? En hoe gaan we dat vastleggen, hoe gaan we dat meten?

A: Ja.

W: Ja? En hoe kan dat tot stand komen? Want als we doorgaan …

A: Dus eigenlijk de eisen, of de wensen die je overbrengt aan een werf, van dit is wat we willen, die is dus veel vrijer geformuleerd, gaat hij worden, dan hij was. Zeg ik dat zo goed?

W: Ja. We legden eerst allerlei dingen op, maar ook de verantwoordelijkheden legden wij hun op. Maar eigenlijk, als je een uitbesteding doet, moet je zorgen, dat je een uitbesteding doet, bijvoorbeeld, je gaat naar de autozaak met je vrouw en je koopt een nieuwe auto. Dan zeg je, een nieuwe Fiat Panda. Nou dan zeggen zij, nou, de stafeiser zegt, nou, ik wil een Fiat Panda, dat had je al besloten thuis, hij moet zwart worden, er moet een stereo-installatie inzitten, navigatie inzitten, nou, goed. Dan ga je naar verschillende bedrijven toe om te vragen van he, ik wil een Fiat Panda hebben. En dan ga je kijken welke, beste, partij, die je dan selecteert, waar je verder mee wil.

A: Ja.

W: En ook in het onderhandelingsproces, wat lever je nog meer voor toegevoegde waarde, of, wat voor advies krijg je dus. Als je zegt, jullie hebben wel een Fiat Panda gekozen, maar als ik jou hoor, wat je ermee gaat doen voor in de toekomst, zou ik deze opties erbij nemen. Of niet meenemen. En dan krijg je dialoog, van innovatie, …

A: Ja.

W: … van, is dat echt nodig, he, want misschien hebben wij wel wensen neergezet, wat helemaal niet meer van toepassing is.

A: Ja.

W: En in de oude beschrijving, legden eigenlijk de hele bouw al vast, wat wij willen, zonder dat de bouwers innovatie, of ook mee konden denken in het project. Want we legden de specificaties zo vast neer, dat ze daarna moeten bouwen.

A: Ja.

W: Maar tevens zijn we ook verantwoordelijk voor de bouw. Als ik zeg tegen jou, van, terugkomend op het verhaal van jouw vrouw wil een auto, dan ga je ook niet vanachter de keukentafel iets ontwerpen.

A: Nee.

W: Met vier wielen. Maar als je dat wel doet, en je gaat naar een autobedrijf en je zegt, moet je eens luisteren, ik heb dit ontworpen achter de keukentafel, prachtig ontwerp, chasis, vier wielen, grote motor erop, en dat is 32 knopen, en dat is dit en dat. En dan gaan ze het bouwen en dan komen we tot de conclusie dat je er maar 24 knopen met je auto kan rijden. Wie is nou verantwoordelijk?

A: Jij hebt het ontwerp aangeleverd, dus dan …

W: Ja!

A: Ja.

W: En daar zit nu de crux. Dus, wij doen wel de basisvoorwaarden, wij doen wel welke vorm wij zouden willen wensen, …

A: Ja.

W: … wat wij willen hebben.

A: Ja.

W: Maar de specifieke uitwerking van die wensen naar technische specificaties en naar definitief ontwerp, dat stopt hier. Dat betekent dat jij de werf verantwoordelijk stelt voor het ontwerp, maar ook verantwoordelijk stelt dat die boot 32 knopen gaat varen.

A: Performance.

W: Performance.

A: Ja.

W: Maar ook qua geluidsreductie. Maar als wij nou al zeggen, he, deze uitlaat moet je toepassen, en je moet dit toepassen, en je moet dat toepassen, dan zegt die man dankjewel, dan ga ik dat maken. En opeens hebben wij geen geluidsreductie, of we zitten op de 90 dBA, of 85 dBA.

A: Ja.

W: En dan zegt die werf alleen, ja, moet je eens luisteren, dat heb jij voorgeschreven, deze componenten.

A: Ja. Ja.

W: Dus wiens schuld is dat? Dat is de KNRM, die trekt al die schuld naar zich toe. Daarom zeg ik nee, wij stellen dat netjes op, we gaan het naar de werf toebrengen, we leggen ons eisenpakket neer, we geven de verantwoordelijkheid van het ontwerp op technische specificaties, snelheid, emissie, ligt helemaal bij hun. Want zo gaan hun beter en dieper nadenken. Nu geven we eigenlijk een bouwdoos aan, met verschillende verantwoordelijkheden …

A: Ja.

W: Verschillend, wie is nou verantwoordelijk voor wat?

A: Ja. Maar dan moet je bijna naval architects in gaan huren om dat proces zelf goed te doen, dat is …

W: Dat hebben we ook gedaan.

A: Ok, ja.

W: Ja. Ja, ja. Dat hebben we gedaan. En dat wordt hier dan gedaan, maar op een heel klein kennisgebiedje, zeg maar, maar ook met heel vertrouwde mensen met, die dat al jaren doen en dat betekent wel dat je dan tunnelvisie krijgt. En angst om naar de buitenwereld te kijken en niet denkt dat het project anders gedragen moet worden, dat het breder getrokken moet worden, want met De Vries Lentsch hebben we dat de ontwikkeling gedaan van de van Wijk en het zijn topgasten, alleen ze, de technische specificaties staan nog in steen gegrafeerd. Ja? En nu ben ik met een paar andere alternatieve naval architects aan de gang gegaan met de vraag, had je het anders kunnen doen? Wat heb je gedaan? Zus gedaan, zo gedaan? En ik zeg, maar dit staat toch vast? Ja, maar dat gaat ook om materiaalkeuze, zit erin. En dan zeg ik, waarom zit die materiaalkeuze erin? Ja, omdat dat goed is, zus en zo. En dan ga je een root cause analysis op maken en dan ga je zeggen, maar waarom doe je dat dan? Ja, dat is sterker. En ik zeg ja, waar komt dat vandaan? En ik zeg, waarom is dat zo duur? Ja, maar het is bijna niet beschikbaar. Maar ik zeg, dat zegt mij toch al heel veel, als het niet meer beschikbaar is.

A: Omdat andere mensen andere dingen kiezen.

W: Dat komt omdat dat spul niet meer veel wordt toegepast. En waarom niet? Er zal waarschijnlijk een negatief effect aan kleven. En dat blijkt dus ook wel …

A: Ok.

W: Ja? Vijftien jaar geleden werd dat materiaal toegepast bij heel veel aluminiumconstructies, maar ze hebben toch geleerd, in de evaluatie van het materiaal dat het toch niet helemaal het materiaal is dat we willen hebben.

A: Ok.

W: Ja, en dan zeg ik van waarom passen we dat toe? Het is kostenverhogend, ja? Het is slijtvast. Maar ik zeg, als we nou op een zandbank lopen, of we lopen tegen een dijk op en die plaat is stuk, moeten we vier weken wachten op een stukje plaat en ligt die boot stil. Nee, je moet zorgen dat het materiaal wat je nu kiest, ja? … binnen 2 uur beschikbaar is, van de snijderij. Een belletje naar een platen, tenminste, naar een snijbedrijf, specificaties van het aluminium neerleggen en de volgende dag heb je een reparatieplaat liggen. Zo moet je denken. Maar goed, dat is eruit gehaald.

A: Ok.

W: Daarom wil ik zeggen van, nieuwe innoverende dingen, van materiaal, van eh, verbindingtechniek, lastechniek, de WPS'en … Hoe kunnen we nou beter bouwen, maar ook lichter en sterker.

A: Ja. Win-win-win.

W: Ja, nee, maar dat bedoel ik, dat is dat, daar heb ik nu de streep, dat is het proces waar ik nu naartoe ga.

A: Ja.

W: En dat geeft veel meer vernieuwing.

A: Duidelijkheid vooraf.

W: Ja, maar ook vernieuwing.

A: Vernieuwing.

W: Nieuwe inzichten, waarom doen we dit?

A: Leuk, interessant!

W: Ja.

A: Ik ben benieuwd wat eruit komt!

W: Ja, maar dat is … En dat zie je in het proces wat ik nu gevolgd heb in het delen van het dashboard … Dat is precies hetzelfde traject eigenlijk, van ok, zet het maar op. Ten eerste, wat ik zeg, prachtig dashboard wat ze hier gemaakt hebben. En dan zeg ik van, past het wel in de constructie? Maar we hebben naval architects, dus dan zou je bijna zeggen van he, het past.

A: Ja, ja.

W: Dus ik heb een tweede ingehuurd, van een speed over systeem toe te passen, van ga jij de boel maar even nakijken, ga jij die 3D model maar opzetten, ga jij die componenten er maar in zetten. Past het allemaal? Hebben we de zichtlijnen ervan? Hoe gaan we die zichtlijnen bepalen? Bepalen we dat op een papiertje, of doen we dat op een nieuwe techniek? Nou, die man gaat het op een nieuwe techniek bepalen. Om zichtlijnen te creëren … Dus dat doen we met eh … dat kan ik je wel even laten zien … maar dat geeft een heel ander perspectief.

A: Met een 3D model?

W: Nee, het 3D model, dat is … Ik moet even kijken of ik dat zo 1-2-3 kan vinden zometeen. Dat geeft eigenlijk aan dat, voorheen werden de zichtlijnen geprojecteerd door uit het oogpunt van de mensen te bekijken. Maar, dat is prachtig, dat zijn vier lijnen, maar je weet nog niet wat je ziet. Met een hele andere manier van benadering om die zichtlijnen te bepalen, zie je de boot en dan kan je dus zien, met kleuren, wat de roerganger wel ziet, ja? En wat de navigator ook ziet. Dat zie je gewoon, de sterke vlakken, want dat wordt dus, met een felheid van kleuren licht of donkerder te geven, zie je dus aan, wat iemand ziet.

A: Ja, ja.

W: Dat is dus een nieuwe, dat is een innovatie. Dat is helemaal nieuw.

A: Ja.

W: Maar dat geeft wel helemaal een andere dimensie aan, van wat zien we nu.

A: Ja.

W: Maar dat kan je ook meten. Ja, en zo … Dus terugkomend naar het proces. Dat is het proces van wat, waar we nu mee bezig zijn.

A: Ja.

W: Dus dat heb ik nu proberen vast te stellen. Dat ga ik ook, dit zijn dus de spelregels, wat ik nu tegen je zei, ook met de all weather stations, dat we het op deze manier doen, dus ook vantevoren weten de mensen al in te vullen van he, ik krijg dit, ik kan hierop reageren, ik mag hierop reageren, in plaats van allemaal blind allemaal papieren te verzamelen of vragen van te beantwoorden van, …

A: … te formuleren …

W: … en een antwoord krijgen maar er verder niks mee doen.

A: Ja.

W: Dus dat eh, maar goed, dat is het proces.

A: Ja.

W: Lang antwoord.

A: Duidelijk. En het geeft ook wel … Een van de volgende vragen die ik wil, wat zou je eventueel willen verbeteren, veranderen, die hebbe we al meteen meegepakt. Ik heb nog een, de laatste vraag, wat jij moet ook door …

W: Ja, ja.

A: Hoe houd je, breng je balans in verschillende criteria, waarin je toetst. Waarin je zegt, van bijvoorbeeld een kleine verbetering in duurzaamheid, die relateert zich tot zoveel kosten, of tot eh …

deze extra effort die mensen moeten doen om te leren werken met het materiaal, of ehm, of nou ja, zo heb je allerlei verschillende criteria die uiteindelijk van invloed zijn op een heel ontwerp.

W: Je moet me even, beginnen, de vraag nog een keer stellen.

A: Ehm, hoe houd je balans tussen de weging waarin je verschillende criteria meeweegt? Dus, de ene is, het ene is … Zeg dat je twee ontwerpen hebt, en de een scoort goed op duurzaamheid, de ander is wat goedkoper, de volgende, die wat duurzamer is, daar moet je heel veel opleidingen doen om de mensen daarmee te leren werken. Hoe ga je nu afwegen, ja, ze hebben allebei voors en tegens, hoe ga je zorgen van, ik maak een eerlijke afweging, die transparant is, en waar de criteria op een duidelijke manier meegenomen hebt?

W: Ja, dat is een goeie … Die vraag kan ik niet 1-2-3- beantwoorden, want zo ver ben ik nog niet in het proces.

A: Ok.

W: Dat is, een hele lastige is dit.

A: Ja.

W: Want, hoe kom je op een snijvlak terecht, dat beslismoment, dat discussiemoment, of dat instemmoment dat kan je pas goed doen, als mensen ook, dat willen. En dat inzicht hebben.

A: Ja.

W: En, ik denk dat de KNRM intern daar nog niet helemaal op geprojecteerd is.

A: Ok.

W: Dus dat vind ik een moeilijkheid, een, wat ik al zeg, …

A: Ja.

W: … je hebt de dinosaurus die zegt: “Dieselmotor!”. En ik zeg waterstof, ja? Daar zit gewoon een bandbreedte in.

A: Ja.

W: Van te groot, dat zie ik nu ook al, met de brandstof. Ik zeg brandstof, en meteen hakken in het zand door te zeggen van, dat gaan we niet doen! Schade, dit en dat, allemaal paniek zaaien, …

A: Ja.

W: … allemaal angst creëren binnen de organisatie, dat gaan we niet doen, he. En dat is een heel klein onderwerp dan he, …

A: Ja.

W: … klein, of groot onderwerp, hoe je het mag noemen, en dan zie je al de uiterste van, wat ik net al zei, van he, weet je wat het is, misschien wel een toekomst, een mogelijk brandstoftype wat we kunnen … Ik ga me erin verdiepen, ik ga kijken, wat we ermee kunnen doen, en ik ga dan er goed over nadenken, of dat van toepassing is. En als dat van toepassing is, en dan ook verder uitrollen. Ehm, dus dat beslismoment, van hoe we dan, met nieuwe boten, zulke beslissingen nemen, dat vind ik wel een hele uitdaging nog.

A: Ok, ja.

W: Dat is, daar ben ik ook eerlijk in, …

A: Ja.

W: Want ik heb erover nagedacht, …

A: Ja.

W: Dus dat, daar is het ook een beetje bij gebleven, want omdat ik nog onvoldoende draagvlak heb,

A: Ja.

W: En ambassadeurs binnen de organisatie, die dat mee willen dragen.

A: Ok. Ja.

W: En dat is de evolutie die hier nu moet plaatsvinden, van …

A: Het balletje nog boven aan de helling is, het balletje moet nog gaan rollen.

W: Ja, we hebben milieu of groen denken, ik denk dat de meeste mensen het daar wel mee eens zijn, maar dan het omzetten naar groen acteren en doen, dat is, en doen, dat moet nog gerealiseerd worden.

A: Ok.

W: En dat is niet alleen op de werkvloer, maar ook op de raad van toezicht van willen we dat, hoe krijgen we dat tot stand, en willen we dat. Dat kost extra geld, maar hebben we dat ervoor over om het te realiseren. Dat evenwichtsbruggetje, dat is nu gaande.

A: Hmhmm.

W: Een voorbeeld is die brandstof. Dat kost extra geld, ok goed, …

A: Hmhmm.

W: Ok, hoe kunnen we dat compenseren? Ok, donaties, ok, hoe krijgen we dat terug? Dus dat is … duurzaamheid kost geld he?

A: Niet per se, het kan ook geld opleveren.

W: Nou ja, kijk, je hebt je, ik zal het zo zeggen, vooral op onbekende gebieden van toepassing, gaat het geld kosten.

A: Ja.

W: Ja? Als je zegt, op duurzaamheid, okee, we gaan een tractor elektrificeren, alle componenten bestaan, is bekend, is een hoop geld. Maar dat geld haal je nooit meer terug. Een investering van €150.000, - €200.000 krijg je niet meer terug uit die trekker. Het is meer, dat we ermee bezig zijn. Dus dat is een investering. He, we doen nu een investering.

A: Ja.

W: Als je had gezegd van ik heb €200.000 voor milieu, he, dan zou ik zeggen, plak even op elk station allemaal zonnepanelen, want, over vijf a zes jaar, zeven jaar, heb ik een verdienmodel gecreëerd, dat we dus energiezuiniger zijn, ja, we zijn CO2 neutraal, per station, en we verdienen de investering, over vijf tot zeven jaar terug.

A: Ja.

W: Dus dat zijn de aspecten, welke kant willen we op? Met duurzaamheid, he.

A: Ja.

W: Hoe ga je duurzaamheid in?

A: Ja.

W: Dus dat is bestaande, hoe noem je dat eigenlijk ook al weer …

A: Bestaande concepten implementeren, of bestaande verdienmodellen implementeren, of ga je zeggen van, nou ja, we gaan investeren in iets nieuws, waarvan we niet van tevoren weten van het op gaat leveren.

W: Ja. En dat is ook een mindset. Dus wat we, best practise van duurzaamheid is dan windenergie toe te passen en zonnepanelen op de stations toe te passen, dus de meest eenvoudige dingen om te zeggen van we zijn duurzaam bezig. Dat zijn bestaande modellen.

A: Ja.

W: En bewezen modellen. En dat innoverend, van een HVO toe te passen, dat gaat extra geld kosten, in het begin.

A: Ja.

W: Maar nu kom ik op de vraag, ja, dat gaat nu extra geld kosten, maar misschien wordt het zo meteen wel opgelegd, he. Dat zie je dus ook bij andere bedrijven, eh, het HVO 20 wordt nu zo meteen opgelegd, door het ministerie. Die moeten ermee varen. En dan zeg ik, dan moeten we niet achterblijven.

A: Nee. Want als je dan nog de investeringen in de motoren moet doen, staat iedereen in de rij bij dezelfde aanbieder en dan ..

W: Nou, dat wil ik nog niet zeggen, he, want …

A: Nee.

W: Want die ontwikkeling duurt best wel lang, he, maar ik denk over tien jaar, dat dat, voordat we dat helemaal uitgefaseerd hebben. Maar daar zijn we wel, als KNRM, al wel zeggen, we zijn groen georiënteerd, we zijn groen bezig.

A: Ja.

W: Ja? Dus daar zijn we … Het gaat om dat balletje te … Dat groen, duurzaamheid moet gaan leven. Maar ook, hoe kunnen we duurzaamheid gaan verwerken in onze producten, he? En collectieve duurzaamheid meer uit gaan spreiden binnen de organisatie, meer bekendheid geven.

A: Ja. Ik heb een laatste vraag eigenlijk, dat komt eigenlijk weer terug op die besluitvorming, met die criteria en die balans. Hoe staan jij er tegenover om daar een hulpmiddel voor te gebruiken? Een tool die het inzichtelijk moet maken, en dan, de tool die ik vanuit de universiteit zou willen aanraden, is een tool die het probeert simpel te houden. Het is een complex probleem, dus het zal altijd complex blijven ergens, maar die probeert het simpel te houden en transparant te maken. Dat je uiteindelijk opties versus criteria tegen elkaar af gaat wegen om tot een beste beslissing te komen. Maar niet zeggen van nou, dit is de beste, maar ook, dat je terug kan halen waarom is dat de beste?

W: Ja, traceability.

A: Ja. En eh, ook, waar je ook nog een hulpmiddel hebt om de discussie met elkaar te hebben, van nou ja, deze komt er wel als beste uit, maar we kunnen ook zien waar het vandaan komt …

W: Ja.

A: … en zijn we het daarmee eens …

W: Ja.

A: … staan we daar achter?

W: Ja.

A: Zou je daar wat in zien?

W: Ja, ja, tuurlijk. Tracability is altijd goed voor nu, …

A: Ja.

W: … maar ook voor later, als je daar vragen krijgt, waarom bepaalde … Wat heel veel mensen doen met zulke dingen is dat wij tracability, de bron van herkomst, …

A: Ja.

W: … altijd vergeten te monitoren, van hoe is dat nou tot stand gekomen?

A: Ja, kan ik me voorstellen, ja.

W: He, en dan kom ik weer terug, mocht het verkeerd gaan, dan kan je je root-cause analyse maken, de stappen, dus te zeggen, dit hebben we goed gedaan, ok, dit is niet, deze fase is goed. Fase is ook goed. He, fase drie, he, daar zit het probleem. Hoe is dat tot stand gekomen? Volgens mij kun je daar al veel beter lessons learned uit halen.

A: Ja.

W: Maar dat is ook een, hoe noem je dat? Een … Dat kan, en ik ben een voorstander om zulke dingen ook te gebruiken. Alleen, dan kom ik weer terug op de onderlaag, mensen moeten ook getraind worden om dat te beseffen, en het te gebruiken.

A: Ja.

W: En dat merk ik hier, is dat het toch wel een beetje een opleiding … of niet opleiding, dat maakt niet uit … de gedachtegang is te weinig gepromoot in dat opzicht.

A: Ja, okee, ja.

W: Maar goed, dat is wel …

A: Ja.

W: Het delen van informatie, en dat bediscussiëren, is hier niet echt geweest.

A: Ok.

W: Dat is eh …

A: Zonde. Want daar komt juist de beste beslissing uit.

W: Ja, maar goed, wat ik nu doe, is dat bijvoorbeeld, ik hou nu toolbox meetingen, dat is allemaal simpele dingen, he, ik ga zo meteen van .. ik ben met het HVO bezig he, ik heb me ingeleefd en ik ga er eigenlijk al een beetje vanuit als mensen in deze industrie zitten, dat ze eigenlijk wel weten, wat alternatieve brandstoffen zijn, he? Maar gisteren kreeg ik de vraag, wat is nou eigenlijk HVO?

A: Ok, ja …

W: Ja, ik eh, dat is eigenlijk stom, dus ik heb eigenlijk gevraagd van nou, aan die over … GP Groot , kan je niet een presentatie maken? En dat betekent niet dat ik dat wil, nee, ik wil dat een buitenstaander dat gaat vertellen. Want als ik, als ik het constant ben dan wordt ik … Als een buitenstaander dat kan vertellen, met passie en motivatie en het is een bron van …

A: Zijn ziel en zaligheid zit erin.

W: Ja. Dan komt dat heel anders over.

A: Veel meer overtuiging in, ja.

W: Nee, maar overtuiging, maar dat betekent ook dat de discussie die je gaat leiden niet meer tussen mij en de technische dienst die ineens, maar dan krijg je de D-A-D discussie, dan ga ik me, dan weet ik op een gegeven moment geen uitsluitsel meer, of geen goed antwoord, dan ga ik me verdedigen. Nee, het moet een triple D situatie worden, snap je, dat het …

A: Kan ik het oplossen?

W: Ja.

A: Ja.

W: En daarom, dat ik het nu vraag bij buitenstaanders, omdat je dan de kennis van buitenaf naar binnen trekt. En dat geeft een leuke dialoog, en gaan mensen er anders over nadenken en dan andere vragen stellen aan andere mensen.

A: Aha.

W: Aan echt een expert. En dat bedoel ik met, en dat zie ik hier ook niet, ik ben gewend om, wel de dingen te initiëren, maar dat gaat hier anders. Dus haal ik wel de specialisten erbij, die gaan dat vertellen. En zo krijg je vorming. Dat is wel eh …

A: Duidelijk !

After this conclusion, we parted, while I expressed my sincere gratitude for the time and effort Gert-Jan took for this interview.

C

Presentation introduction Best-Worst Method

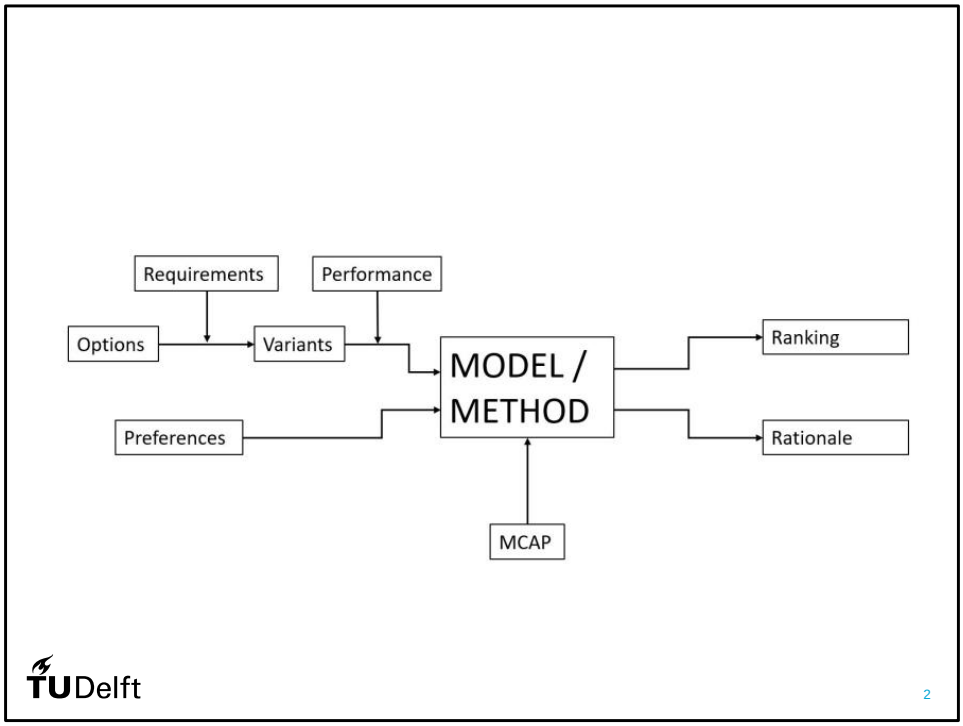
This appendix shows the presentation that was used to introduce the Best-Worst method (BWM) to the interviewees. The presentation was either presented to the interviewees, sent in advance or sent in advance and a summary presented, depending on the interviewees schedule and preference. In some cases, the presentation was tailored to the interviewee to some extend, but the core message remained the same. Copies of the presentation as sent to each interviewee can be requested from the author.

Naar aanleiding van eerdere interviews met de directeur en e, heb ik een gedetailleerd onderzoek gedaan naar welke methode het meest geschikt zou zijn voor de KNRM.
Daarbij ben ik uitgekomen op de Best-Worst Methode (BWM), die is ontwikkeld door ass. Prof. Jafar Rezaei (TU Delft).

In deze presentatie een korte introductie van de methode, een kleine toelichting op de data die nodig is om het model 'onder de motorkap' te laten werken en als laatste de doelstelling voor de huidige ronde met interviews.

Ik heb voor de Best-Worst Methode gekozen om de volgende redenen:
- De grote eenvoud zowel in het gebruik als in het begrijpelijk presenteren van de uitkomsten. (En ook al zal het niet meteen voor iedereen even eenvoudig zijn; binnen de beschikbare modellen die voldoen aan de andere gestelde eisen is dit een van de meest simpele, en misschien wel de meest simpele)
- Het model splitst het besluit en het vergelijken van varianten op in kleine deelvergelijkingen die veel beter te behappen zijn voor de gebruiker.
- Het model is in staat om een groot aantal criteria met elkaar te vergelijken (>10 criteria)

- Het model maakt analyse van uitkomsten mogelijk doordat het een ranking presenteert (in tegenstelling tot modellen die alleen een keuze presenteren, of oplossingen sorteren in categorieën)
- Het model is in staat om meetbare harde criteria te integreren met gevoelsmatige data.

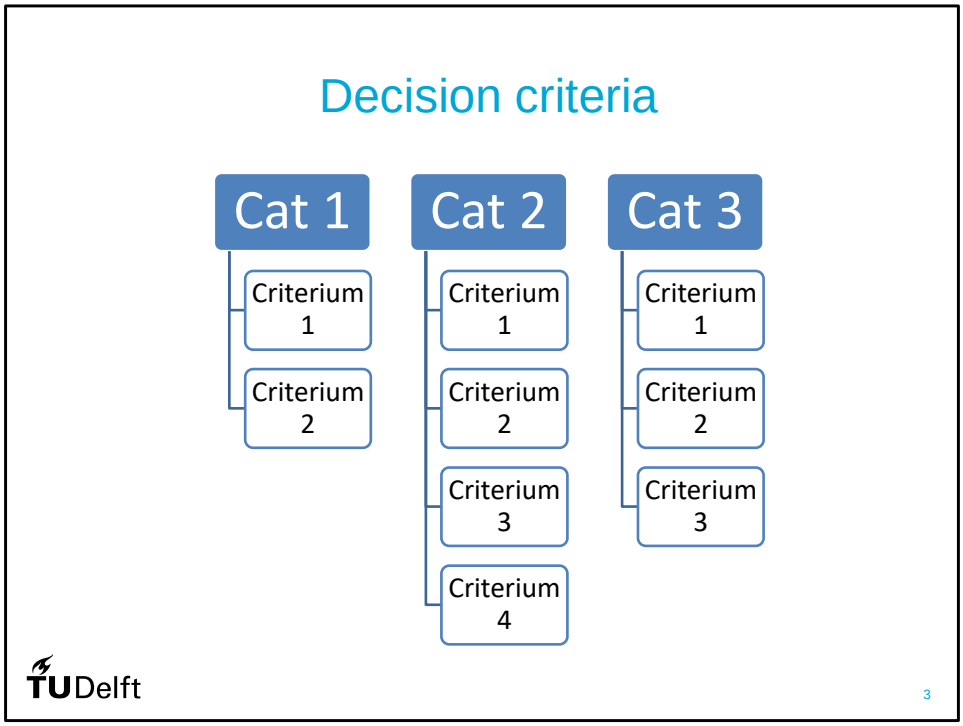


Bovenstaand figuur geeft schematisch de flow weer van de beslissing bij het gebruik van de Best-Worst Methode.
Aan de voorkant moet er een keuze gemaakt worden uit alle beschikbare opties. Hier worden eerst alle niet-relevante opties gefilterd aan de hand van een set met minimale vereisten.
Hierdoor blijven dus alleen de varianten over die voldoen aan de eisen van de organisatie, en daarmee relevant zijn om met elkaar te vergelijken.
Deze varianten leveren een bepaalde performance ten opzichte van alle denkbare en mogelijke toetsingscriteria.
Separaat, en bij voorkeur voorafgaand aan het vaststellen van de varianten, wordt er gekeken naar welke criteria er relevant zijn voor de beslissing en in welke mate zij meewegen in het uiteindelijke besluit.

De MCAP is de set van rekenformules die gebruikt wordt door het model. En omdat ik op zoek ben gegaan naar een simpel en transparant model, zijn alle berekeningen gemiddeldes, producten en sommen, dus eenvoudig te volgen.

Mijn onderzoek richt zich erop om de set van voorkeuren (preferences), bestaande uit het een set van toetsingscriteria en een bijbehorende vector van gewichten voor de

KNRM vast te stellen en te valideren met een case- studie. Dit zal in een aantal stappen moeten geschieden, omdat eerst een set met criteria moet worden vastgesteld die collectief wordt gedragen. En pas daarna kunnen de gewichten worden vastgesteld. De juistheid van het totale werk moet worden vastgesteld met een validatie aan de hand van een case-studie. Hier ben ik nog over in overleg met Gert-Jan hoe we dat vorm gaan geven.

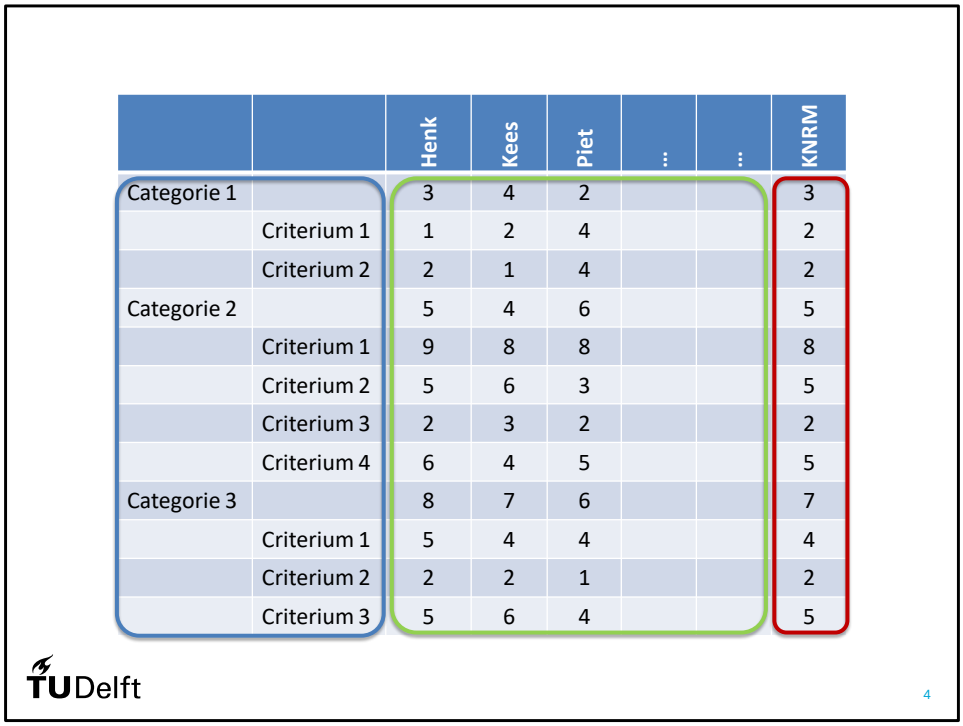


In de eerste stap gaat het om het vaststellen van de set van criteria.
De criteria zijn onderverdeeld in hoofdcategorieën. Hierbij kan bijvoorbeeld gedacht worden aan: 1) sociale aspecten (aspecten gerelateerd aan vrijwilligers, medewerkers, donateurs, omwonenden en omstanders, en overige belanghebbenden) 2) milieuaspecten 3) stakeholders (m.n. gericht op maatschappelijke aspecten, uitstraling naar de buitenwacht etc.) 4) financiële aspecten 4) technische aspecten 5) operationele aspecten enz. enz.

Deze categorieën worden dus onderverdeeld in de individuele toetsingscriteria. Zo kunnen financiële aspecten bijvoorbeeld worden onderverdeeld in life cycle costs en mogelijkheden voor fondsenwerving enz. enz. Binnen de set met criteria is het van belang dat er geen overlap zit tussen de criteria. Dat kan tot afwegingen leiden, als criteria raakvlakken of overlap vertonen tussen de categorieën. Er is dan geen goede of foute keuze in welke categorie het criterium komt te staan, daar waar het het beste past. Soms is het wel van belang welke zaken wel en niet onder een criterium worden gerekend en kunnen er losse elementen uit een criterium gehaald worden om zo een duidelijker beeld te geven. Dit brengt ook extra werk met zich mee. Het is dus altijd weer een afweging om bepaalde relevante zaken te combineren in een criterium of om deze op te delen. Een voorbeeld hiervan zijn de kosten. Kosten

kunnen uitgesplitst worden in de individuele criteria investeringskosten, gebruik (usage), onderhoud (upkeep) en afstorten (disposal). Deze kosten kunnen ook samengevoegd worden tot een lyfe cycle cost, welke bestaat uit de som der delen gedeeld over de verwachte levensduur. Deze keuzes verschillen van beslisser tot beslisser en hierom is het van belang om zoveel mogelijk de mening van experts op hun eigen vakterrein in de set met criteria te kunnen verwerken.

Omdat het model zowel kan werken met meetbare als met moeilijk meetbare criteria, kunnen ook criteria benoemd worden die gebaseerd zijn op bijvoorbeeld evaluatie en/of ervaringen van terzake kundige experts. Zo kan bijvoorbeeld ‘gebruiksgemak’ worden opgenomen als criterium, bijvoorbeeld wanneer er gekozen moet worden voor een nieuwe boot. Er kan dan aan een expert gevraagd worden (of aan bijvoorbeeld meerdere bemanningen die een proefvaart/-periode hebben gehad, geïntegreerd middels een gewogen gemiddelde) om hiervoor een cijfer te geven.



		Henk	Kees	Piet	...	...	KNRM
Categorie 1		3	4	2			3
	Criterium 1	1	2	4			2
	Criterium 2	2	1	4			2
Categorie 2		5	4	6			5
	Criterium 1	9	8	8			8
	Criterium 2	5	6	3			5
	Criterium 3	2	3	2			2
	Criterium 4	6	4	5			5
Categorie 3		8	7	6			7
	Criterium 1	5	4	4			4
	Criterium 2	2	2	1			2
	Criterium 3	5	6	4			5

Nadat in de eerste stap de set met criteria is geformuleerd, voeg ik deze samen tot een set met criteria, die zoveel mogelijk recht doet aan de individuele sets met criteria. Ik doe dit bijvoorbeeld door rekening te houden met relevante expertises en een objectieve scheiding van de inhoud van criteria. Uiteraard komt de set niet volledig overeen met de criteria zoals aangeleverd in de sets door de individuele beslissers, ik zal hen moeten overtuigen van mijn integratie aan de hand van de argumenten voor mijn integratie en een duidelijke omschrijving wat wel en wat niet onder een bepaald criterium gerekend wordt.

In de volgende stap gaat het erom de weegfactoren van de criteria ten opzichte van elkaar vast te stellen.
Hier komt het voordeel van het gebruik van de best-worst methode het beste tot zijn recht, omdat deze methode voorschrijft dat binnen een categorie criteria alleen hoeven worden vergeleken met het belangrijkste en met het minst belangrijke criterium. Technisch gezien resulteert dit in een uitkomst met een hogere consistentie (dus objectiever en eerlijker) dan vergelijkbare methoden, zoals bijvoorbeeld het Analytical Hierarchy Process van Thomas Saaty, wat veel gebruikt wordt in commerciële multi-criteria decision making (MCDM) toepassingen.
De data die benodigd is voor deze stap is – als voorbeeld – weergegeven in het

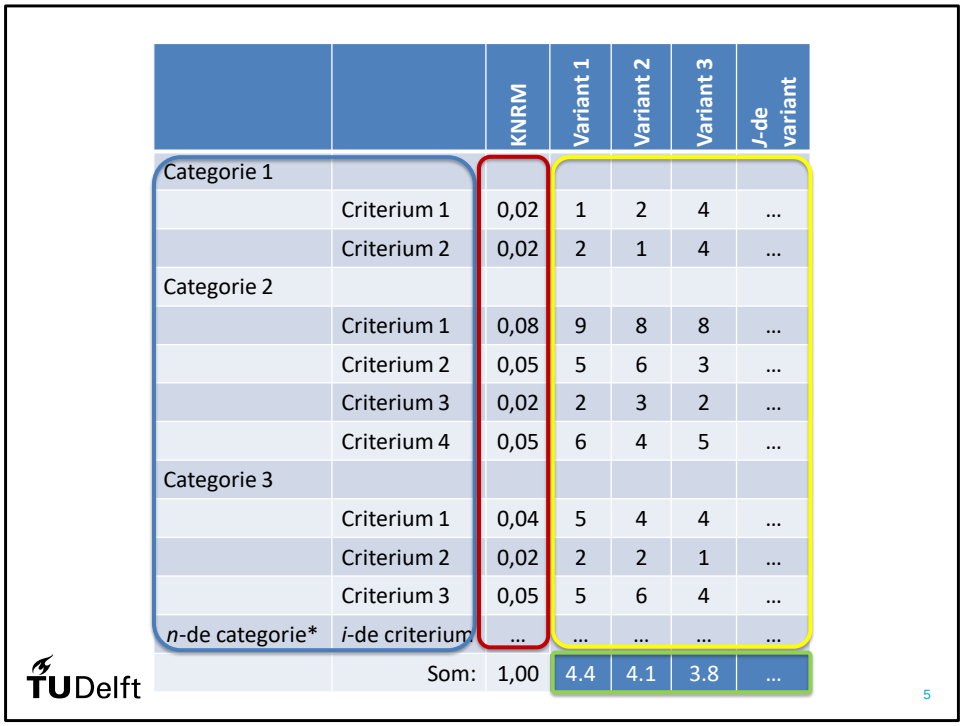
groene kader.

Deze individuele gewichten worden vervolgens samengevoegd tot een algemene set van gewichten, die geldt voor de KNRM als organisatie.
Deze worden berekend als een gewogen gemiddelde (som van alle scores gedeeld door het aantal deelnemers).

In deze twee stappen is het van groot belang om zoveel mogelijk beslissers mee te kunnen nemen in het interview. Hiervoor zijn twee belangrijke redenen:

- Alleen op deze manier wordt de set met criteria en de weegfactoren ook daadwerkelijk een representatie van de KNRM als organisatie (versus een individuele weergave)
- Dit draagt bij aan de herkenbaarheid van de totale uitkomst als een logisch product van de individuele input van de beslissers. Men ziet hapklaar terug hoe zijn/haar mening is verwerkt in het model en dat is van groot belang voor het tegengaan van een black-boxeffect en het bouwen aan draagvlak voor het gebruik van de methode.

Als laatste geldt ook dat dit vanuit academisch oogpunt (compleetheid van de dataset) van belang is.
Dat neemt natuurlijk niet weg dat het verzamelen van deze gegevens wel wat vraagt van de organisatie, ik ben mij daarvan zeker bewust.



		KNRM	Variant 1	Variant 2	Variant 3	*J*-de variant
Categorie 1						
	Criterium 1	0,02	1	2	4	…
	Criterium 2	0,02	2	1	4	…
Categorie 2						
	Criterium 1	0,08	9	8	8	…
	Criterium 2	0,05	5	6	3	…
	Criterium 3	0,02	2	3	2	…
	Criterium 4	0,05	6	4	5	…
Categorie 3						
	Criterium 1	0,04	5	4	4	…
	Criterium 2	0,02	2	2	1	…
	Criterium 3	0,05	5	6	4	…
n-de categorie*	*i*-de criterium	…	…	…	…	…
	Som:	1,00	4.4	4.1	3.8	…

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5

Het uiteindelijke gebruik van de methode geeft een resultaat als weergegeven in de matrix hierboven. In het rode vierkant staan de weegfactoren die de uitkomst zijn van de eerdere stappen. Hierbij geldt dat de weegfactoren berekend zijn door het gewogen gemiddelde van het criterium te vermenigvuldigen met het gewicht van de categorie.

(Eventueel kunnen er – afhankelijk van de casus – in een later stadium criteria toegevoegd of verwijderd worden, wat gevolgen heeft voor het aantal rijen en de waarden in het blauwe en rode vierkant.)

Daarna moet iedere variant gescoord worden op de verschillende criteria, zoals weergegeven in het gele vierkant.

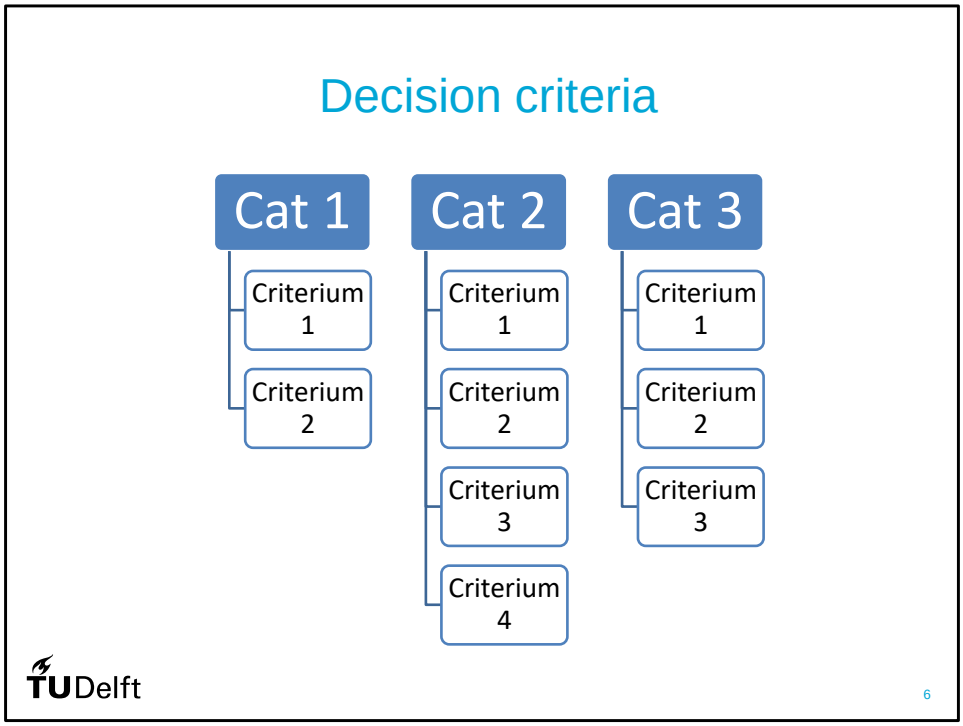
In het groene wordt de som weergegeven van alle producten van de score en de weegfactoren. Hiermee worden de opties gerangschikt op volgorde van overeenkomst met de set van voorkeuren van de organisatie. De score laat niet alleen de volgorde zien, maar ook de afstand tussen de verschillende opties. Hierdoor wordt het inzichtelijk of sommige varianten al buiten beschouwing gelaten kan worden terwijl er misschien een klein deelbereik nog eens nader bekeken moet worden

omdat de verschillen tussen die varianten juist klein zijn. In de matrix kan vervolgens teruggezocht worden waar verschillen vandaan komen. Zo kan het bijvoorbeeld zijn dat een van de voorstellen op 1 zwaarwegend criterium beter scoort, maar 10 minder zwaarwegende criteria slechter dan de andere varianten. Dat kan dan meegenomen worden in de uiteindelijke keuze. Ook kan het bijvoorbeeld zijn dat er ontwikkelingen te verwachten zijn op 1 of meerdere criteria. Door de waarden in het groene vierkant aan te passen naar de verwachte scores in de toekomstige situatie, kan geëvalueerd worden wat de impact hiervan is op de uitkomsten van de scores en op een eventuele keuze.

Als laatste hebben we het erover gehad om het model op enig moment te presenteren, bijvoorbeeld in de vorm van een workshop of case-study. Hoe we daar precies invulling aan gaan geven, daar komen we nog op terug. In tijden van Corona en drukke agenda's zitten er veel praktische problemen aan. Ik kom te zijner tijd – in nauw overleg met Gert-Jan – met een nader plan.

Al met al ontstaat een methode die ten eerste een vaste procedure volgt, die de organisatie in staat stelt om vooraf openheid te geven over welke criteria ze belangrijk vindt, om verwachtingen te managen ten aanzien van inbreng en evaluatie door mensen en dat in staat is om transparantie te bieden naar de buitenwacht, zoals donateurs en andere stakeholders.

* Note that the last row above the summation row was added in hindsight to clarify the weights always add up to 1, although this wouldn't be the case with these random numbers.



Nu draait het in eerste instantie om het inventariseren van de wensen met betrekking tot de criteria. Van te voren kan alvast nagedacht worden over de criteria, waarbij aandacht voor de exacte beschrijving en betekenis van belang is. Hier wil ik het graag in het interview over hebben.

Ik beantwoord ze graag!

D

Second interview with the CEO

This transcript denotes what was being said during the interview between the author and the CEO of the KNRM on the 1^{st} of October 2020, which lasted approximately one hour and a half. Because of the COVID19 restrictions and recommendations, the interview was held online, using video-teleconferencing software. The interview was used to establish the criteria as per step 1 of the BWM.

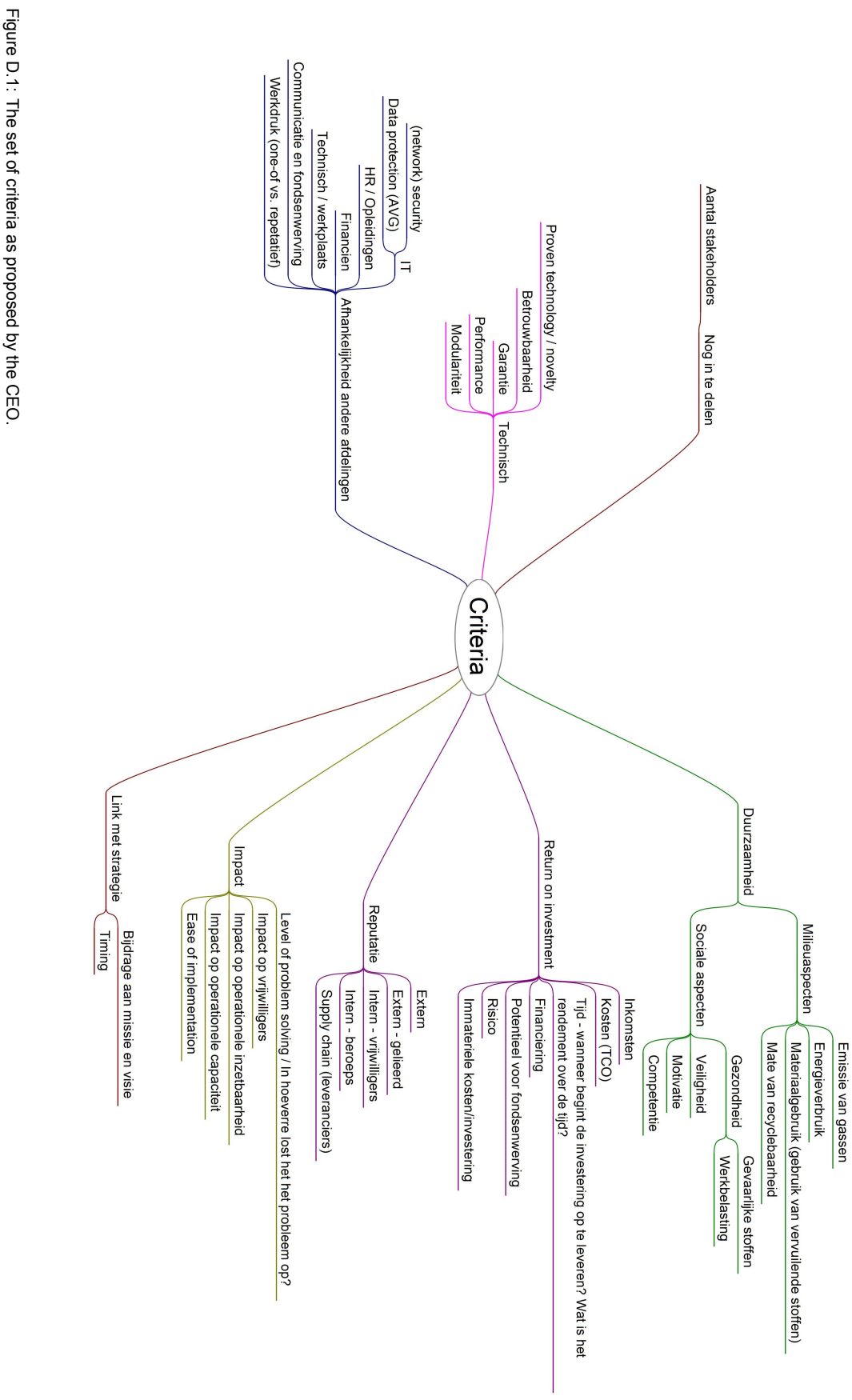


Figure D.1: The set of criteria as proposed by the CEO.

E

Second interview with the CTO

This transcript denotes what was being said during the interview between the author and the CTO of the KNRM on the 25^{th} of September and the 19^{th} of October 2020, which lasted approximately one hour and a half. The interview was used to establish the criteria as per step 1 of the BWM.

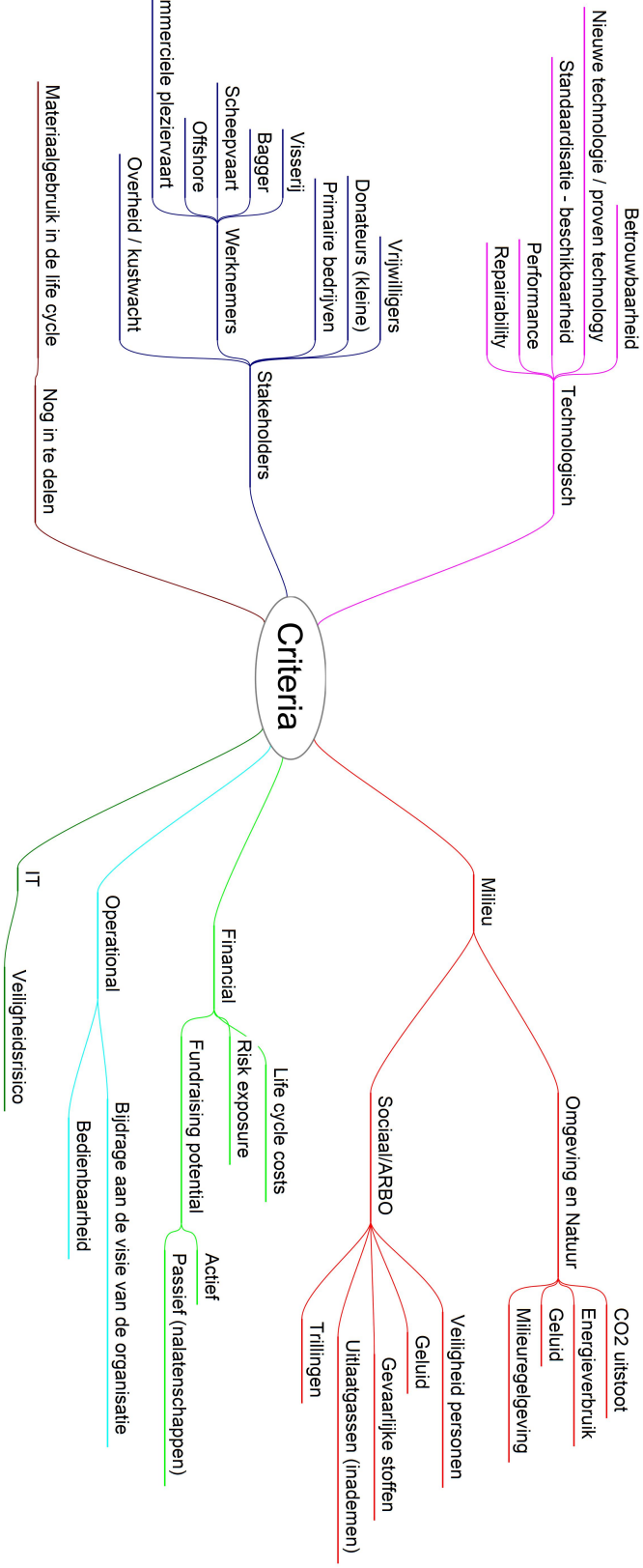


Figure E.1: The set of criteria as proposed by the CTO.

F

Interview with a project engineer

This transcript denotes what was being said during the interview between the author and a project engineer at the KNRM on the 20^{th} of October 2020, which lasted approximately one hour and a half. The interview was used to establish the criteria as per step 1 of the BWM.

During the interview, the interviewee emphasized the importance of reliability, which was, in his opinion, the first and foremost important criterion. This should be obtained as a result of the second phase, weighting the criteria.

As most criteria speak for themselves, only the criterion of employability may require additional explanation. This criterion reflects on the usability of a project for multiple stations, as many stations have specific local needs and desires, requirements for tailoring a solution to their needs. This should thus be incorporated in the design. The criterion should also evaluate the usability of a solution for a station it is not initially planned on being used.

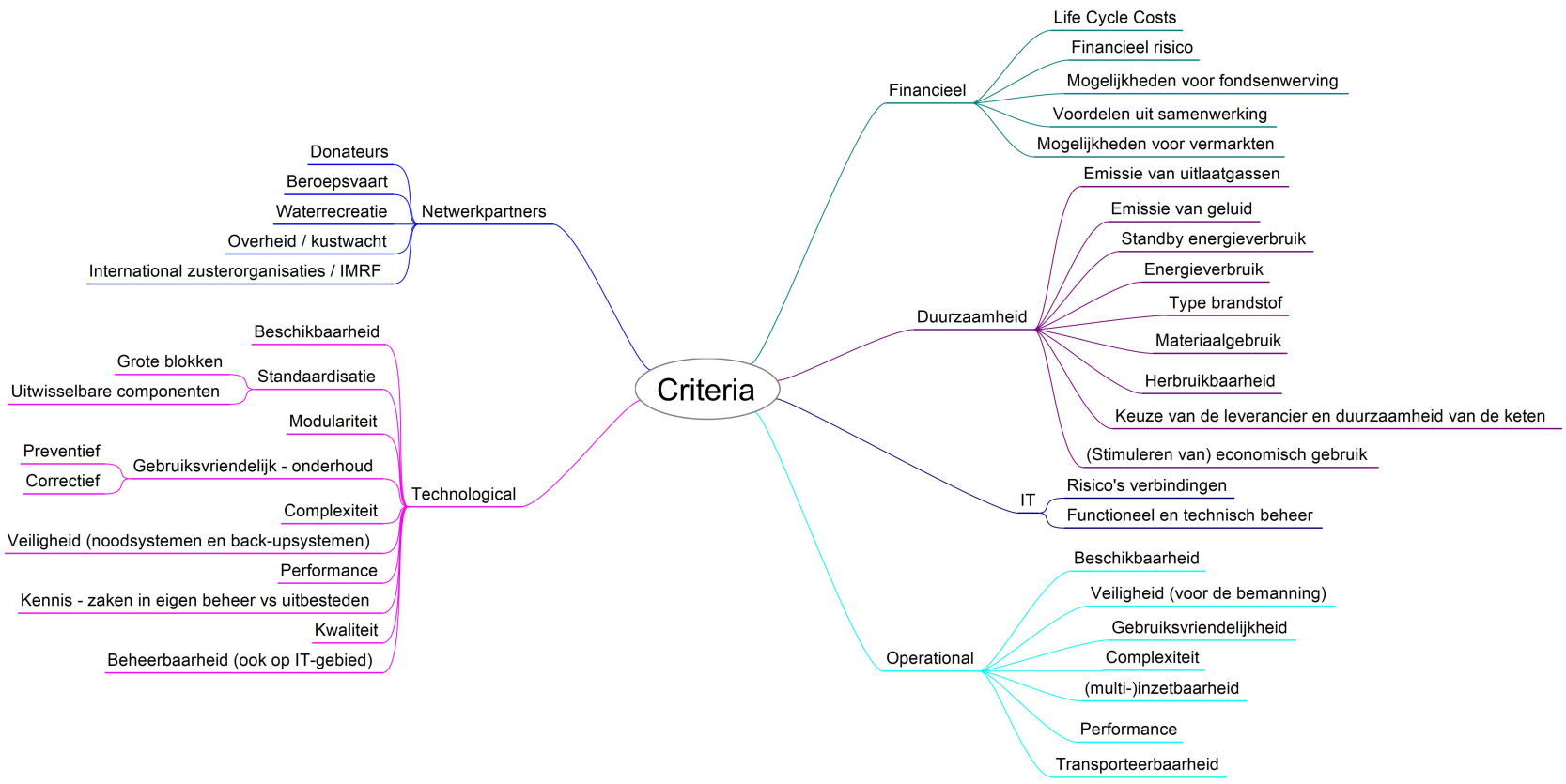


Figure F.1: The set of criteria as proposed by the project engineer.

G

Interview with a communications and fund raising specialist

This transcript denotes what was being said during the interview between the author and a fund raiser, part of the communication and fund raising department of the KNRM on the 22^{nd} of October 2020 and the 5^{th} of November , which lasted approximately one hour and a half in toto and was held online, due to the COVID19 restrictions. The interview was used to establish the criteria as per step 1 of the BWM.

The interviewee commented on the independence of the organisation, which is an essential condition for the inclusion of any variant. As such, the importance of this criterion warrants its inclusion as a requirement for an option to be taken into comparison as a variant.

The interviewee also stipulated it is important for any tool or model to deliver an argumentation as a basis for a decision. Such an argumentation should be solid enough to steer a project organisation clear of any discussions in the line of: 'We should never have done that.". The argumentation should show that the decision was taken based on a strong score on a number of arguments in comparison to the other variants taken into account.

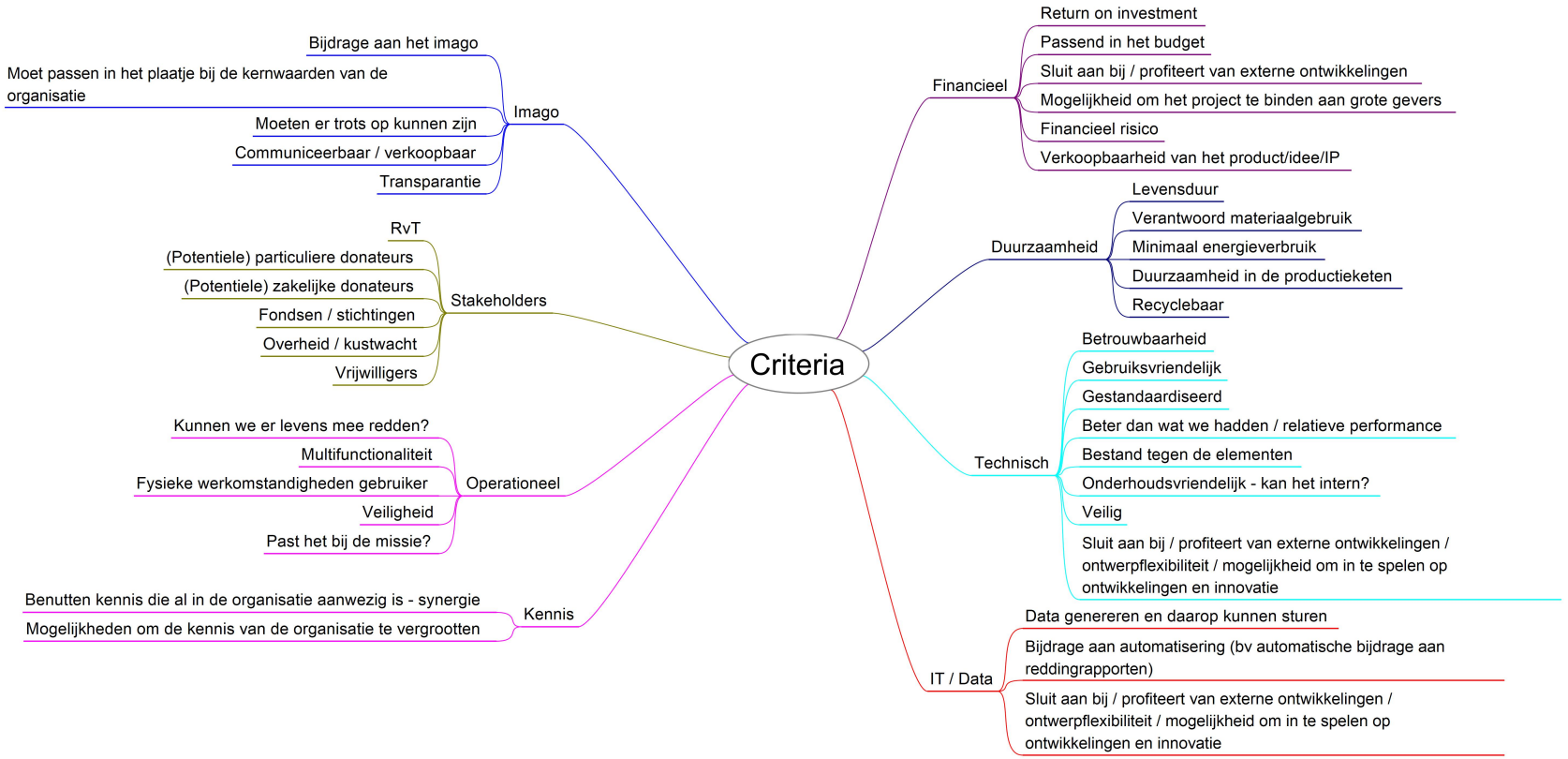


Figure G.1: The set of criteria as proposed by the fund raising expert.

H

Interview with the policy advisor

This transcript denotes what was being said during the interview between the author and a policy advisor of the KNRM on the 21^{st} of October 2020, which lasted approximately three hours and was held online, due to the COVID19 restrictions. The interview was used to establish the criteria as per step 1 of the BWM.

Other than the criteria that speak for themselves, the interviewee made some clarifications. She stipulated the importance to clearly evaluate how variants are separated from all available options. She mentioned for instance to include some elements of the mission and vision of the organisation as requirements for selection of the variants, such as the requirement of enabling a rescue free of charge for the victim and so on. These core values of the company may not be jeopardised by any variant. The independence the organisation, which is included as a criterion, should also be included as a requirement, however, after meeting the requirement, there is a scale as to what extend a variant contributes to the organisational objectives. This warrants the inclusion amongst the criteria.

The relative workload integrates the workload experiences by individual employees and volunteers with the workload on the organisation as a whole.

The criterion of being future proof does not only relate to flexibility incorporated in the design to cope with changing circumstances, it also integrated the level of preparedness for predictable organisational developments for the next 10 to 20 years and alignment with the future vision of the organisation, how it sees itself operating in 10 or 20 years from now, the length of the period in relation to the expected life of the innovation, but not strictly limited to that.

When talking about the alignment with the user, this includes the full spectrum of the term. Thus including alignment with his knowledge and experience, including alignment on a cultural level (relevant for his willingness to operate the product), and so on. It should also go beyond the stereotype employee or crew member, including all employees and crew members.

The contribution to the development of the organisation also reflects on a number of factors or subcriteria, such as:

- The contribution to the knowledge and experience of employees and crew members.
- Future positioning of the organisation.
- Effects on personnel (hiring and outflow).
- Age structure of the organisation.
- Job satisfaction.
- Average time on the job, lead time of employees and volunteers.
- Employability of staff and crews.

Finally, when reflecting on the secondary financial effects and benefits, she mentioned as an example, amongst others, the reduction of financial burdens from health issues. If a project or innovation con-

tributes to a reduction of illness and work leave, this benefits the organisation and these secondary effects are to be included in the decision.

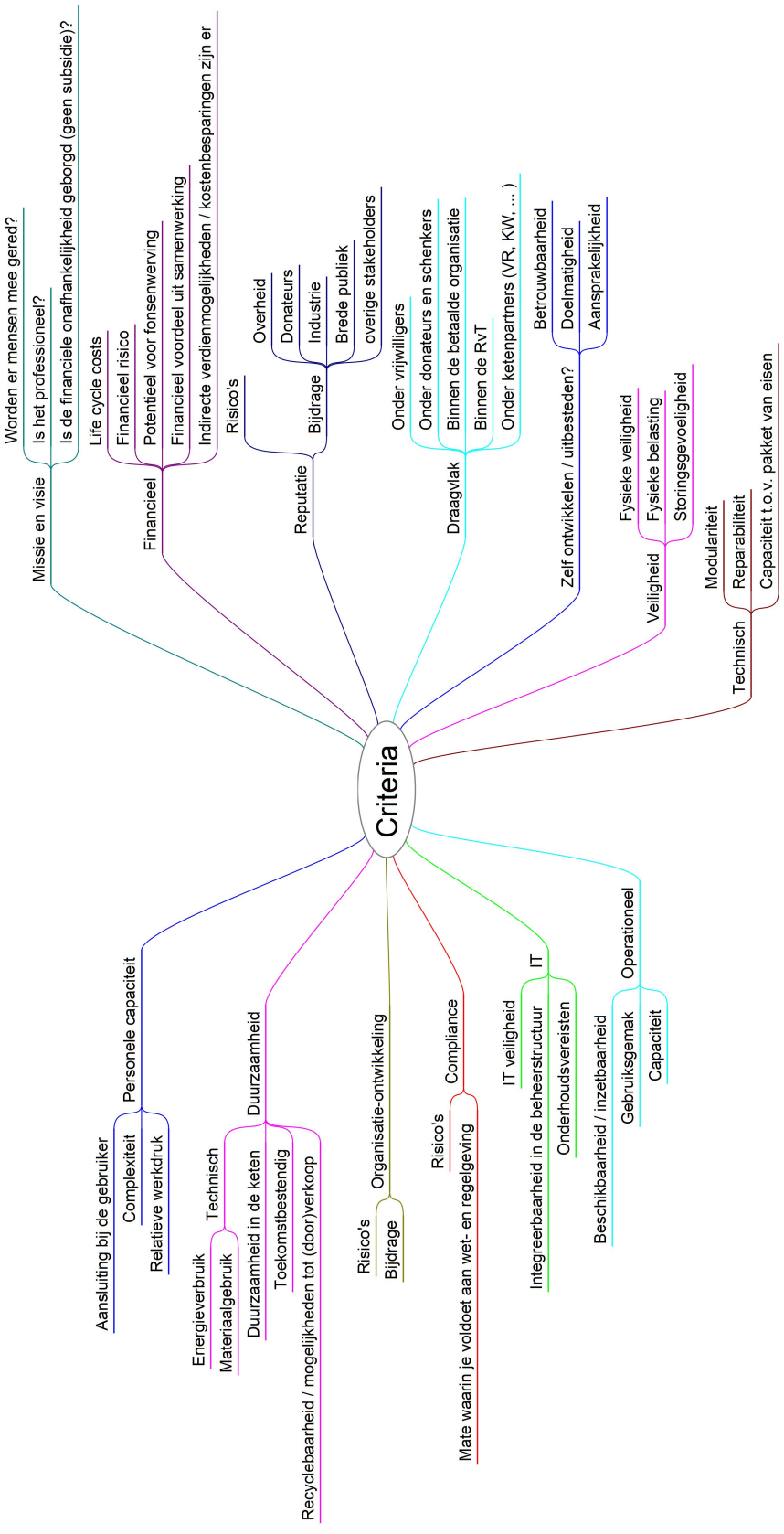


Figure H.1: The set of criteria as proposed by the Policy Advisor.

Interview with a financial specialist

This transcript denotes what was being said during the interview between the author and a financial expert, working at the financial department of the KNRM, on the 23^{rd} of October 2020, which lasted approximately an hour . Because of the COVID19 restrictions and recommendations, the interview was held online, using video-teleconferencing software. The interview was used to establish the criteria as per step 1 of the BWM.

The expert commented on the necessity of filtering out irrelevant options prior to usage of the model, the criteria presented reflect a set of criteria relevant only to viable alternatives rather than all available options.

She also mentioned safety measures should also include reduction of vibrations and shock absorption. Similarly, cyber security is integrated in the criterion for safety. And when addressing donors, this integrates the opinion of all donors irrespective of their background, groups or other characteristics.

She stipulated morale should be an essential part of the appearance and experience. This criterion is to include the effects the project has on users and observers, as such a much richer appreciation than it may seem at first glance.

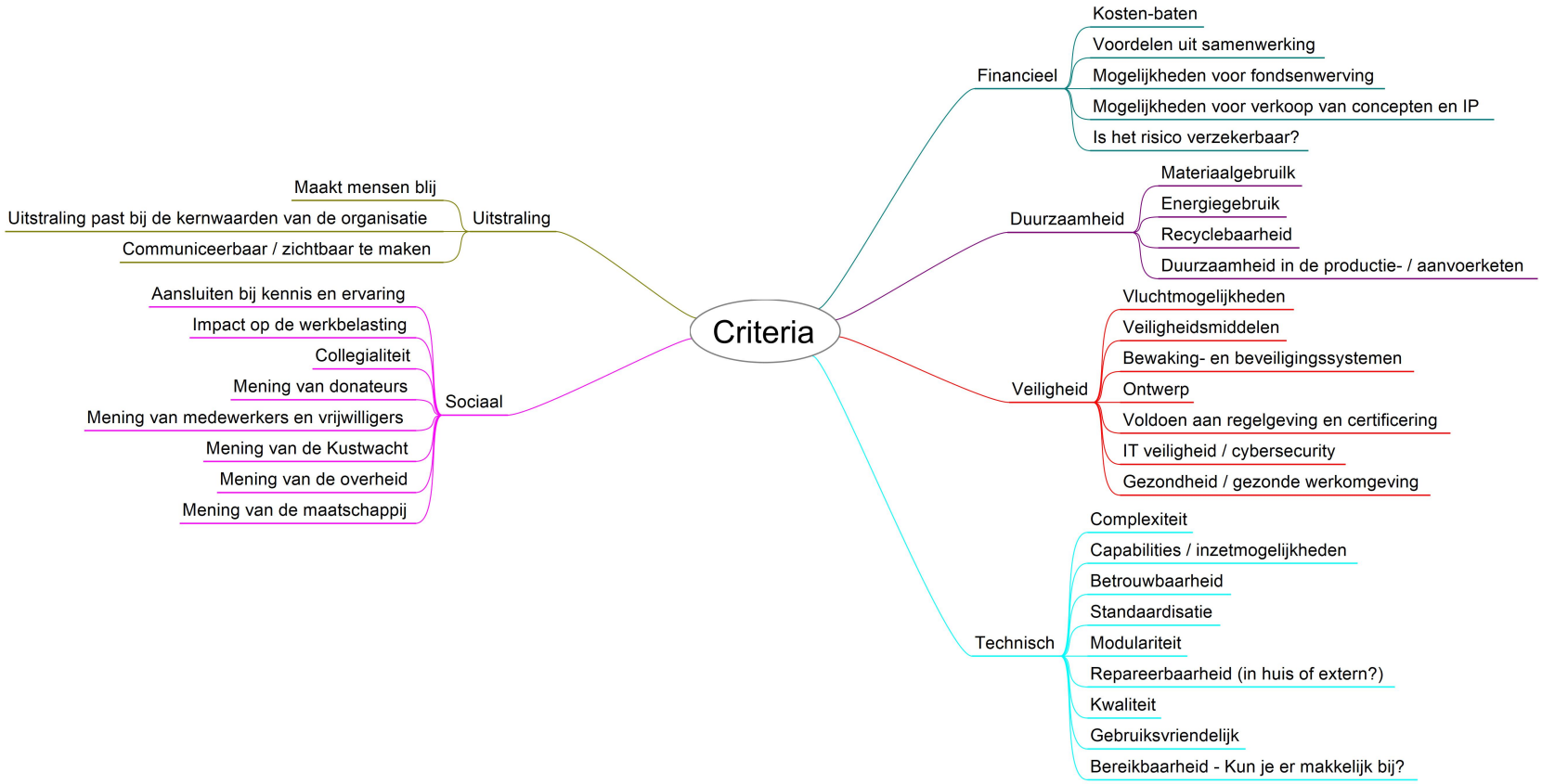


Figure I.1: The set of criteria as proposed by Nancy Barten.

J

Criteria integration

After the initial integration, a number of criteria was identified to supplement the model. An overview of the initial integration is shown in figure J.1.

To acquire this set of criteria, the following steps have been taken:

1. Create the category of operational criteria.
2. Rename the category 'to be categorised' to read 'Other'.
3. Integrate 'Reputation' and 'Support' to read 'Perception amongst stakeholders'
4. 'Dependencies internal departments' is integrated in 'Internal reputation - professional', where the definition of 'Reputation' is to include 'effects on relationship'.
5. 'Workload' is introduced as an criteria under 'Social aspects' and integrates the safety aspect of the workload as mentioned by some, the health aspect of workload mentioned by others and the physical workload.
6. Introduce category 'Project specifics' to include some criteria mislocated in other categories, such as the number of stakeholders involved, whether to do in-house or source externally, ease of implementation and contractual conditions.
7. The category of compliance is also integrated within the category of 'project specifics'.
8. The criterion 'Knowledge - In our own hands or need for outsourcing?' is reformulated to read 'Dependency on outsourcing for specific knowledge' and as such moved to the category 'In house / outsourcing'.
9. The criterion of 'vibrations' is relocated under the category of 'health aspects' rather than 'safety'.
10. The criterion of 'exhaust fumes (i.r.t. inhalation)' is relocated under the category of 'health aspects' rather than 'safety'.
11. Remove criteria that were mentioned by one interviewee only[1]. The following criteria have been removed:
    - The distinction between preventive and corrective maintenance, under repairability.
    - The distinction between large blocks of components and interchangeable components. The prior is already included in the model under 'modularity', while 'standardisation' is to read the interchangeability of both modules and individual components.
    - 'Access' in relation to maintenance. This is also to be taken into account when assessing the repairability.
    - 'Can withstand the elements', as mentioned as a technical criterion, is integrated with 'quality'.
    - 'Controllability' is mentioned both in a technological as well as in an Information Technology (IT) sense. These interpretations are integrated into the criterion 'controllability'.
    - IT maintenance requirements. This criterion is to be integrated with the integration of the IT-department dependency on internal departments, which is integrated in the reputation category.

[1] Of these criteria, some are left in, when deemed that they fill an essential gap or a function deemed essential for the model to fulfil the tasks mentioned in the main text of the research, as described in paragraphs 2.5 and 3.4.2.

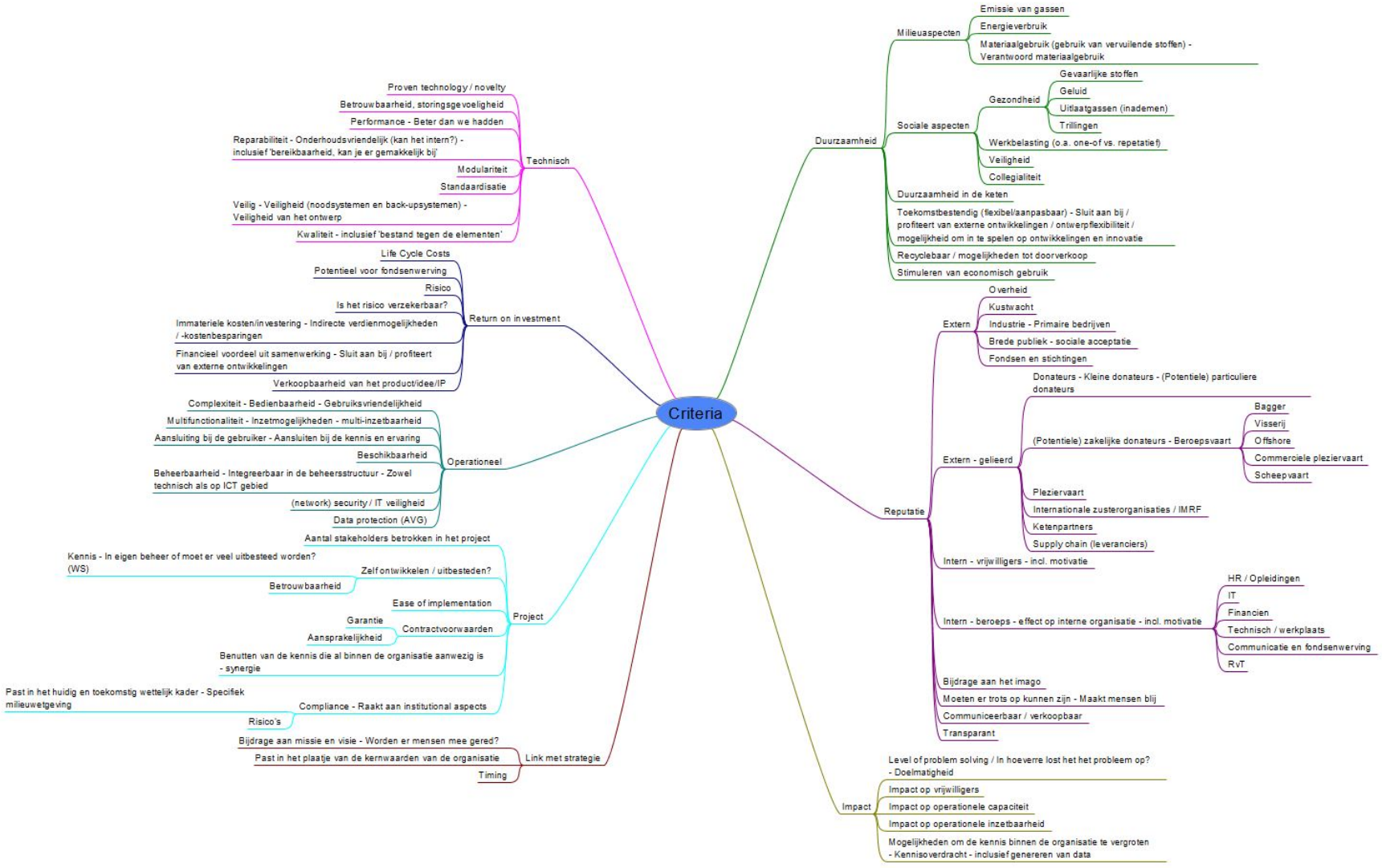


Figure J.1: The set of criteria after the first part of the integration has been completed.

- The criterion 'synergy with external developments and design flexibility' mentioned specifically for IT aspects, is mentioned singularly and therefore this criterion is integrated with the same criterion mentioned in the 'sustainability' category.
- The criterion 'IT security risk' is removed, as it overlaps with 'IT security' or '(network) security'.
- The criterion 'relative workload' is removed from the category 'operational' as this criterion also exists in the category 'social aspects' of 'sustainability'.
- The criterion 'automation - contribution to a reduction in workload' is removed from the category 'acrshortit', as this argument is deemed to be part of the overall assessment of the workload, while no other interviewee underwrites the need to further specify this criterion.
- The criterion 'Data generation which can be used for control purposes' is integrated in the criterion 'knowledge transfer'.
- The criterion 'transportability' is removed.
- The criteria 'availability' mentioned under the category 'technical' and 'operational' are integrated into a single criterion.
- The criterion 'Contribution to the the organisational development' is removed as it doubles with the category impact.
- The criterion 'Risks' is removed from the category 'organisational development'.
- The criterion 'efficiency' is integrated with the criterion 'level of problem solving' in the category 'impact'.
- The criterion 'Compliance with the law' is removed, as it is a requirement for any option to be taken into account as a variant.
- The criterion 'CO_2 emissions' is removed.
- The distinction between operational energy consumption and standby consumption is removed.
- The criterion 'Fueltype' is removed. Most interviewees argued that the overall energy consumption, together with the emission of gasses together would cover the same arguments.
- The criterion 'Healthy working environment' is integrated with its category 'health aspects'.
- The criterion 'Physical safety' is removed, as it is integrated in the general 'safety' criterion.
- The criterion 'Escape options' is removed, as it is integrated in the general 'safety' criterion.
- The criterion 'Safety means' is removed, as it is integrated in the general 'safety' criterion.
- The criterion 'Safety and security systems' is removed, as it is integrated both in the general 'safety' criterion and in the criterion 'safety' within the 'technical' category, which entails emergency- and back-up systems.
- The criterion 'motivation' is removed, as it overlaps both with the reputation amongst internal actors and the 'impact under volunteers' criterion.
- The criterion 'competence' is removed, as it is integrated in the criteria 'complexity' and 'possibility to extend the knowledge within the organisation'.
- The criterion 'lifespan' is removed.
- The criterion 'benefits' is removed, as this aspect is covered in the criterion 'Life Cycle Costs'.
- The criterion 'costs (total costs of ownership)' is removed, as this aspect is covered in the criterion 'Life Cycle Costs'.
- The criterion 'return on investment' is removed, as this aspect is covered in the criterion 'Life Cycle Costs'.
- The criterion 'fits within the budget' is removed, as this aspect is covered as an requirement for an option to be included in the variants.
- The criterion 'time - related to the development of the return on investment over time' is removed.
- The criterion 'financing' is removed.
- The distinction between active and passive opportunities for fund raising is removed.
- The criterion 'Other stakeholders' is removed, as this is already covered in the criterion 'the public at large'.
- The criterion '(reputation) risks' is removed.
- The criterion 'professionalism' is removed.
- The criterion 'financial independence' is removed.

12. Then, a number of criteria was integrated, based on the specific specialism of the interviewee

who contributed them. This entails the following criteria:
- Exhaust fumes - in relation to inhalation.
- Vibrations.
- Funds and foundations.
- Contribution to the reputation.
- Transparency.
- Impact on volunteers.
- Impact on operational performance.
- Impact on operational capacity.
- Timing.
- The number of stakeholders involved in the project, in relation to the effort and risk stemming from the management of a large number of contractors and/or sub-contractors.

13. In the categories that refer to groups of stakeholders, externally and internally, a subdivision has bee sought covering the full range of stakeholders, from the groups that were mentioned by the interviewees.
14. The criterion 'does it save lives?' doesn't qualify to be a single criterion within the category 'alignment with the mission and vision of the organisation'. Therefore, it is removed as a sub-criterion and integrated with the mission and vision.
15. The category 'IT' is removed, the two criteria remaining inside this category are included under the category 'operational'.
16. The category 'organisational development' is removed. The criterion 'synergy' is moved to the 'project' category, whilst the criterion 'opportunity for organisational learning' is moved to 'impact'.

Having concluded the initial part of the integration, some questions remained. This originated either from criteria that (partially) overlapped, or different scopes mentioned for certain criteria by different interviewees. This clearly showed, amongst others, the need for a clear scoping of certain criteria that were not immediately, or in a similar manner, clear to the interviewees.

Then, the model allows the doubling of criteria, in particular when the scope of one criteria is larger than the scope of the other criteria. This allows the organisation to further emphasize certain aspects within the scope of any given criterion. For instance, insurance is only one of many risk mitigation measures. So, if, for any reason, the organisation has particular interest in taking the insurance into account more profoundly, it can be included as a separate criterion next to risk mitigation. However, this choice is one the organisation has to address. Therefore, the remaining dilemma's were stated as questions and posed to the organisation to answer.

The set of criteria gained from the integration is shown in figure J.2. The arrows in the figure refer to the remaining dilemma's.

The dilemma's were presented to the organisation as shown in figure J.3.

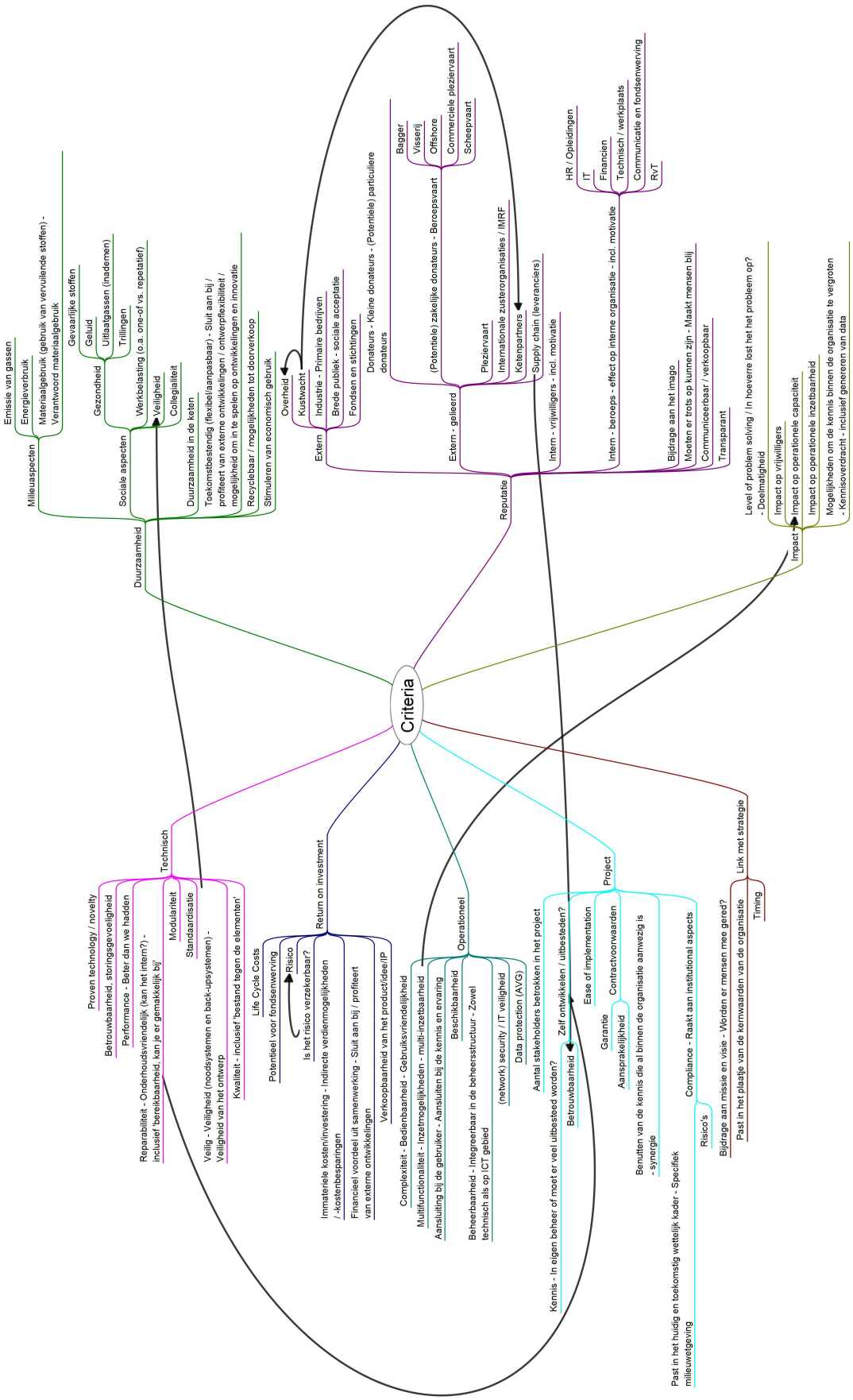


Figure J.2: The integrated set of criteria, before answering the dilemma's.

Dilemma's

Voor het compleet maken van de criteria zit ik met de volgende dilemma's. Het gaat om criteria die maar een of twee keer genoemd zijn in de interviews (onder de drempel voor integratie), maar waarvan het mogelijk toch zinvol is om ze op te nemen. Het gaat om de volgende criteria:

1. Het element 'veilig' is nu twee keer opgenomen, waarbij de aangegeven betekenis niet vrij is van overlap. Dit geeft duidelijk het belang aan van dit criterium. Is de manier waarop het nu is opgenomen, waarbij de ene interpretatie technisch ((technische) voorzieningen) kijkt en het andere criterium ook de emotionele beleving van veiligheid en de 'gevolgen' van veiligheid kijkt. Hoe kijk(en) jij/jullie hier tegenaan?
2. Het criterium 'toeleveringsketen' wordt nu in twee categorieën meegenomen, zowel waar het gaat om de reputatie van de stakeholders binnen een project, als waar het gaat om de duurzaamheid in de keten. Deze criteria overlappen wel, het tweede deel belicht een klein deel van alle eigenschappen van een aanbieder. Aan de andere kant wordt hierdoor een specifieke eigenschap nader belicht, wat extra context geeft over hoe de KNRM naar haar toeleveranciers kijkt. Hoe kijk(en) jij/jullie hier tegenaan?
3. Moet er een criterium worden opgenomen die de risico's ten aanzien van het verwerken van persoonsgegevens i.r.t. de AVG meeneemt in de afweging?
4. M.b.t. de reputatie van de leveranciers, is er behoefte om onderscheid te maken tussen de betrouwbaarheid van de leveranciers van variant A, vs. de reputatie van variant A onder andere leveranciers, waarbij het laatstgenoemde criterium meer kijkt naar 'zouden andere leveranciers er iets van vinden als je met leverancier/consortium A zaken zou doen voor het construeren van variant A'?
5. Als het gaat over het criterium financieel risico, is het dan zinvol om een apart criterium op te nemen voor het verzekerbaar zijn van dit risico? Of wordt dit meegenomen door het financieel risico te definiëren als het restrisico na verzekeren en de kosten van een eventueel gekozen verzekering op te nemen in de life cycle kosten?
6. Met betrekking tot het voldoen aan toekomstige regelgeving, is het zinvol om onderscheid te maken tussen het voldoen aan verwachte toekomstige regelgeving en de compliance risico's?
7. Er wordt nu een aparte afweging gemaakt aangaande zelf ontwikkelen vs. uitbesteden (een overweging die niet uit het onderzoek naar voren komt maar evengoed relevant kan zijn, in hoeverre de huidige criteria ingaan op de vraag of er ook optimaal gebruik gemaakt wordt van de kennis en competentie in de markt). Daarnaast wordt er bij het criterium 'reparabilitiet' meegewogen of het onderhoud in eigen beheer gedaan kan worden of moet worden uitbesteed. Deze laatste vraag speelt geen rol in de criteria die nu zijn opgenomen in de categorie 'zelf ontwikkelen / uitbesteden', waardoor er geen overlap is. Hoe wil(len) jij/jullie deze criteria opgenomen hebben?
8. Wanneer er wordt gekeken naar de stakeholders, worden onder andere de volgende drie criteria aangehaald: 'Overheid', 'Kustwacht' en 'ketenpartners'. Wanneer het gaat over de Kustwacht, maakt deze, in meerdere of mindere mate, onderdeel uit van al deze groepen, waardoor er ook overlap ontstaat tussen de criteria. Op welke manier moet de Kustwacht opgenomen worden? Hoe kijk(en) jij/jullie aan tegen dit onderscheid, is het zinvol om alle criteria apart te evalueren, is dat onderscheidend?

Figure J.3: The dilemma's as presented to the KNRM

K

Interview with the CTO addressing some dilemma's

This transcript denotes what was being said during the interview between the author (A) and the Chief Technology Officer (CTO) of the Koninklijke Nederlandse Reddingmaatschappij (KNRM) on the 27^{th} of January 2021, which lasted approximately one hour.

During the interview, a number of dilemma's have been discussed, in order to address issues that were identified while integrating the criteria. This interview was used to establish the organisations standpoint on these criteria.

First of all, safety was discussed. As found during the initial interview, safety is an important criterion to the organisation. This is reflected in the criterion being mentioned in two different contexts. First of all, it was mentioned in a technical context, referring to the presence of redundancy and the effectiveness of safety systems. Second of all, it was mentioned in a social context, referring to the safety for the volunteers or staff working with the product, equipment, or other evaluated project. Rather than the focussing on the systems, it focusses on the human side of things and the effect, including the emotional effect, of a project, on staff and volunteers. Therefore, both criteria were found to cover a different ground and both have their value in the model and both are to be retained.

The interviewee also mentioned the organisation implements a task risk assessment during its decision making process. Therefore, an evaluation of what risks should be insured, is also part of the process. Therefore, insurance is not needed as a separate criterion; it is covered in the mitigated risk, while the costs of insurance are integrated into the life cycle costs.

The interviewee stated the inclusion of the risks in respect to the General Data Protection Regulation, was in order, integrating the risk with other risks originating from data protection.

With respect to the supply chain, the interviewee mentioned that it was important to evaluate projects from their perspective, as there are many companies delivering products or services either with a reduction or even below production costs as a charity donation to the KNRM. Thus, the KNRM has an interest in these suppliers as stakeholders in the organisation and the continuation of this kind of support is of great future value to the organisation.

When it comes to compliance, there is no need to distinguish between current and future regulations. Covering both regulations as a single criterion, along with risks resulting from potential compliance issues, covers the interests of the organisation.

The repairability is assessed to be a technical criterion and not related to the decision whether the balance of in-house and procurement matched the organisation profile. The pressure on the organisation, both in workload and in motivation is also taken into account in other criteria, for instance in the impact on the organisation and in the internal reputation criteria.

The Coastguard and the government should both be retained, as they are both stakeholders in the Search and Rescue (SAR) 'industry'. As such both are valuable stakeholders to take into account. Furthermore, both stakeholders play a different role in shaping the state of play. For instance, the government focuses on policy and large concepts on a strategic level, while the Coastguard is a player active in the hot phase of the operation and therefore active both in the tactical and operational level.

These answers result in the transformation of the set of criteria shown in figure J.2 into the set of criteria shown in figure 5.1.

Test case

This document presents the test case used for evaluation for the model evaluation phase of this research. During the course of the research, some minor changes were made to the test case, which didn't affect the core of the document. On the following pages, version 1.1 is shown, including these changes. Some interviewees received version 1.0 to base their decisions upon. This version is also available for comparison and can be requested from the author if required.

The choice presented in the document below, was both actual and relevant to the interviewees, as the Koninklijke Nederlandse Reddingmaatschappij (KNRM) is about to select the successor of the current Caterpillar tractor for launching and recovering the lifeboats of the organisation. Many of choices and criteria are currently under scrutiny, for instance whether or not to include them in the document of requirements, or what solutions for certain problems are being preferred by the organisation. This both contributed to the interested of the interviewees, but also sometimes resulted in discussions and conversation on the future discussion for the KNRM. Although this may have occasionally been distracting from the aim of this research, it also contributed to the decision the KNRM is about to take and was therefore of value to the organisation.

Furthermore, some parts of the test case are blanked out. This involves part of intellectual property of a third party involved in designing the alternatives for the KNRM. The information concerns specific details of the implementation of the electrical system of the variants. This information was important to include, as it influenced the initial choices made by the interviewees. An original can not be released by the author unless a request comes accompanied from a signed permission from Next Generation Machinery, giving their consent to the release.

Technische Universiteit Delft

Evaluatie projectvoorstellen vervanging Lanceervoertuig Strandreddingboot

Auteur:

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[3] *Koninklijke Nederlandse Reddingmaatschappij*

May 30, 2021

Abstract

Dit stuk presenteert een aantal (fictieve) oplossingen voor het vervangen van de lanceervoertuigen (tractor) voor de strandreddingboten van de Koninklijke Nederlandse Reddingmaatschappij (KNRM). Het doel hiervan is om een kader te scheppen voor het evalueren van de projecten aan de hand van de - voor de organisatie - relevante criteria. Daarvoor wordt een fictief scenario geschetst, waarbij beslissers de keuze wordt voorgelegd tussen meerdere varianten. Dit document geeft achtergrond bij die diverse varianten, al dan niet expliciet op de criteria waarop getoetst gaat worden. Het eerste scenario is het referentie-scenario, namelijk het vervangen door een nieuwere generatie tractors gebaseerd op hetzelfde principe als de huidige - diesel aangedreven - tractors. Het tweede scenario is een vergelijkbaar scenario, maar ditmaal wordt uitgegaan van Hydro-treated Vegetable Oil (HVO) als brandstof. Het derde scenario gaat uit van dezelfde tractor, maar ditmaal met een elektrische aandrijving en het laatste scenario gaat uit van een afstand-bestuurde geïntegreerde bootwagen, waarbij aandrijving, energieopslag en de boot alledrie geïntegreerd zijn in hetzelfde platform. Van dit laatste scenario zijn twee varianten opgenomen, die afkomstig zijn van twee fictieve aanbieders, met verschillende karakteristieken. Zo is een divers scenario gecreëerd met meerdere verschillende varianten, om een zo realistisch mogelijke casus te genereren en de gebruikers van het model een zo realistisch mogelijke keuze voor te leggen, waarbij er ook wat valt te kiezen (e.g., de varianten zijn onderscheidend).

Koninklijke Marine

KNRM

TU Delft

Toelichting

Deze cases horen bij een onderzoek naar de rol van duurzaamheid binnen de strategische besluitvorming over projecten binnen de Koninklijke Nederlandse Reddingmaatschappij (KNRM). Deze cases zijn fictief en hebben tot doel om een realistische keuze te simuleren voor de vervanging van de huidige tractoren, nu deze het einde van de levensduur naderen en de aanhangwagens aangepast moeten gaan worden voor de Van Wijk-klasse. In de cases worden drie verschillende tractoren besproken, die niet alleen in het ontwerp van elkaar verschillen, maar ook in de rest van de project en op andere criteria van elkaar verschillen. Het is nu aan de beslisser om een keuze te maken tussen de alternatieven. Dat gaat zowel op basis van gevoel en in een tweede instantie door de alternatieven te scoren met behulp van het model. Hierbij wordt er onder andere gekeken of dit tot dezelfde keuze lijdt.

De criteria die in het model zijn opgenomen zijn niet allemaal evenveel van toepassing op deze casus, danwel zijn er criteria waarop de alternatieven niet van elkaar verschillen, omdat het om min of meer vergelijkbare oplossingen gaat voor hetzelfde probleem. Het model is echter ook in staat om andersoortige probleemstellingen aan te kunnen. Daarom is het dan in dit geval nodig om de alternatieven dezelfde score te geven, omdat de alternatieven op een dergelijk criterium niet van elkaar verschillen. Deze criteria zijn dan niet onderscheidend binnen dit probleem.

Uiteindelijk lossen alle alternatieven het probleem - een reddingboot naar de vloedlijn vervoeren, te water laten, oppikken en terug brengen naar het reddingstation - op, maar alle alternatieven hebben voor- en nadelen. Een keuze zal dus altijd een afweging zijn tussen deze argumenten. Er is dan ook geen goed of fout, de keuze moet aansluiten bij persoonlijke kennis, ervaring en gevoel.

Figure 1: Lancering van de reddingboot van Katwijk door een Caterpiller Beach Launcher (foto: KNRM)

De vijf concepten verschillen met name op het gebied van aandrijftrein en besturing. Daarbij is de eerste variant een nulmeting, gebaseerd op de huidige tractor. De tweede variant is daar direct van afgeleid. Het is dezelfde tractor, maar dan geoptimaliseerd voor het gebruik van Hydro-treated Vegetable Oil (HVO). De derde variant is ook gebaseerd op het huidige casco, maar dan met een elektrische aandrijving, zoals onderzocht door het bedrijf NGM[1]. De vierde en vijfde variant hebben ook een elektrische aandrijving, maar dan zonder een bestuurder op de tractor. In die plaats wordt de tractor op afstand bestuurd. Er zijn twee bedieningsmogelijkheden, een op de reddingboot en een op het strand. Wie de primaire besturing heeft kan tussen de bestuurders onderling worden afgesproken en overgegeven. Dit geeft de mogelijkheid om de onderdelen die nodig zijn voor de aandrijftrein op een andere manier te integreren in de trailer. In een van de opties is gekozen voor een volledige integratie in de trailer, in de andere optie is gekozen voor een losse unit die modulair te vervangen is.

[1]Zie ook: Grootes, T en Bakker, R., *Haalbaarheidsonderzoek elektrische tractor aandrijving.* Revisie 0, 22-5-2020.

De overige verschillen zitten onder andere in de filosofie, missie en visie van de aanbieder en de aangedragen oplossingen. Aan de andere kant zijn er ook een aantal zaken niet onderzocht, en vragen om een interpretatie van de gebruiker. Een voorbeeld hiervan is het effect op het imago of effect op de moraal van de vrijwilligers en of er verzekeringen zijn die (een deel van) de risico's van de projecten willen verzekeren, en zo ja, tegen welke premie. Deze gegevens zullen in een echte situatie/toepassing ook niet bekend zijn, danwel geld kosten om te achterhalen (bijvoorbeeld omdat een aanbieder hier onderzoek voor moet doen of er enquêtes moeten worden georganiseerd onder een bepaalde partij of stakeholder).

Bij alle tractoren wordt uitgegaan van een levensduur van 25 jaar, want het casco en de tracks zijn de grootste beperking in levensduur, niet de aandrijftrein. Daarnaast wordt er verondersteld dat binnen de gehele vloot geen motoren te hoeven worden vervangen, het gebruik is dusdanig laag dat daar, bij regulier gebruik, geen aanleiding voor is. Verder is er bij alle tractoren, om een eerlijk vergelijk mogelijk te maken, uitgegaan dat alle tractoren vervangen moeten worden en ontwikkelkosten verdeeld kunnen worden over het afnemen van tien tractoren.

Wanneer er een cabine wordt gebruikt op de tractoren, zal deze uitgerust worden met dezelfde apparatuur, die bovendien, waar mogelijk, gestandaardiseerd is met de apparatuur op de reddingboten (zoals bijvoorbeeld C2000, VHF en Reddingbrigade-setjes).

Evaluatie huidige tractor

Alvorens de keuze te maken voor een nieuwe tractor, is er gekeken naar de ervaringen met de huidige tractor en is daaraan het een en ander aan data verzameld. Zoals waarschijnlijk bekend dient de tractor om de strandreddingboten te verplaatsen van het boothuis naar de vloedlijn. Om de reddingboot, die in een trailer vervoerd wordt, moet de tractor een stuk de zee inrijden, waarna de steunen in de trailer hydraulisch naar beneden bewogen, waarna de boot uit de trailer kan varen. Bij het recoveren van de boot verloopt het proces omgekeerd. De boot vaart het strand op, waarna de tractor de trailer onder de boot manoeuvreert

Momenteel bestaat de vloot van tractoren uit de volgende types:

Aantal	Type	Vermogen
2x	Challenger 65D	320 pk
1x	Challenger 65E	320 pk
3x	Challenger 75E	340 pk
3x	Challenger 85E	370 pk
2x	Challenger 95E	410 pk

Table 1: Huidige vloot van tractoren

In een eerder onderzoek[2] is het gebruiksprofiel van de tractor op Terschelling geanalyseerd. Hieruit zijn een aantal bevindingen gedaan die inzicht geven in hoe de tractors nu ingezet worden en waaraan een opvolger zou moeten voldoen. In dit onderzoek kwam naar voren dat de langste inzet van de tractor in de gemeten tijd 3,8 uur per etmaal bedraagt, over de meetperiode van een jaar. Het totaal aantal draaiuren in de meetperiode was 78 uur. Daarnaast laat het onderzoek zien dat het geïnstalleerde vermogen slechts zelden aangewend wordt en dat de motoren het grootste deel van de tijd in deellast draaien, waarbij de motor ongeveer 33% van de tijd stationair draait.

Brandstofverbruik

Bij de metingen is een totaal jaarlijks brandstofverbruik gemeten van 1361,5 liter. Hierbij moet wel worden opgemerkt, dat de laatste anderhalve maand samenvielen met de eerste lockdown op 12 maart 2020, waardoor in de praktijk mogelijk een licht hoger jaarlijks verbruik verwacht kan worden. Daarbij geldt dat een liter diesel een energetische waarde heeft van 10 kWh, waarbij geldt dat HVO een licht hogere energetische waarde heeft. Dit verschil is klein en wordt daarom in deze berekeningen niet meegenomen. In de tabel 2 worden de energieprijzen van de verschillende brandstoffen weergegeven, alsook omgerekend naar prijs per kWh. In de berekening hiervan wordt er rekening mee gehouden dat de energie uit de brandstof wordt omgezet in een verbrandingsmotor, waarbij wordt gerekend met een gemiddelde motorefficiëntie van 30 %.

[2]NGM heeft het gebruikspatroon geanalyseerd in een haalbaarheidsstudie voor een elektrische tractor.

Diesel (B7)	**HVO 100**	**HVO 50**	**HVO 30**	**HVO 20**	**Elektriciteit**
0,70 [ct/l]	+ 15 - 20 [ct/l]	+ 8 - 10 [ct/l]	+ 5 - 7 [ct/l]	+ 3 - 5 [ct/l]	-
23 [ct/kWh]	29 [ct/kWh]	26 [ct/kWh]	25 [ct/kWh]	25 [ct/kWh]	13 [ct/kWh]

Table 2: Caption

Hieruit kan worden afgeleid dat de brandstofkosten voor de tractor in Terschelling bedroegen:

$$1361,5\ [l/jaar] * €\,0,70 = €\,953,05\ [/jaar] \tag{1}$$

Een tractor die in plaats van reguliere diesel op HVO 30 draait, kost jaarlijks aan brandstof:

$$1361,5\ [l/jaar] * €\,0,76 = €\,1034,50\ [/jaar] \tag{2}$$

Hierbij moet wel worden opgemerkt, dat HVO-brandstoffen nog niet direct beschikbaar zijn bij alle brandstofaanbieders. Dat betekent dat er mogelijk transport georganiseerd moet worden om de brandstof op het station te krijgen. Anderzijds, door ontwikkelingen in met name de transportsector, is te voorzien dat dit probleem op de middellange termijn (5 tot 10 jaar) zal verdwijnen. Daarnaast kan er hierbij synergie optreden als ook de reddingboten zelf overschakelen op brandstoffen waarin HVO is bijgemengd. Een gelijke mengverhouding is dan natuurlijk wel een voorwaarde om hiervan te profiteren.

Ter vergelijking, een elektrisch voertuig dat een motorefficiëntie haalt van 95 %, kost jaarlijks in het verbruik:

$$1361,5\ [l/jaar] * \frac{10\ [kWh/l] * 0,3}{0,95} * €\,0,13\ [/kWh] = €\,558,95\ [/jaar] \tag{3}$$

Figure 2: De huidige beach launcher van Caterpillar met een conversie van Habbeke shipyards. (foto: Roy Storm)

Batterijtechniek

De ontwikkelingen op het gebied van batterijen gaat heel snel. Daarmee geldt in het algemeen de aanbeveling om de keuze voor batterijtechniek en de leverancier uit te stellen tot op een later moment in het project, omdat dan de laatste ontwikkelingen meegenomen kunnen worden in het project. Aan de andere kant is er in dit geval voor gekozen om de aanbieders te laten presenteren waar ze op sturen, bijvoorbeeld op de filosofie van de aanbieder of op bepaalde eigenschappen van de batterijen, zoals de capaciteit per gewichtseenheid (energiedichtheid) van de batterij. Voor industriële toepassingen wordt overwegend gekozen voor levensduur en constante performance (lage degradatie). Of dit voor de KNRM ook het leidende argument moet zijn, moet nader onderzocht worden, met name omdat het aantal laad- en ontlaadcycli dat de batterijen ondergaan aanzienlijk minder is dan in een gebruikelijke industriële toepassing.

Er geldt in het algemeen dat alle voordelen meestal ook een of meerdere nadelen kennen, waardoor er geen universele techniek aan te wijzen is die voor alle toepassingen de optimale keuze is. Zo heeft een batterij die een optimale capaciteit per kilogram gewicht vaak het nadeel dat deze langzaam oplaadt en een korte levensduur heeft. Een batterij voor industriële toepassing heeft daarom vaak een beperkte capaciteit, omdat er gekozen wordt voor een optimale levensduur. De keuze is dus altijd maatwerk in relatie tot de specifieke toepassing waarvoor de batterij bedoeld is. En de keuze is dan ook een van de belangrijkste keuzes in een ontwerp. De kosten van de batterijen zijn nu opgenomen in de bouwkosten, maar het zou ook interessant kunnen zijn om deze apart op te nemen in een kostenoverzicht.

Om een algemeen beeld te geven van de huidige stand van zaken, worden er een aantal actuele technieken besproken en worden de belangrijkste eigenschappen toegelicht[3]. Voor het analyseren van de laad- en ontlaadsnelheid wordt gebruik gemaakt van de C-ratio. Deze ratio gaat uit van een standaard ontlaadtijd van 1 uur bij een stroom van 1 A. Een batterij met een ontlaadratio van 2C levert dan 30 min lang een stroom van 2 A, waarbij hetzelfde vermogen dus in minder tijd beschikbaar komt.

Lithium Kobalt Oxide

Lithium Kobalt Oxide (LCO) ($LiCoO_2$) kenmerkt zich door een hoge energiedichtheid, waardoor de batterijen uitermate geschikt zijn voor kleine toepassingen en kleine apparaten, zoals elektronica, laptops en mobiele telefoons. Naast de LCO kathode bestaat de batterij uit een anode van grafiet en carbon. Het nadeel van dit type batterijen is de relatief korte levensduur, lage thermische stabiliteit en beperkte laad- en ontlaadvermogen (de grote hoeveelheid opgeslagen energie is dus niet direct beschikbaar, maar komt vrij over een lange ontlaadperiode). Dat heeft onder andere tot gevolg dat wanneer de batterij bij lage temperatuur te snel geladen wordt, de structuur van het elektrolyt veranderd, waardoor het elektrolyt dikker wordt aan de anode en er een lithium laag aangroeit. Deze degradatie beperkt het aantal laad- en ontlaadcycli, afhankelijk dus van de temperatuur en de laadstroom.

Als laatste is voor deze batterijen veel Kobalt nodig, dat onder erbarmelijke omstandigheden in overwegend de Democratische Republiek Congo gewonnen wordt.

Lithium Manganese Oxide

Lithium Mangaan Oxide (LMO) ($LiMn_2O_2$) is een eerste verbeteringsslag ten opzichte van de LCO batterijen, met name op het gebied van veiligheid (vanwege de hogere thermische stabiliteit), maar ook met een lagere interne weerstand. Daar staat tegenover dat de batterijen een aanzienlijk lagere specifieke energie (ongeveer 1/3 van LCO) en een kortere levensduur hebben, zowel in het aantal laad- en ontlaadcycli, maar ook in absolute (kalender) leeftijd. Aan de andere kant kunnen deze parameters nog wel een beetje beinvloed worden aan de hand van de specifieke wensen van de klant, waardoor de batterijen, binnen een zeker bereik, nog iets bijgesteld kunnen worden. Ook zijn er nog ontwikkelingen in het specifieke design, waardoor de specifieke energie, veiligheid en levensduur nog continue verder verbeterd worden, bijvoorbeeld door de kathode te mengen met Lithium-Nikkel-Mangaan-Kobaltoxide (NMC).

De lagere interne weerstand zorgt voor een betere energieafdracht, waardoor de batterij sneller ge- en ontladen kan worden, waardoor er meer vermogen in een korte tijd beschikbaar is, zonder dat er veel warmte vrijkomt.

Vanwege deze eigenschappen, worden de batterijen veel toegepast in (zwaar) gereedschap, medische instrumenten en hybride- en elektrische auto's (voor het laatste vooral in combinatie met NMC).

[3]Voor deze analyse is de website https://batteryuniversity.com als bron gebruikt, geraadpleegd op 21 februari 2021, waarbij de laatste update, als vermeld op de website, ook op deze datum had plaatsgevonden.

Lithium Nikkel Manganese Kobalt Oxide

Een andere succesvolle batterijtechniek gebruikt NMC, ($LiNiMnCoO_2$) als kathode. Alhoewel nikkel en mangaan individueel grote beperkingen kennen, levert het samenvoegen van deze metalen een legering die de beter is dan de som der delen. Zo heeft nikkel een hoge energiedichtheid, maar is het ook heel erg instabiel. Mangaan aan de andere kant vormt een speciale structuur[4] die zorgt voor een lage interne weerstand (wat hogere vermogens mogelijk maakt), maar heeft een lage energiedichtheid. En door de metalen samen te voegen, worden de positieve eigenschappen van beide metalen versterkt. Daarbij kan, door het veranderen van de mengverhouding, verder gespecialiseerd worden, afhankelijk van het gebruik van de batterij. Hierbij worden energiecellen (hoge energiedichtheid) onderscheiden van powercellen, die een hoog vermogen kunnen leveren.

Doordat er meerdere metalen in de legering zitten, wordt er in deze variant minder kobalt verwerkt dan in de eerder genoemde varianten (LCO en LMO). In de basis is de mengverhouding 1 op 3 nikkel, 1 op 3 kobalt en 1 op 3 mangaan. Dit staat ook wel bekend als 1-1-1. Hierbij wordt het reactieve nikkel gestabiliseerd door het kobalt. Maar vanwege de schaarste en de problemen met de winning is er veel onderzoek verricht naar het verminderen van de hoeveelheid kobalt in de mengverhouding, wat dan ook tot in zekere mate is gelukt. Zo zijn er combinaties met 6 delen nikkel, 2 delen kobalt en 2 delen mangaan, NMC622, en nog een aantal varianten.

NMC wordt dan ook gebruikt voor (zwaar) gereedschap, elektrische fietsen, aandrijftreinen van auto's en voertuigen, medische apparatuur en industriële toepassingen. Het gebruik van NMC is in opkomst, waardoor de prijzen steeds lager worden en het aanbod steeds breder. Het gebruik is vooral in opkomst bij gebruikers die de batterijen intensief gebruiken, dus waarbij levensduur een belangrijke factor is, zoals in de automobielindustrie en voor energieopslagoplossingen.

Parameter	$LiCoO_2$	$LiMn_2O_2$	$LiNiMnCoO_2$
Voltage [V]	3,60 V nominaal	3,70 V nominaal	3,60 - 3,70 V nominaal
Laadsnelheid [C-ratio]	0,7 - 1 C	0,7 - 1 C stand., oplopend 3 C	0,7 - 1C
Ontlaadsnelheid [C-ratio]	1 C	1 C stand., oplopend 10 C	1 - 2 C
Specifieke energie [Wh/kg]	150 - 200 Wh/kg	100 - 150 Wh/kg	150 - 220 Wh/kg
Cycle life	500-1000 cycli	300 - 700 cycli	1000 - 2000 cycli
Thermal runaway [°C]	150 °C	250 °C	210 °C
Kosten [$/kWh]	onbekend	onbekend	∼$420 per kWh

Table 3: Vergelijking van de batterijtechnieken LCO, LMO en NMC op een selectie van de belangrijkste parameters.

Lithium IJzer Fosfaat

Het volgende type kathodelegering is Lithium-IJzer-Fosfaat (LFP) ($LiFePO_4$). Deze kathode zorgt voor een batterij met een hoog vermogen, lange levensduur, goede veiligheid, hoge thermische stabiliteit en een hoge tolerantie voor mishandeling. Zo is de batterij onder meer beter bestand tegen snelladen. Daar staat tegenover dat de energiedichtheid aanzienlijk lager is dan bij andere batterijtechnieken.

Een ander groot voordeel is dat voor deze techniek geen kobalt nodig is. Daarmee heeft deze batterij veel minder ethische bezwaren dan andere technieken. Daarnaast heeft de abtterij relatief veel last van zelf-ontlading, wat alleen tegengaan kan worden met dure regelapparatuur.

LFP batterijen worden veel gebruikt ter vervanging van de loodaccu's in auto's. Daarbij is het wel een probleem dat de LFP-cellen minder goed bestand zijn tegen continue overladen, zoals dat in auto's wel gedaan wordt om sulfatering tegen te gaan.

Lithium Nikkel Kobalt Aluminium Oxide

De volgende techniek, Lithium Nikkel Kobalt Aluminium Oxide (NCA), of $LiNiCoAlO_2$, is nog volop in ontwikkeling. Het is een doorontwikkeling van NMC, waarbij er verder gezocht is naar een mogelijkheid om gebruik te maken van de hoge specifieke energie van nikkel, maar waarbij aluminium toegevoegd wordt aan de legering van de kathode om voor de stabiliteit te zorgen. Daarmee deelt de techniek de voordelen van NMC, zoals een hoge specifieke energie, hoog vermogen en lange levensduur. Daar staan hoge kosten en een matige thermische stabiliteit (en daarmee veiligheid) tegenover.

Deze techniek wordt nu alleen nog gebruikt in specialistische toepassingen, medische apparatuur, industriële toepassingen en een beperkt aantal automerken.

[4] Een spinel-structuur.

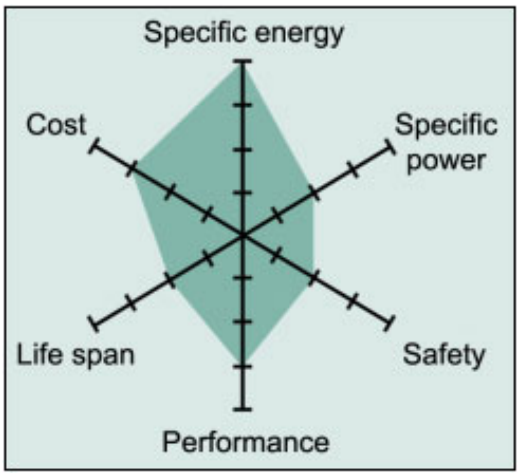
Lithium Titanium Oxide

In deze techniek wordt niet de kathode, maar de anode, van Lithium Titanate Oxide (LTO) (Li_2Ti_3) gemaakt. De kathode kan dan van een van de eerder genoemde legeringen worden gemaakt, zoals bijvoorbeeld van NMC. Alhoewel de cellen een beperkte energiedichtheid hebben en erg duur zijn, leveren ze een hoog vermogen, zijn ze erg veilig en gaan ze lang mee. Daarnaast werken ze zelfs goed bij lage temperaturen en hebben ze minder degradatie bij deze temperaturen dan andere technieken. Zo leveren ze bij -30 °C nog een capaciteit van 80 % van de capaciteit bij kamertemperatuur. De lange levensduur wordt bereikt doordat er geen degradatie optreedt waar dat normaal wel het geval zou zijn, zoals bij snelladen en bij gebruik bij extreme temperaturen (vooral laden bij lage temperaturen is schadelijk voor de andere technieken).

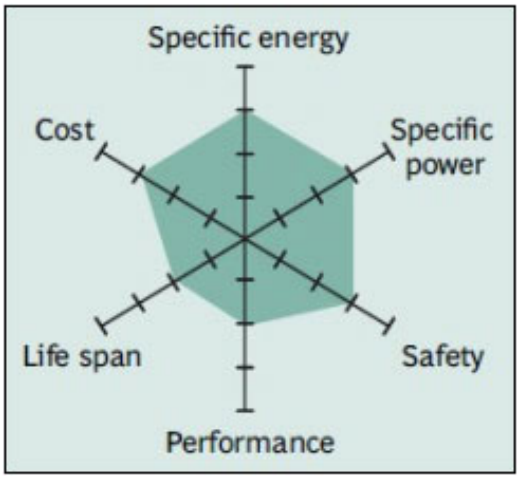
Deze batterijen worden voornamelijk gebruikt voor elektrische aandrijftreinen, Uninterruptable Power Supply (UPS) en straatverlichting op zonne-energie.

Parameter	**$LiFePO_4$**	**$LiNiCoAlO_2$**	**Li_2Ti_3**
Voltage [V]	3,20 - 3,30 V nominaal	3,60 V nominaal	2,40 V nominaal
Laadsnelheid [C-ratio]	1 C	0,7 C	1 C, tot max 5 C
Ontlaadsnelheid [C-ratio]	1 C standaard, tot wel 25 C	1 C	tot 10 C
Specifieke energie [Wh/kg]	90-120 Wh/kg	200 - 260 Wh/kg	50 - 80 Wh/kg
Cycle life	2000+ cycli	500 cycli	3000 - 7000 cycli
Thermal runaway [°C]	270 °C	150 °C	unknown, one of the safest
Kosten [$/kWh]	∼$580 per kWh	∼$350 per kWh	∼$1005

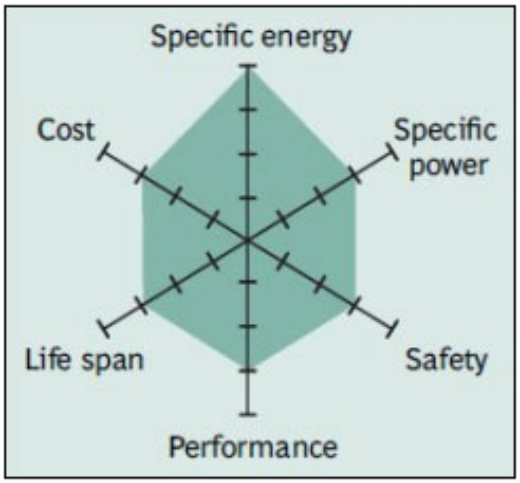
Table 4: Vergelijking van de batterijtechnieken LFP, NCA en LTO op een selectie van de belangrijkste parameters.



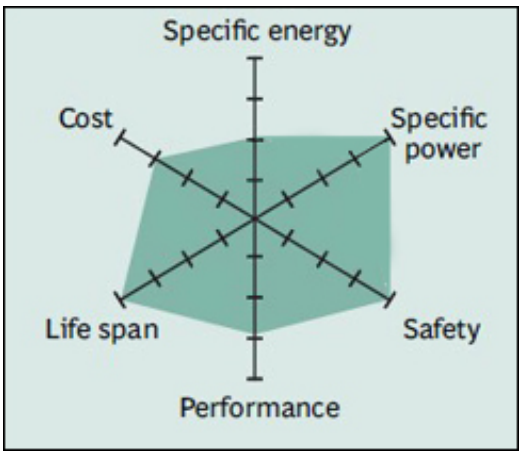
(a) Performance van de LCO batterij



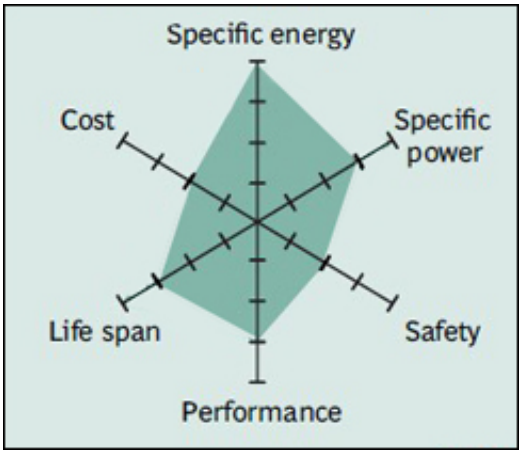
(b) Performance van de LMO batterij



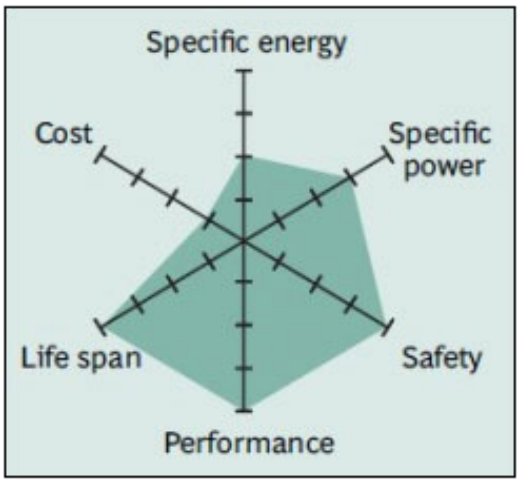
(c) Performance van de NMC batterij



(d) Performance van de LFP batterij



(e) Performance van de NCA batterij



(f) Performance van de LTO batterij

Figure 3: Samenvatting van de belangrijkste performance karakteristieken van verschillende hedendaagse batterijtechnieken (bron: batteryuniversity.com

Ontwikkelingen

De aanschaf van een nieuwe tractor kan natuurlijk niet los gezien worden van de huidige tijd, zoals de ontwikkelingen rondom de Van Wijk-klasse, die ook met de nieuwe tractor vervoerd moeten worden. Voor de rest is er een trend waarneembaar, onder meer bij de overheid, voor het aanhalen van normen op het gebied van milieu en uitstoot, met name in en nabij Natura 2000 en andere natuurgebieden. Deze ontwikkelingen moeten dan ook meegenomen worden in de evaluatie van deze beslissing. Een van de effecten die dat heeft, is dat er van drie boothuizen bekend is, dat de huidige tractorcombinatie met een Van Wijk-klasse, qua afmetingen niet in het boothuis past. Dit heeft als effect dat het boothuis mogelijk verbouwd moet worden om de tractor te laten passen. Dit zou het geval zijn voor de opties 1 en 2. De kosten voor de verbouwing kunnen ingeschat worden op ongeveer €700.000 in toto. En wanneer ervan uitgegaan wordt dat alle tien de tractoren vervangen zullen worden, komt dit neer op €70.000 per tractor in de ontwerpkeuze.

Een andere ontwikkeling is die rondom synthetische brandstoffen. Er zijn sterke signalen dat het gebruik van biobrandstoffen vanuit de Europese Unie en daarna ook vanuit de nationale overheid, waarschijnlijk in eerste instantie in bijgemengde varianten. Daarmee zal de beschikbaarheid van deze brandstoffen enorm toenemen. Op welke termijn deze verplichtingen van kracht worden, is momenteel nog niet bekend. Het effect hiervan is wel, zoals eerder aangehaald, dat de beschikbaarheid van deze brandstoffen verder toeneemt en daarmee het transport minder effect impact heeft op de KNRM.

Ook is er een toenemend bewustzijn bij het grote publiek van klimaatveranderingen en de noodzaak om bewust met de (natuurlijke) leefomgeving om te gaan. Dat betekent dat milieuvervuiling in natuurgebieden veel vaker en sterker tot verontwaardiging zal leiden bij het brede publiek en daarmee onder potentiële donateurs. Ook de overheid gaat mee in deze beweging en er is dan ook te verwachten dat in de komende tijd meer en meer duingebieden aangewezen zullen worden als Natura 2000 gebieden, met de extra regels op het gebied van milieu die daaraan gekoppeld zijn. Daarbij spreekt de verduurzaming van de organisatie mogelijk ook een nieuwe generatie vrijwilligers aan. Daarmee past een slag maken in de verduurzaming goed in een breder maatschappelijk kader en maatschappelijke beweging. Daar staat tegenover dat de KNRM op dit moment een vrijstelling heeft van emissie- en milieu-eisen. Het is echter, binnen het strategische speerpunt duurzaamheid, wenselijk om, waar mogelijk, op zijn minst aan de regelgeving te voldoen. Of dit mogelijk, en met name wenselijk is, is een keuze die onder andere voorligt in deze evaluatie.

Een volgende ontwikkeling is het project om 0 op de meter, danwel volledig duurzaam opgewekte energie. Binnen dit project wordt de elektriciteitshuishouding van de KNRM verduurzaamd wordt, onder andere door het plaatsen van zonnepanelen, bezuinigen op gebruik en het duurzaam verwerven van de resterende energiebehoefte. Aan de ene kant zorgt het elektrificeren van de tractoren tot een toename van het elektriciteitsgebruik, aan de andere kant zet het de verduurzaming ook verder kracht bij.

1 Huidige tractor

Deze optie is een voortzetting op de ingeslagen weg. De tractor en bootwagen blijven dezelfde als de huidige. Met betrekking tot de motoren, wordt er gekozen voor de laatste techniek (door te kiezen voor een upgrade naar een EU stage IV dieselmotor), waardoor er een 3,4% reductie in verbruik en uitstoot kan worden gerealiseerd, als de motor op temperatuur is. De technieken zijn bekend, beproefd en de mensen zijn er bekend en vertrouwd mee. Deze optie is schematisch weergegeven in figuur 4

De tractor heeft een gemiddeld brandstofverbruik van ongeveer 17 l/uur. En omdat het grote zware motoren zijn, is het moeilijk om het geluid efficiënt te isoleren en daarmee zijn de machines lawaaiig. De machines produceren 90 dB op een afstand van 1,5 meter, ondanks alle aangebrachte geluidsisolatie in de motorruimte.Er wordt dan ook voorzien in gehoorbescherming met intercom-functie om te kunnen communiceren over de boordradio's.

Wanneer het gaat over het falen en/of repareren van de tractor, blijkt dat de motoren overwegend geen groot onderhoud nodig te hebben. Een enkele keer moet een V-snaar of een dynamo vervangen worden. Daarnaast moeten de tractoren jaarlijks zo nu en dan uit de beschikbaarheid genomen voor het periodieke onderhoud, zoals bijvoorbeeld voor het verversen van de smeerolie.

Storingen in de tractor zijn zeldzaam en hebben vooral te maken met manchetten, keerkringen en waterdichte afdichtingen. Deze zullen vergelijkbaar zijn voor de andere opties, alhoewel een kleinere massa van sommige varianten een afname in het aantal en de ernst van deze voorvallen met zich meebrengen. Hoe groot dit effect precies is, is lastig om van te voren aan te geven.

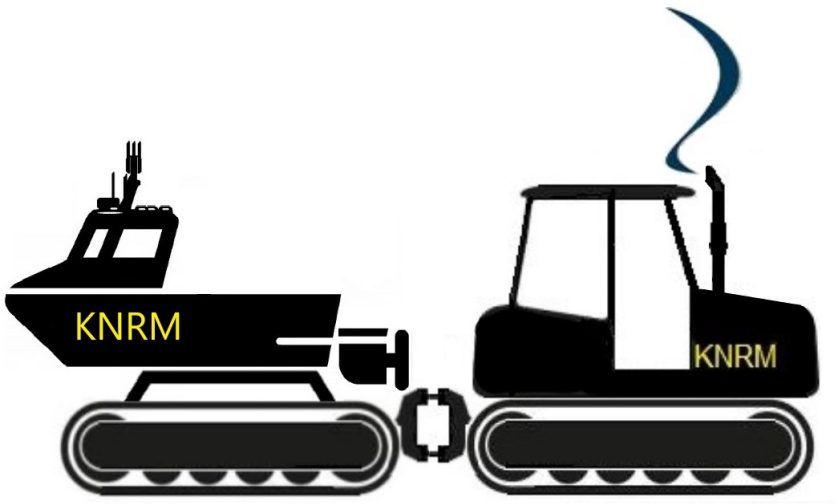


Figure 4: Een schematische weergave van de eerste optie.

1.1 Financieel

Name	Costs
Aanschaf	€55.000
Ombouw	€275.000
Vervangen motor	€200.000
Brandstof	€35.000
Onderhoud	€50.000
Doorverkoop	€-20.000
Totaal	€595.000

1.2 Duurzaamheid

De tractor heeft een gemiddeld brandstofverbruik van ongeveer 17 l/uur, maar, zoals eerder aangegeven, door het gebruik van de nieuwste motortechniek kan er een reductie van 3,4% worden gerealiseerd in het verbruik. En omdat het grote zware motoren zijn, is het moeilijk om het geluid efficiënt te isoleren en daarmee zijn de machines lawaaiig. De machines produceren 90 dB op een afstand van 1,5 meter, ondanks alle aangebrachte geluidsisolatie in de motorruimte. Er wordt dan ook voorzien in gehoorbescherming met intercom-functie om te kunnen communiceren over de boordradio's.

Bij de bedrijven waar zaken mee wordt gedaan, wordt naar duurzaamheid gekeken, maar dat is niet de kern van de propositie. Daarmee presteren zij gemiddeld op dit gebied. Daarentegen hebben de producent, de dealer (die ook het onderhoudscontract uitvoert voor de KNRM) en de werf die de ombouw uitvoert een goede reputatie en is bekend dat zij doorgaans een goede kwaliteit leveren.

2 Een schonere brandstof

Deze tractor is gebaseerd op hetzelfde concept als de huidige tractor. Deze wordt aangepast voor het gebruik van HVO. Het optimale bijmengpercentage van de synthetische brandstoffen is nog in onderzoek, en zo ook de langetermijneffecten van de bijmenging voor de motor. Alleen voor de bijmengpercentages van 20 en 30% zijn de effecten al redelijk bekend en deze cijfers zullen dan ook als basis dienen voor de oplossing die hier geschetst wordt. Daarbij geldt dat de brandstof die ontstaat bij 30% bijmenging (B30), voldoet aan de ISO 8217 en de EN 590 normen, waardoor garantie op de motoren intact blijft (het wordt de KNRM dan ook aangeraden om, in afwachting van meer onderzoek, de geteste oplossingen toe te passen). Deze optie is schematisch weergegeven in figuur 5.

Buiten de brandstof is dit dezelfde machine als in het vorige hoofdstuk is beschreven, dus dezelfde leveranciers en andere parameters als in hoofdstuk 1 en de evaluatie van de huidige tractor gelden ook hier.

Figure 5: Een schematische weergave van de tweede optie.

2.1 Financieel

Name	Costs
Aanschaf	€55.000
Ombouw	€275.000
Vervangen motor	€200.000
Brandstof	€37.500
Onderhoud	€50.000
Doorverkoop	€-20.000
Totaal	€597.500

Zoals eerder aangegeven moet de brandstof voorlopig specifiek getransporteerd worden naar de stations die met HVO gaan werken. De kosten voor deze transporten zijn (nog) niet bekend en ook niet meegenomen in het overzicht.

2.2 Duurzaamheid

Er wordt er naar het materiaalgebruik gekeken. Hierbij kijken we ernaar om het materiaalgebruik over de hele levensduur tot een minimum te beperken. Zo worden er zoveel mogelijk materialen gebruikt die tenminste de levensduur van de tractor meegaan, zodat deze niet vervangen hoeven te worden, waar mogelijk.

Met betrekking tot het brandstofverbruik heeft HVO B30 zijn er een groot aantal voordelen ten opzichte van reguliere Marine Gas Oil (MGO). Zo is de verwachting dat het brandstofverbruik met ongeveer 2% zal afnemen[5], de zwaveluitstoot zal verminderen tot minder dan 1%[6], de uitstoot van stikstof en NO_x met 30%[7], de uitstoot van roetdeeltjes met ongeveer 60%[8] en de CO_2 uitstoot met ongeveer 80% zal afnemen[9] . Ook het hogere octaangetal maakt de B30 een zeer geschikte brandstof. En tenslotte is het percentage Fatty Acid Methyl Ester (FAME) aanzienlijk lager zijn dan bij reguliere MGO. Dit heeft ook een positief effect op de motor, omdat de FAME zorgt voor vervuiling en slijtage van de motor. Al met al kan geconcludeerd worden dat het gebruik van B30 een hele positieve invloed heeft op de milieu-effecten, zeker in vergelijking met de reguliere MGO.

De effecten van het transport van de brandstof naar de stations op de duurzaamheid is niet doorgerekend, maar het effect is er wel. Het transport resulteert ook in brandstofverbruik en uitstoot. Er is ook nog weinig te zeggen over hoe lang het nog duurt tot er een betere infrastructuur beschikbaar komt voor deze brandstoffen. Dat zal eerder jaren zijn dan een decade (10 jaar).

[5] Dit komt door de hogere calorische waarde van de brandstof ten opzichte van reguliere MGO. (Zie ook het rapport van TNO)
[6] Zie www.goodfuels.com/marine.
[7] Zie www.goodfuels.com/marine.
[8] Zie www.goodfuels.com/marine.
[9] Zie ook het rapport van TNO.

3 Elektrisch

In deze variant wordt gekozen voor een elektrische tractor-aanhangwagen combinatie op een dubbele rups (dus links en rechts). Deze oplossing is uitgedacht door Ruud Bakker en Tim Grootes van NGM en de hoofdlijnen van dit concept worden ontleend aan een studie die zij momenteel voor de KNRM uitvoeren. Deze studie geeft een goed inzicht in wat een elektrische voortstuwing in zou moeten houden om een reddingboot te kunnen lanceren. De optie is schematisch weergegeven in figuur 6.

[redacted]. Verder maakt dat mogelijk dat er eenvoudige en modulaire componenten (zoals bijvoorbeeld batterijcellen) gebruikt kunnen worden, waardoor deze eenvoudig door een ploeg op het station zelf uitgewisseld kunnen worden. Er kan ook over nagedacht worden om dezelfde modules te gebruiken voor het eventueel elektrificeren van het kusthulpverleningsvoertuig (KHV). Daarmee ontstaat nog meer standaardisatie van de voertuigen van de KNRM. Door de eenvoudige opbouw van het systeem kan deze eenvoudig geschaald worden naar de vermogens en energiebehoefte die benodigd is voor een KHV. Alhoewel er nog moet worden uitgezocht of er een hydraulische aandrijving nodig is voor aanvullend koppel, voor dit voorstel wordt ervan uitgegaan dat een directe aandrijving door een of twee elektromotoren per rups volstaat. Door twee elektromotoren te gebruiken wordt, als er inderdaad wordt gekozen voor een hydraulische aandrijving, de redundantie verder vergroot. Dat is een extra vergroting van de bedrijfszekerheid, want een elektromotor levert voldoende kracht om de tractor te verplaatsen [redacted]. Het voordeel van het gebruik van een combinatie en een enkele rups, is aan de ene kant een gewichtsafname van 9000 kilo en aan de andere kant het effect dat de rups minder geneigd is om zichzelf in te graven bij het wegrijden vanaf het strand. De gewichtsafname heeft een positieve uitwerking op het verbruik, waardoor volstaan kan worden met een batterij van 125 kWh (gemeten op het einde van de levensduur van de batterij) wat voldoende is voor 5 lanceringen (incl. recovery) op een batterijlading. En, afhankelijk van de andere gebruikers op de stroomaansluiting van het boothuis, kan de batterij in 6 tot 12 uur volledig opladen.

Er wordt zo veel mogelijk gebruik gemaakt van uitgeengineerde componenten (Technology Readiness Level (TRL) 9), omdat alleen op deze manier een goed beeld te krijgen is van de beschikbaarheid van de componenten en daarmee van het hele systeem. De huidige ontwikkeling laat zien dat elektrische systemen veel minder storingen en down-time laten zien. De down-time in traditionele systemen wordt vooral veroorzaakt door onderhoud, en dan vooral preventief onderhoud. Dit kost bij een elektrisch systeem veel minder tijd en daarmee minder down-time. In principe moeten alle elektrische componenten de levensduur van de tractor makkelijk kunnen halen zonder te falen en zonder al te veel onderhoud (mogelijk alleen het smeren van de bewegende delen).

Doordat de koppeling tussen de tractor en de aanhanger ontbreekt, kan deze waarschijnlijk 1 meter korter worden gemaakt ten opzichte van het huidige ontwerp, waardoor de combinatie in de huidige boothuizen past. Verder wordt de combinatie uitgerust met een cabine voor een bestuurder, zodat deze beschut is van de elementen.

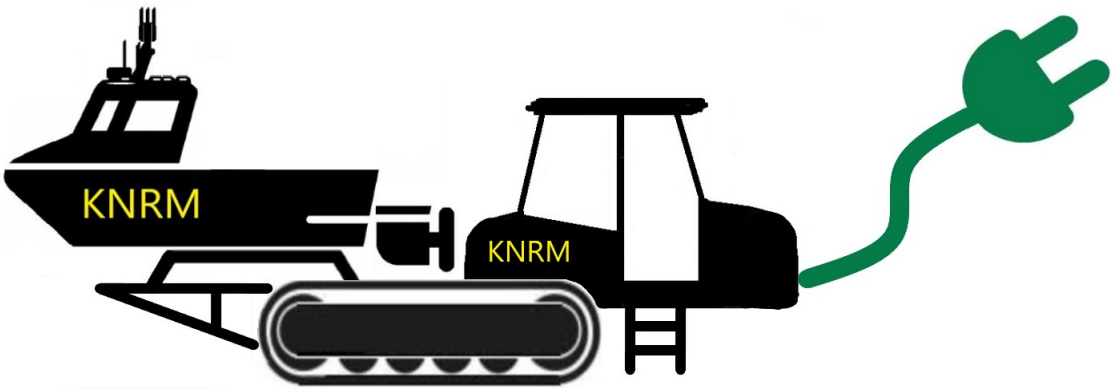


Figure 6: Een schematische weergave van de derde optie.

3.1 Financieel

Name	Costs
Engineering	€40.000
Bouw	€450.000
Elektriciteit	€15.000
Onderhoud	€25.000
Doorverkoop	€-40.000
Totaal	€490.000

3.2 Duurzaamheid

Op het gebied van duurzaamheid zijn in dit ontwerp enorme stappen gemaakt voor de KNRM. Door voor elektrificatie te kiezen, wordt de uitstoot volledig teruggedrongen en worden ook het geluid en de trillingen veel minder. Daarnaast wordt gekeken naar de batterijmodules. Voorlopig moet worden vastgesteld dat deze - afhankelijk van de laatste ontwikkelingen op dat gebied - voorlopig veel giftige grondstoffen bevatten, op een energie-intensieve manier gemaakt worden en ook maar heel beperkt gerecycled kunnen worden. Immers, een groot deel van de industrie maakt gebruik van batterijen die onder erbarmelijke omstandigheden worden geproduceerd en die materialen bevatten, zoals Kobalt, dat onder erbarmelijke omstandigheden in overwegend de Democratische Republiek Congo wordt gewonnen. Daarom kiezen we voor een batterij die geen gebruik maakt van Kobalt, maar van een Lithium-IJzer-Fosfaat (LFP) kathode ($LiFePO_4$). Deze batterijen hebben een iets lagere capaciteit en energiedichtheid, maar kent een lage degradatie bij een groot aantal laadcycli. Daarmee moet de batterij de hele levensduur van de tractor meegaan. Daarmee gaan eigenlijk alle onderdelen van de tractor de gehele levensduur mee.

Ten aanzien van het materiaalgebruik wordt er gekozen voor materialen die tenminste de levensduur van de tractor moeten hebben, waardoor er in principe geen onderdelen hoeven te worden vervangen. Het verleden leert dat dat goed mogelijk is, de enige componenten die gevoelig zijn voor falen zijn mogelijk de waterdichte afdichtingen en de lagers van het loopwerk van de tracks. Ook al wordt hiervoor gezocht naar kwalitatief goede oplossingen en producten die goede performance laten zien, deze componenten worden vol bloot gesteld aan de elementen en falen is daarom niet uit te sluiten.

4 Integratie - aanbieder ASD

Dit is de eerste elektrische variant die niet voorziet in een cabine voor de bestuurder. De trailer is gecombineerd in een voertuig, net als de vorige variant. De trailer wordt in principe op het strand op afstand bestuurd. Alleen op de openbare weg is nog een umbilical cable nodig om de voldoen aan de wetgeving. De bestuurder kan daarmee naast het voertuig lopen, maar ook op de reddingboot gaan zitten, bijvoorbeeld tot de tractor het water in rijdt. Er wordt voorzien in twee bedieningsunits, zodat ook de bemanning op de boot bijvoorbeeld de bootsteunen voor de lancering kan bedienen. Daarnaast kan deze gebruikt worden als er een storing is met het eerste systeem. Daarbij kan de umbilical cable ook in een extra veiligheid voorzien, doordat deze voorziet in een andere manier om de bedieningsunit met het regelsysteem van de besturing te verbinden. De optie is schematisch weergegeven in figuur 7.

Wij zien het kostenelement als belangrijkste factor. Door op te kosten te letten bij de bouw een aanbesteding, blijft er meer geld over voor onderhoud en reservedelen en uiteindelijk voor een vervanging. Op deze manier hebben we een tractor ontwikkelt die prima voldoet aan de eisen, geven we geen nodeloos geld uit aan nice-to-have opties en ontstaat een lean and mean, maar toch milieuvriendelijke elektrische tractor.

Er wordt gekozen voor twee enkelvoudige elektromotoren voor het aandrijven van de tracks, een per track. De batterijen zijn in een grote waterdichte ruimte geplaatst onderin de tractor. Daarboven bevindt zich een tweede ruimte waarin zich de regelapparatuur en randapparatuur bevindt, zoals een hydrauliekpomp en accumulator. De tractor wordt direct geïntegreerd in de voorkant van de trailer, waardoor de tractor een geheel vormt met de trailer. Dit zorgt voor een strakke look, maakt de combinatie zo klein mogelijk en zorgt voor een laag zwaartepunt en is daarmee qua ontwerp vergelijkbaar met de derde variant. Om deze reden wordt er ook gekozen voor batterijen met de beste prijs-kwaliteit verhouding en beste energiedichtheid (dus capaciteit per kg gewicht). Daarom wordt gekozen voor een Lithium-Nikkel-Mangaan-Kobaltoxide (NMC)-kathode ($LiNiMnCoO_2$) batterij, die ook gangbaar is in de auto-industrie en de industrie, zoals voor landbouwmachines.

Er wordt gebruik gemaakt van hoogspanning (400 Volt). Dit is ook gebruikelijk in de industrie, waardoor er gebruik gemaakt kan worden van systemen die al ver ontwikkeld en veelbeproefd zijn. Dat geeft vertrouwen in de bedrijfszekerheid van het materiaal. Daarnaast geldt dat hierdoor gewerkt kan worden met kleine en lichtere bekabeling en schakelingen, waardoor deze weinig plek in hoeven nemen en makkelijk in te passen zijn. Dit stelt ons in staat om een kleine en compacte machine te maken die zo min mogelijk de zichtlijnen beperkt, met name vanaf de reddingboot. Want wij verwachten dat de bestuurder zich daar een deel of een groot deel van de tijd zal bevinden.

De bedrijfszekerheid is zo groot, dat de ervaring leert dat de componenten niet falen tijdens de hele levensduur van de tractor, dus dat moet meer dan voldoende zijn voor het doel van de KNRM. De regelapparatuur is verbonden met een antenne op een van de hydrauliekcilinders op de trailer, zodat deze ten alle tijden boven water blijft. Standaardisatie vindt natuurlijk plaats tussen de verschillende tractoren, maar daarbuiten zien wij weinig overeenkomsten of mogelijkheden voor standaardisatie. Op het gebied van modulariteit zijn natuurlijk de batterijcellen modulair uit te wisselen.

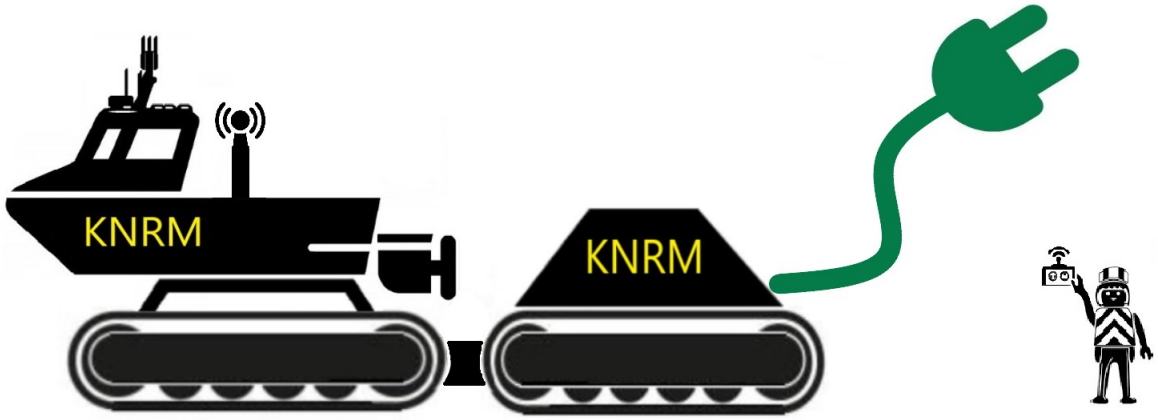


Figure 7: Een schematische weergave van de vierde optie.

4.1 Financieel

Naam	Kosten
Engineering	€45.000
Bouw	€400.000
Elektriciteit	€15.000
Onderhoud	€25.000
Doorverkoop	€-40.000
Totaal	€445.000

4.2 Duurzaamheid

Duurzaamheid interpreteren wij vanuit de KNRM. Wij gaan er namelijk vanuit, dat de KNRM gebaat is bij een zo kosteneffectief mogelijke oplossing, zodat zij voldoende geld overhoudt voor haar belangrijke werk. Daarom zoeken wij naar de goedkoopste en meest effectieve oplossing om een boot naar zee te kunnen transporteren. Ten aanzien van duurzaamheid, gaan wij ervan uit, dat wanneer we zo min mogelijk materiaal gebruiken bij de bouw, dit goed is voor het budget en voor het milieu. Echt win-win dus. Een laag materiaalgebruik houdt ook het gewicht laag, wat weer een positieve uitwerking heeft op de hoeveelheid benodigde energie. Daarmee is deze oplossing de meest energievriendelijke keuze in het gebruik. Ook op het gebied van de batterijen is de focus op de gebruiker. Door te kiezen voor een optimale verhouding tussen het geleverde vermogen per kilogram gewicht en de prijs, kiezen wij een variant die het meeste power levert voor de euro en daarmee het dichtst bij onze doelstelling staat om zo veel mogelijke waarde te leveren voor iedere geïnvesteerde euro.

Ook in dit geval geldt dat kiezen voor een elektrische optie een stille en trillingsarme oplossing is om een reddingboot naar zee te verplaatsen.

5 Integratie - aanbieder ZXC

Ons uitgangspunt in dit ontwerp is een zo duurzaam mogelijke tractor, gezien over de hele productieketen en levensloop van de tractor. Daarmee leveren wij een op de toekomst gerichte kwalitatieve en duurzame oplossing voor de KNRM, waarmee zij jaren vooruit kan. Wij houden hierbij rekening met de vitale rol van de KNRM in de hulpverlening op het water en de belangrijke rol die de tractoren hierin spelen. Daarvoor zullen wij ons maximaal inzetten om een kwalitatieve en veilige optie te leveren, die de redders ten alle tijden veilig thuis zal brengen. Aan de andere kant zien wij dat de ontwikkelingen op het gebied van elektrische voertuigen en batterijtechniek zich enorm snel ontwikkelt. Wij streven ernaar om de laatste techniek te gebruiken, maar alleen als daarbij de veiligheid en de betrouwbaarheid voldoende zijn aangetoond en bewezen. De optie is schematisch weergegeven in figuur 8.

De tractor gebruikt vier elektromotoren voor de voortstuwing - twee per kant (waarbij geldt dat alle elektromotoren intern drievoudig redundant zijn uitgevoerd). Er zal onderzocht worden wat de optimale verdeling is van de elektromotoren, er wordt vanuit gegaan dat de motoren in de track van de tractor komen en niet in de track van de trailer. De batterijen zijn ingedeeld in drie waterdichte modules, waarbij elke batterijmodule twee elektromotoren aandrijft. De module is wel vrij klein, omdat er geen plek is voor een bestuurder. Het gewicht wordt bepaald als een optimum voor grip in het zand (als de module te licht is, slipt hij makkelijk door in rul zand) en benodigd vermogen en energie voor het verplaatsen van de combinatie (hoe zwaarder, hoe meer vermogen en energie er benodigd is). Onderzoek naar het juiste gewicht maakt onderdeel uit van het programma.

Voor de motoren wordt gekozen voor een nieuw ontwerp dat de laatste kennis integreerd op het gebied van vermogen, rendement en warmtegeneratie, omdat warmtestuwing in de afgesloten behuizing mogelijk voor problemen, slijtage en rendementsverlies kan zorgen. Desondanks is de verwachting dat een elektromotor kan worden gevonden of ontwikkeld die optimaal is afgestemd voor de omgeving waarin hij moet opereren en dat de levensduur van de motoren veel langer zal zijn dan de levensduur van het casco van de tractor.

Voor de batterijen wordt gekozen voor een optimale verhouding tussen de opslagcapaciteit, het gewicht, de levensduur (en de degradatie van de capaciteit bij het verwachte gebruikspatroon). Omdat de ontwikkelingen op het gebied van batterijen erg snel gaat, zowel op het gebied van gewicht en capaciteit (en ook op het aantal kWh per kilogram), zal gekozen worden voor de laatste technieken om zo tot een optimaal product te komen. Hierbij wordt wel een minimale eis gesteld van een beschikbaarheid van 99,99%. Deze keuze wordt op het laatste moment gemaakt (just-in-time productie).

De drie batterijen zitten alledrie in een eigen waterdichte behuizing, en zijn verbonden met de regelmodule en met twee elektromotoren. Alledrie de batterijen zijn, met hun behuizing als modules te verwijderen en vervangen. De regelmodule bevindt zich bovenop de tractor en bevindt zich in een eigen waterdichte behuizing. De regelmodule is vervolgens verbonden met een zend- en ontvangstmodule op de trailer (waardoor de antenne's boven water blijven). Onder de regelmodule bevindt zich een module met hulpsystemen. Hierin bevindt zich onder meer een hydrauliekpomp en accumulator voor de hydraulische bediening van de stuurinstallatie en de bootsteunen.

Twee batterijpakketten (en twee motoren) zijn in staat voldoende vermogen te genereren voor 97,5% van alle voorkomende situaties. Als de waterstand het toelaat om de schakelkast op de regelmodule te openen, kunnen alle motoren op de 2 batterijmodules worden gekoppeld, waardoor al het beschikbare vermogen weer beschikbaar komt. In deze schakelkast zitten alle connectoren afgeschermd van zeewater. De stekkers en connectoren zijn zelf ook waterdicht, waardoor een dubbele afscheiding van het water ontstaat.

Voor het in stand houden van deze dubbele waterdichte integriteit moeten de modules wel secuur gekoppeld worden, Er wordt voorzien in een module waarmee opstappers op de stations zelf de connectoren waterdicht kunnen testen. Daarmee kunnen de modules op de stations zelfstandig worden gewisseld.

De tractor wordt bestuurt middels een afstandsbediening. Deze is klein en kan door 1 persoon getild en bediend worden. Per tractor worden 2 afstandsbedieningen voorzien, waarbij er wordt uitgegaan van een bedrijfsmodus waarbij 1 afstandsbediening op de kant blijft bij de walploeg, de tweede is aan boord en kan bijvoorbeeld gebruikt worden voor het laten zakken van de bootsteunen op het moment dat de schipper de trailer wil verlaten. Omdat een op afstand bestuurbaar voertuig op dit moment nog niet is toegestaan op de openbare weg, komt er een mogelijkheid om de afstandsbediening met een zogenaamde umbilical cable (een kabelboom met stekker) aan te sluiten op de tractor, waarmee ook binnen de wet op de openbare weg gereden kan worden. Er wordt geen cockpit voorzien voor de bestuurder, er wordt vanuit gegaan dat deze bij grote drukte en tijdens de lancering meeloopt naast de tractor. Wanneer het rustig is en er over grotere afstanden verplaatst moet worden, verwachten we dat de bestuurder meerijdt op de reddingboot. Er wordt daarom voorzien in een makkelijke op- en afstap.

Als laatste zijn ook de tractoren als geheel los te koppelen van de trailers en los uitwisselbaar.

Overal worden hoogwaardige materialen en coatings gebruikt, om zo het materiaalgebruik, het degraderen en het vervangen van onderdelen en materiaal zo veel mogelijk te beperken.

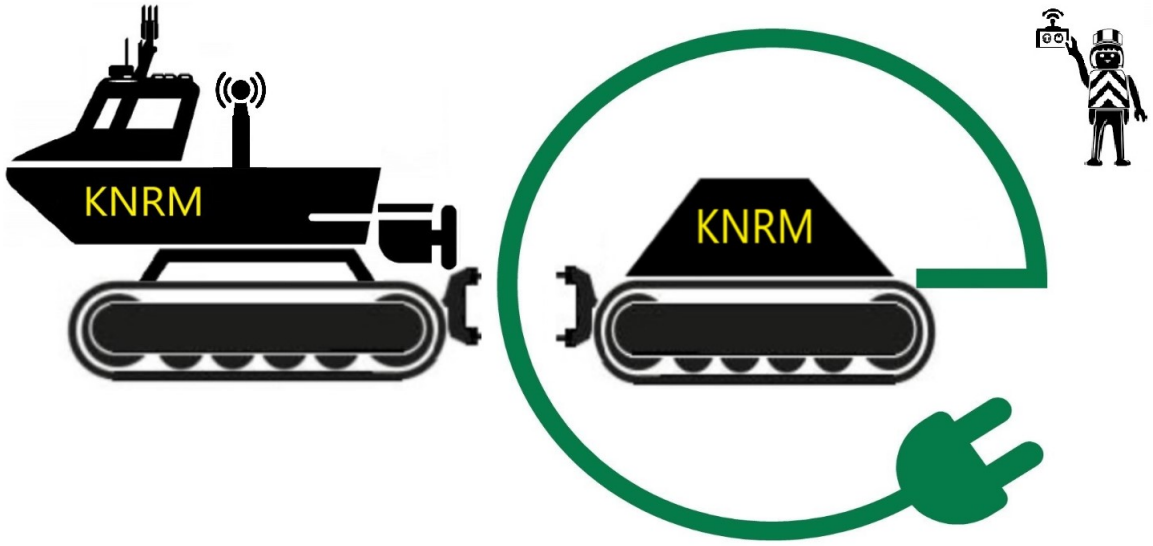


Figure 8: Een schematische weergave van de vijfde optie.

5.1 Financieel

Naam	**Kosten**
Engineering	€50.000
Bouw	€450.000
Elektriciteit	€15.000
Onderhoud	€25.000
Doorverkoop	€-40.000
Totaal	€500.000

5.2 Duurzaamheid

Qua uitstoot is de uitstoot van deze variant nihil. Op het gebied van materiaalgebruik wordt de filosofie gehanteerd dat het beter is om te kiezen voor herbruikbare materialen en materialen met een lange levensduur en hoge kwaliteit. Zo wordt er bijvoorbeeld bij voorkeur gewerkt met kunststoffen die niet degraderen door het toedoen van zeewater[10]. Hiervoor wordt niet alleen gekeken naar de materialen die in het eindproduct verwerkt worden, maar ook naar materialen die nodig zijn en verbruikt worden in het productieproces. Het materiaalgebruik wordt over de hele levensduur beschouwd, waarbij ook rekening wordt gehouden met verwachte reparaties en vervanging van materialen over de levensduur. Ook wordt er gekeken naar het energieverbruik tijdens de productieproces en andere duurzaamheidscriteria bij alle aannemers en leveranciers. Leveranciers moeten een veilige en verantwoorde productieproces hanteren en goede werkomstandigheden bieden aan werkgevers, ook al beperkt dit de keuze in batterijen en aanbieders enorm. Daarom kiezen wij voor een batterij-leverancier die een duurzame verwerving van de materialen en productie hanteert, en al tijdens de constructie voorzieningen treft voor de recycling, zoals bijvoorbeeld het Zweedse bedrijf Northvolt.

Hiervoor wordt nauwkeurig uitvraag gedaan bij alle mogelijke toeleveranciers, waarbij wij ernaar streven om een product te kiezen dat de beste balans geeft tussen operationele performance en capaciteit per kg, en duurzame productie, verwerking en recyclingmogelijkheden aan de andere kant.

[10]Degradatie door zonlicht wordt wel rekening mee gehouden maar wordt als minder belangrijk ervaren omdat de tractoren en trailers overwegend binnen en uit het zonlicht staan.

Figure 9: Lancering van de reddingboot van Katwijk (foto: Arie van Dijk)

Acronyms

FAME Fatty Acid Methyl Ester. 12

HVO Hydro-treated Vegetable Oil. 1–3, 11, 12

KHV kusthulpverleningsvoertuig. 13

KNRM Koninklijke Nederlandse Reddingmaatschappij. 1, 4, 8, 10, 11, 14–17

LCO Lithium Kobalt Oxide. 4, 5, 7

LFP Lithium-IJzer-Fosfaat. 5–7, 14

LMO Lithium Mangaan Oxide. 4, 5, 7

LTO Lithium Titanate Oxide. 6, 7

MGO Marine Gas Oil. 12

NCA Lithium Nikkel Kobalt Aluminium Oxide. 5–7

NMC Lithium-Nikkel-Mangaan-Kobaltoxide. 4–7, 15

TRL Technology Readiness Level. 13

UPS Uninterruptable Power Supply. 6

M

Weights sheet

This appendix shows sheets that were filled in by the interviewees to establish the weights they give the different criteria. The file contains a sheet for every set of weights, an example of which is presented in figure M.2. In the grey area, the criteria in the set are shown, along with a more elaborate description and scope. From this set of criteria, the interviewee had to select the most important criterion (best) and enter this in the field shown in the green square. Then, the least important criterion (worst) was selected and entered in the red square. The orange square shows the BO vector. The yellow square contains the internal consistency. This was used during the interview to evaluate the consistency of the values provided while filling out the sheet. The consistency measure wasn't strictly adhered to. Either when the deficiency was very small of when the number of criteria in the set is small (three or four) and the values were cognitively consisted, the values were accepted. The square coloured light green shows the global consistency and its threshold, as calculated by Liang et al. (2020). The light blue square contains the OW vector. The dark blue square gives the outcome of the linear model, which is the outcome of equation 4.12. The purple square shows the outcome of the calculations of w_{min} and w_{max}, using equations 4.10 and 4.11. The brown square shows the characteristics of the outcome. The weights are visualised using the graph in the black square, showing the linear outcome in blue and the average of w_{min} and w_{max}.

The scale for filling out the vectors BO and OW is shown in figure M.1.

The meaning of the numbers 1-9:
1: **Equal** importance
2: Somewhat between Equal and Moderate
3: **Moderately** more important than
4: Somewhat between Moderate and Strong
5: **Strongly** more important than
6: Somewhat between Strong and Very strong
7: **Very strongly** important than
8: Somewhat between Very strong and Absolute
9: **Absulutly** more important than

Figure M.1: The scale used when establishing the vectors BO and OW.

Return on investment

Aantal criteria = 6	Criterium 1	Criterium 2	Criterium 3	Criterium 4	Criterium 5	Criterium 6
Namen v/d criteria	Life cycle costs	Potentieel voor fondsenwerving	Restrisico	Immateriele kosten	Financieel voordeel	Verkoopbaarheid

Select the Best	Life cycle costs
Select the Worst	Verkoopbaarhei

Best to Others	Life cycle costs	Potentieel voor fondsenwerving	Restrisico	Immateriele kosten	Financieel voordeel	Verkoopbaarheid
Lokale consistentie	0	0,166666667	0,166666667	0,166666667	0,166666667	0

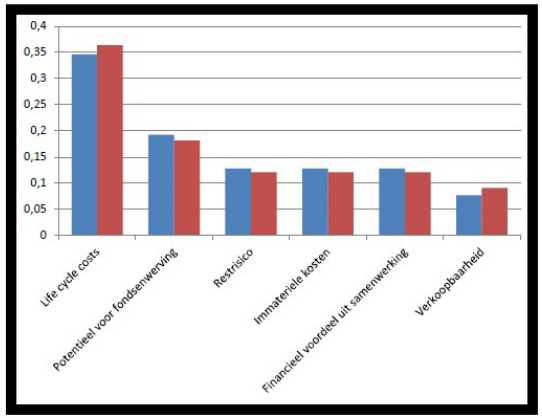
Globale consistentie	0,166666667
Threshold	0,2206

Others to the Worst	Verkoopbaarhei
Life cycle costs	4
Potentieel voor	3
Restrisico	2
Immateriele kosten	2
Financieel voordeel uit	2
Verkoopbaarheid	1

The meaning of the numbers 1-9:
1: **Equal** importance
2: Somewhat between Equal and Moderate
3: **Moderately** more important than /B
4: Somewhat between Moderate and Strong /B
5: **Strongly** more important than
6: Somewhat between Strong and Very strong
7: **Very strongly** important than
8: Somewhat between Very strong and Absolute
9: **Absulutly** more important than

Weights	Life cycle costs	Potentieel voor fondsenwerving	Restrisico	Immateriele kosten	Financieel voordeel	Verkoopbaarheid
	0,346153846	0,192307692	0,12820513	0,128205128	0,128205128	0,076923077
Wmax						
Wmin*	0,360332038	0,178000564	0,11895642	0,11895642	0,11895642	0,089379929
W* (midden)	0,363616969	0,181827001	0,12122899	0,12122899	0,12122899	0,090916423
W* (midden, norm)	0,363599748	0,18181839	0,12122325	0,121223248	0,121223248	0,090912117
breedte	0,003284932	0,003826438	0,00227257	0,00227257	0,00227257	0,001536494
verschil	0,006569863	0,007652875	0,00454514	0,004545139	0,004545139	0,003072987

Ksi*	0,038461538
Consistency index	1,63
Consistency ratio	0,023596036
Threshold	0,2928
Psi	0,015465572
Max(psi)	0,8607
Kappa	0,982031402



Criterium 1: Life cycle costs, dus het totaal van alle kosten tijdens de gehele levensloopcyclus, van aanschaf tot recycling, gedeeld door d
Criterium 2: Potentieel voor fondsenwerving, hoeveel fondsen er aangeschreven kunnen worden om specifiek in dit project mee te doen
Criterium 3: Restrisico na mitigerende acties, waaronder het verzekeren van (een deel van) het risico (de premie wordt meegenomen in
Criterium 4: Immateriele kosten/investeringen, indirecte verdienmogelijkheden / - kostenbesparingen
Criterium 5: Financieel voordeel uit samenwerking, sluit aan bij - en prcfiteert van externe ontwikkelingen
Criterium 6: Verkooppotentieel van het product/idee/kennis/intellectueel eigendom

ksi	Wmax	W1max	W2max	W3max	W4max	W5max	W6max
0,038462		0,366902	0,185653	0,123502	0,123502	0,123502	0,09245292
7		6	6	6	6	6	6
WAAR		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
WAAR		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
WAAR		WAAR	ONWAAR	WAAR	WAAR	WAAR	ONWAAR
WAAR		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
32767		32767	32767	32767	32767	32767	32767
0		0	0	0	0	0	0

	Wmin	W1min	W2min	W3min	W4min	W5min	W6min
		0,360332	0,178001	0,118956	0,118956	0,118956	0,08937993
		6	6	6	6	6	6
		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
		ONWAAR	ONWAAR	ONWAAR	ONWAAR	ONWAAR	WAAR
		WAAR	WAAR	WAAR	WAAR	WAAR	WAAR
		32767	32767	32767	32767	32767	32767
		0	0	0	0	0	0

	Life cycle	Potentieel	Restrisico	Immaterie	Financieel	Verkoopb	0	Criterium 2:
w1max	0,366902	0,17999	0,120752	0,120752	0,120752	0,090852		
w2max	0,364384	0,185653	0,119913	0,119913	0,119913	0,090222		
w3max	0,365755	0,179427	0,123502	0,120375	0,120375	0,090568		
w4max	0,365755	0,179427	0,120375	0,123502	0,120375	0,090568		
w5max	0,365755	0,179427	0,120375	0,120375	0,123502	0,090568		
w6max	0,366256	0,179673	0,12054	0,12054	0,12054	0,092453		
w7max								
w8max								
w1min	0,360332	0,183699	0,121671	0,121671	0,121671	0,090958		
w2min	0,362847	0,178001	0,12252	0,12252	0,12252	0,091593		
w3min	0,361446	0,184266	0,118956	0,122047	0,122047	0,091239		
w4min	0,361446	0,184266	0,122047	0,118956	0,122047	0,091239		
w5min	0,361446	0,184266	0,122047	0,122047	0,118956	0,091239		
w6min	0,360957	0,184018	0,121882	0,121882	0,121882	0,08938		
w7min								
w8min								

Figure M.2: Example of the sheet used to establish the weights used during the interviews.

Having established all weights, the interviewees were asked to score the performance of the variants presented in the test case, which is included in the appendix L. An example of the sheet using to score the variants is shown in figure M.4. In this figure, the black square entails the checkboxes for including a criterion in the evaluation of the variants. The green square presents all the criteria, with their weights shown in the yellow square. If the checkbox is deselected, the value is set to zero, raising the value of the other criteria in the set the criterion originates from, in accordance with the weight preference shown by the interviewee. The red square contains the performance of the variants, which is the part filled out by the interviewee. The blue square contains the outcome of the performance evaluation, which is the summation of the product of the weight for each criterion with the performance of a variant on that criterion. This outcome is visualised in a graph in another sheet in the file and is shown for each interviewee in the respective appendix of this report.

The scale for scoring the performance of the variants is shown in figure M.3.

The meaning of the numbers 1-9:
1: **Huge** deterioration compared to the current situation
2: **Strong** deterioration compared to the current situation
3: **Fair** deterioration compared to the current situation
4: **Modest** deterioration compared to the current situation
5: **Equal** to the current situation
6: **Modest** improvement compared to the current situation
7: **Fair** improvement compared to the current situation
8: **Strong** improvement compared to the current situation
9: **Huge** improvement compared to the current situation

Figure M.3: The scale used for scoring the performance of the variants.

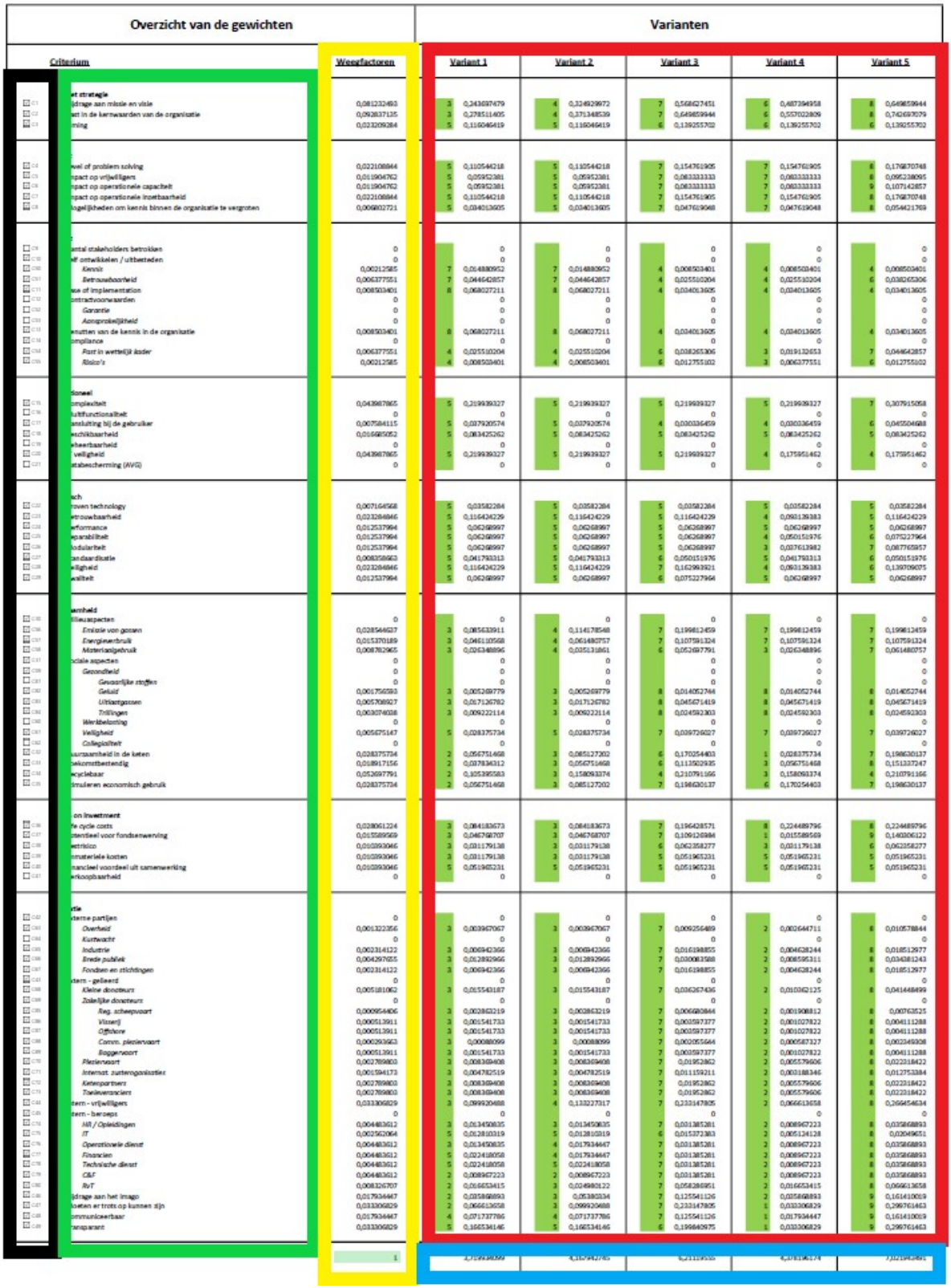


Figure M.4: Example of the sheet used for scoring the performance of the variants on the respective criteria.

N

Interview on the weights with the CEO

This appendix summarises the interview held with the Chief Executive Officer (CEO) of the KNRM on the 11^{th} of March 2021, which lasted approximately 90 minutes and was held online, due to the COVID19 restrictions. The interview was continued on the 28^{th} of April. This second part of the interview lasted for another half an hour.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter

The interviewee was asked to formulate a choice from the five options and build a case why the choice was made, which he didn't find time to do prior to the interview.

The interview had three goals. First of all, the CEO finalised the criteria involved in evaluating the test case. Although not logically the first topic, it was addressed first because it is a critical input for the remainder of the interviews.

Second of all, during the interview the CEO was asked to determine the vectors BO and OW. This was then transformed into weights using the linear problem in order to present an indication to the interviewee on the outcomes.

Third of all, the interviewee was asked to evaluate the test case on the selected criteria.

The first interview started with an evaluation of the criteria formulated for the organisation. Then, the five alternatives were summarised in order to present the background on the decision problem to be evaluated. Hereafter the interviewee was asked what criteria were to be included in the evaluation of the test case, based on the initial filtering done by the author, the CTO and the founder of Next Generation Machinery. The selected criteria are shown in figure N.1. In this figure, the criteria marked in green have been evaluated in the case description. The criteria marked in blue, are scored based on experience and interpretation by the interviewees. The criteria marked in orange are excluded from the evaluation. During the reflection of the criteria, the CEO mentioned some criteria were left out of the evaluation, because the test case doesn't provide any information on them, while he would normally have included them, such as the contractual conditions, data protection, collegiality and some others. This is an effect of using a fictional test case and is deemed not to impact the overall value of the test case itself.

Then, the interviewee was explained how to obtain the BO and OW vector and an initial sheet was filled out to establish a thorough understanding of the procedure. Then the remaining steps of the procedure were explained and the interviewee was offered the opportunity to either continue the procedure together or individually. Having chosen to continue individually, the interview was concluded thanking the interviewee for his participation and the time invested.

In follow-up of the interview, the CEO continued to work on the evaluation of the criteria and supplying the data. Having read the test case, he transferred his vision on the case and his initial choice to the researcher by e-mail. He preferred the fourth option, explaining his choice as follows: *"Ik verwacht dat*

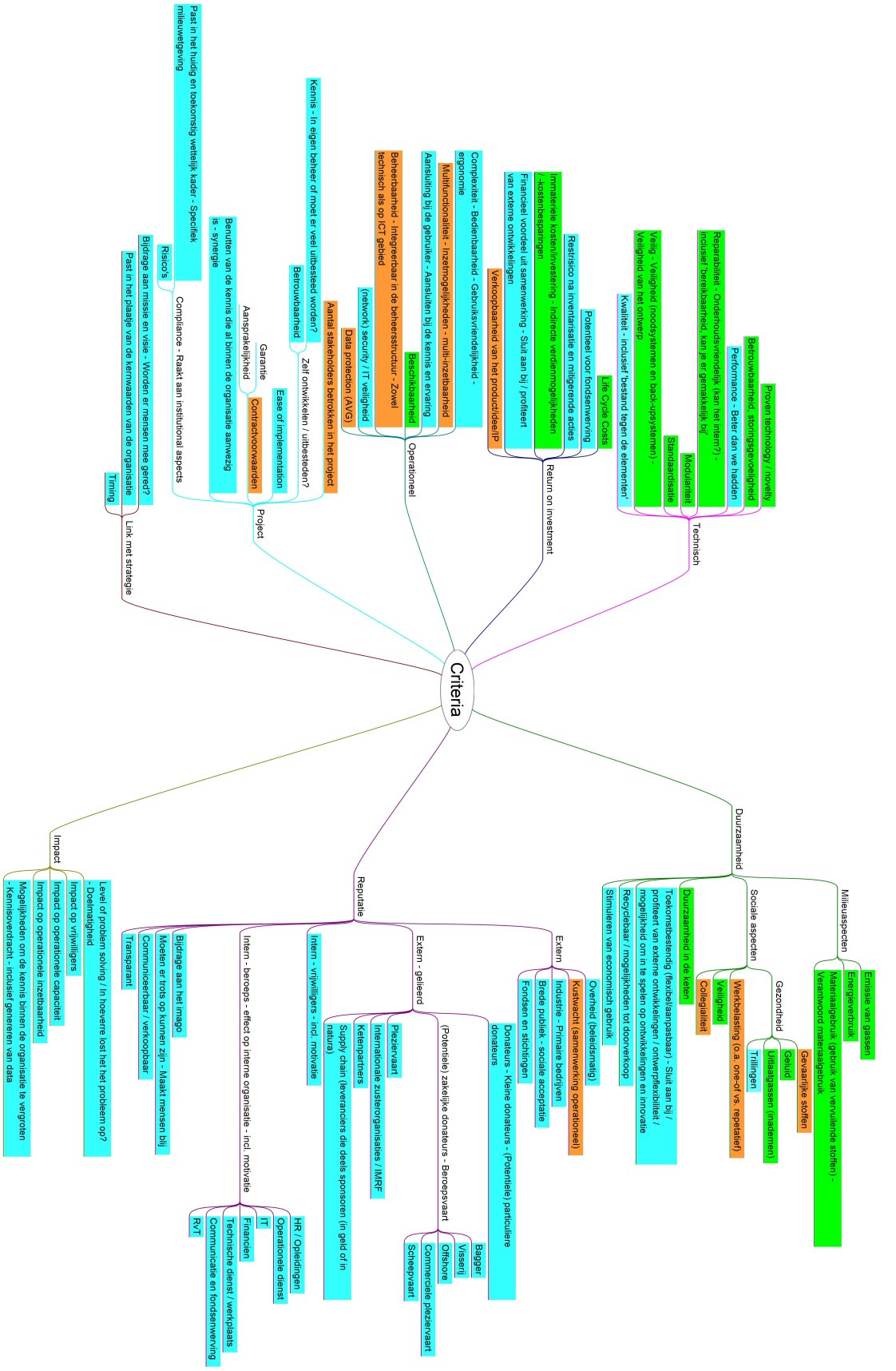


Figure N.1: The selection of the subset of criteria used for the evaluation of the test case.

de maintenance en fall out zo laag is dat modulaire opzet niet loont en ook de KHV[1] uitwisseling vind ik in dit stadium te ver gaan. Vanwege veiligheid van de bestuurder ben ik wel enthousiast over de afstandbediening wederom 100% fail proof uitgevoerd.".

Having finished establishing the weights and scoring the performance of the variants in respect to the individual criteria, the CEO returned the datasheet to the researcher. The researcher prepared the analysis (shown in figures N.4 and N.5). These analyses were the basis for the discussion in the second part of the interview. Next to the analysis, the interviewee was asked if the model lead to new insights that might result in a different choice. Finally, the interviewee was asked for his considerations in respect to the future use of the model by the organisation.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure N.2b and table N.1. These figures were also evaluated with the CEO. He commented the evaluation of life cycle costs against safety was to be one of the most important comparisons in the model. Therefore, he would have wanted to have the criterion 'safety', in the social context, to have ranked higher. This wasn't altered in the model, as the lower score resulted from the layered structure within the model rather than a low score for the criteria itself.

Weights overview

Criterion	Gross weight		Nett weight
Link met de strategie	0.261		
Bijdrage aan de missie en visie	0.657		0.172
Past het in het plaatje van de kernwaarden en strategische thema's	0.271		0.071
Timing	0.071		0.019
Impact van het project op de organisatie	0.053		
Level of problem solving	0.264		0.014
Impact op vrijwilligers	0.426		0.023
Impact op operationele capaciteit	0.088		0.005
Impact op operationele beschikbaarheid	0.176		0.009
Mogelijkheden om de kennis binnen de organisatie te vergroten	0.046		0.002
Eigenschappen van het project	0.022		
Aantal stakeholders dat een rol speelt	0.064		0.001
Zelf ontwikkelen vs. uitbesteden	0.037		
Kennis		0.200	0.000
Betrouwbaarheid van externe partijen/leveranciers		0.800	0.001
Ease of implementation	0.374		0.009
Contractvoorwaarden	0.150		
Garantievoorwaarden		0.167	0.001
Aansprakelijkheidsrisico		0.833	0.003
Benutten van kennis en mogelijkheden	0.150		0.003
Compliance	0.225		
Past in het huidige en toekomstige wettelijke- en beleidskader		0.750	0.004
Risico's die voortkomen uit compliance		0.250	0.001
Operationele aspecten	0.159		
Complexiteit	0.321		0.051
Multifunctinaliteit	0.055		0.009
Aansluiting bij de beoogde gebruiker	0.193		0.031
Beschikbaarheid	0.032		0.005
Beheerbaarheid	0.077		0.012
IT veiligheid	0.129		0.020
Databeveiliging	0.193		0.031
Technische aspecten	0.080		
Proven technology	0.115		0.009

[1]Beach Assistance Vehicle (BAV)

Table N.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Betrouwbaarheid		0.287		0.023
Performance		0.069		0.005
Reparabiliteit		0,086		0,007
Modulariteit		0.029		0.002
Standaardisatie		0.069		0.005
(technische) veiligheid		0.172		0.014
Algehele kwaliteit		0.172		0.014
Duurzaamheid	0.159			
Milieuaspecten		0.304		
Uitstoot van gassen			0.650	0.031
Energieverbruik			0.267	0.013
Materiaalgebruik			0.083	0.004
Sociale aspecten		0.304		
Verzamelde gezondheidsaspecten			0.237	
Gevaarlijke stoffen				0.169 0.002
Geluid				0.226 0.003
Uilaatgassen				0.546 0.006
Trillingen				0.059 0.001
Werkbelasting voor de gebruiker			0.142	0.007
Veiligheid voor de gebruiker			0.554	0.027
(Invloed op) collegialiteit			0.066	0.003
Duurzaamheid in de keten van leveranciers		0.188		0.030
Toekomstbestendigheid		0.075		0.012
Recyclebaar		0.094		0.015
Mate waarin economisch gebruik gestimuleerd kan worden.		0.033		0.005
Return on investment	0.159			
Life cycle costs		0.518		0.082
Potentieel voor fondsenwerving		0.091		0.015
Financieel restrisico na mitigerende acties		0.106		0.017
Immateriele kosten/investeringen		0.128		0.020
Financieel voordeel uit samenwerking		0.050		0.008
Verkooppotentieel		0.106		0.017
Reputatie	0.106			
Externe partijen		0.090		
Overheid			0.169	0.002
Kustwacht			0.253	0.002
Industrie			0.044	0.000
Brede publiek			0.126	0.001
Fondsen en stichtingen			0.408	0.004
Externe partijen gelieerd aan de KNRM		0.135		
(kleine) Donateurs			0.236	0.003
Groep van (potentiele) zakelijke donateurs			0.394	
Reguliere scheepvaart				0.345 0.002
Visserij				0.241 0.001
Offshore industrie				0.241 0.001
Commerciele pleziervaart				0.121 0.001
Baggervaart				0.052 0.000
Pleziervaart			0.079	0.001
Internationale zusterorganisaties / IMRF			0.094	0.001
Ketenpartners			0.157	0.002
Supply chain			0.039	0.001
Intern - reputatie onder vrijwilligers		0.203		0.021
Intern - beroepsorganisatie. Effecten op de beroepsorganisatie		0.270		
HR / Opleidingen			0.086	0.002
IT			0.072	0.002

Table N.1 continued from previous page

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Operationele dienst		0.215	0.006
Financien		0.040	0.001
Technische dienst		0.108	0.003
Communicatie en fondsenwerving		0.144	0.004
Raad van Toezicht		0.335	0.010
Bijdrage aan het image van de organisatie	0.090		0.010
Kunnen er trots op zijn	0.054		0.006
Communiceerbaar	0.023		0.002
Transparant	0.135		0.014

Table N.1: The weights table resulting from the interview with the CEO

Table N.2 indicates the CEO started off using the input-based consistency only during the beginning. This may be attributed to a delay between the explanation by the researcher on how to use the sheet and the moment of entering the data. On the other hand, the table also shows the input-based consistency doesn't always provide an accurate estimate of the actual consistency.

Table N.3 and figure N.3 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant. This shows that the model outcome, in which variant five is preferred, differs from the outcome of the evaluation without usage of the model. This was evaluated in more depth in relation to the analysis as shown in figure N.5. The CEO found the analysis very helpful in understanding the choice. Although he stated he would like to make some minor changes to the outcome, he underlined the overall outcome. When talking in a little more depth about the differences between variants three and five, the insights from the analysis made the CEO change his opinion and go with option five. The main reason for the change was in the performance in respect to the redundancy criterion.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure N.4b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure N.4a. Finally, the choice was analysed and the most relevant variants were selected. In the case of the CEO, this were the variants three, four and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure N.5. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

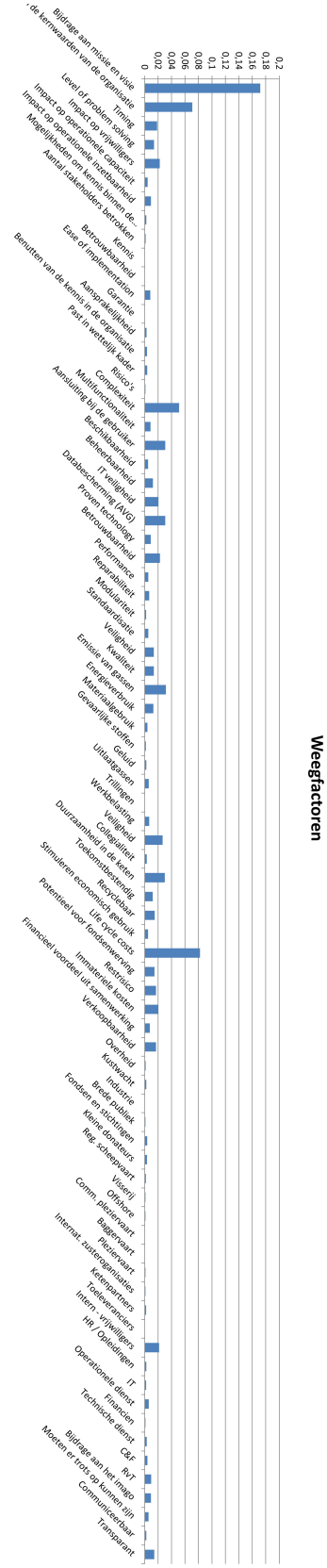
With respect to the analysis, the CEO mentioned this to be the true value of the model. The model should not just present an outcome; instead the rationale behind the outcome makes the model valuable. Beyond the analysis as the rationale of the choice, the analysis also provides insight in what information is decisive in the decision. This could be ground for further research in respect to the variants and could be ground to ask a provider for more details on these aspects of the offering.

The CEO underlined the value of the model, not in to make the decision itself, but to assist in the process, supporting a challenged decision. The model also results in a more thorough decision making process, for instance by providing checks and balances to the Board of Executives (BOE).

The model could also be a tool to deal with, or absorb, conservatism. For instance, conservative viewpoints would relate to certain criteria, whilst not affecting the remainder of the decision set. The conservatism also results in a risk-avoiding attitude. This is also supported by a strong safety culture. This is of course important in relation to the core operation of the KNRM, but could hamper an objective decision when other decisions are involved. The model may also contribute to a solution to solve this, as it supports the objectivity of decision making.

All in all, the CEO sees a clear value of the model, but also some constraints, as it is time consuming to use. Therefore, the model should be put to use with a specific goal in mind. Then again, overall,

(a) Sorted weights as obtained from the interview with the CEO.



(b) Ordered weights as obtained from the interview with the CEO.

Performance indicators									
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.208	0.362	0.057	5.23	0.011	0.459	0.056	1.990	0.972
Link met strategie	0.262	0	0.157	3.73	0.042	0.209	0	0	0
Impact	0.262	0.282	0.102	3.73	0,027	0.373	0.031	0.966	0.967
Project	0.232	0.315	0.075	4.47	0.017	0.423	0.026	1.348	0.981
Zelf ontwikkelen / uitbesteden	0	0	0	1.63	0	0	0	0	0
Contractvoorwaarden	0	0	0	2.3	0	0	0	0	0
Compliance	0	0	0	1	0	0	0	0	0
Operationeel	0.214	0.341	0.064	4.47	0,014	0.438	0.053	1.630	0.967
Technisch	0.214	0.362	0.057	4.47	0.013	0.454	0.049	1.876	0.974
Duurzaamheid	0.310	0.303	0.072	3.73	0.019	0.393	0.046	1.283	0.883
Milieuaspecten	0.3	0.133	0.15	3	0.05	0.216	0	0	0
Sociale aspecten	0.467	0.199	0.158	4.47	0.035	0.292	0	0.52	1
Gezondheid	0.310	0.246	0.131	3.73	0.035	0.331	0	0.566	1
Return on investment	0.304	0.315	0.121	4.47	0.027	0.423	0.016	1.348	0.988
Reputatie	0.5	0.322	0.068	5,23	0.013	0.417	0.098	1.638	0.940
Extern	0.310	0.282	0.098	4.47	0.022	0.373	0.032	0.966	0.967
Extern - gelieerd	0.214	0.315	0.079	4.47	0.018	0.423	0.025	1.348	0.981
Intern - beroeps	0.467	0.314	0.096	4.47	0.021	0.406	0.033	1.427	0.977
(potentiele) zakelijke donateur	0.75	0.231	0.138	3.73	0.037	0.037	0.055	0.782	0.929

Table N.2: Performance indicators for establishing the weights by the CEO.

Variant	Synthesizing criterion
Variant 1	5,000
Variant 2	5,304
Variant 3	6,283
Variant 4	6,269
Variant 5	6,449

Table N.3: The outcome of scoring the performance of the variants by the CEO

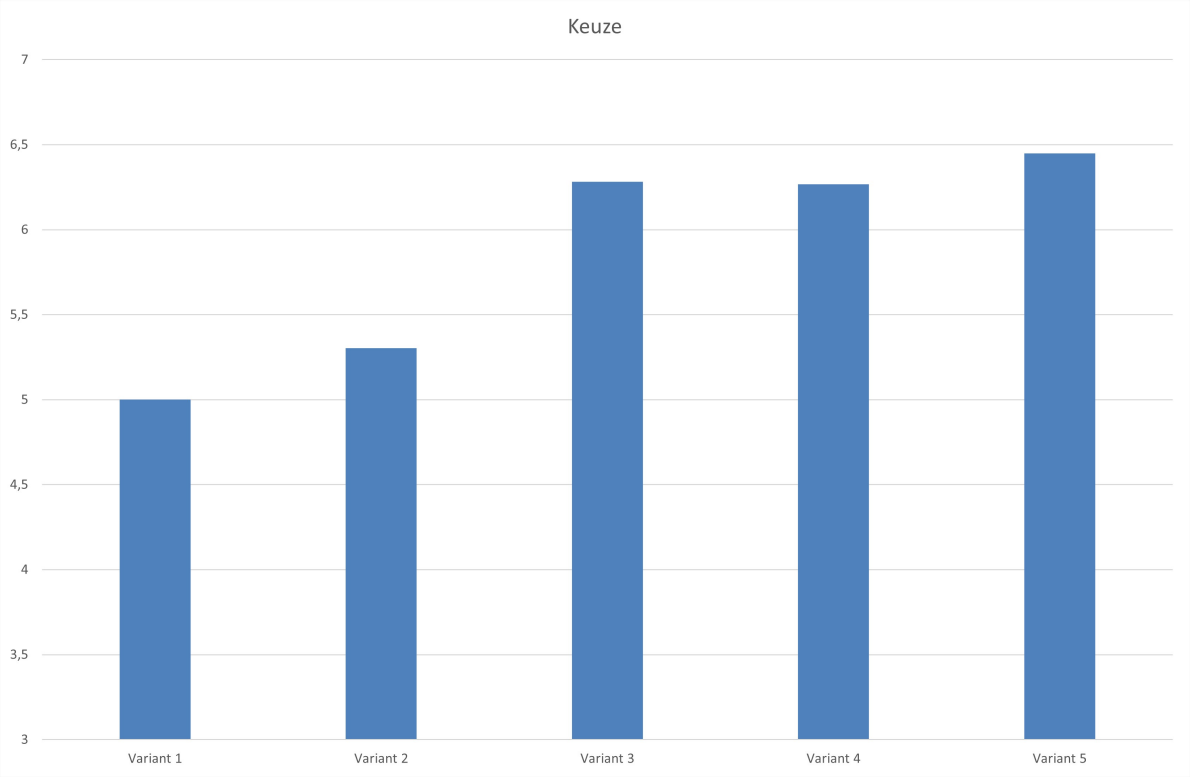
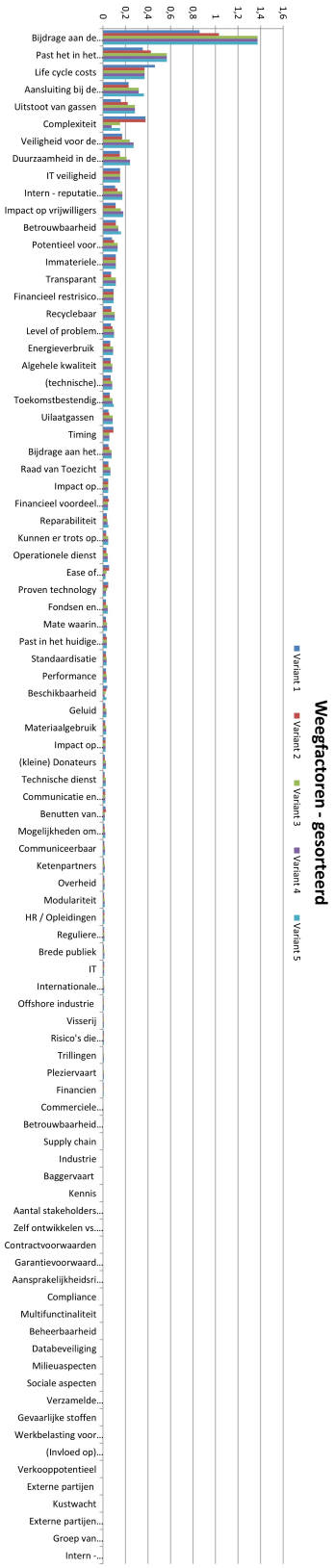
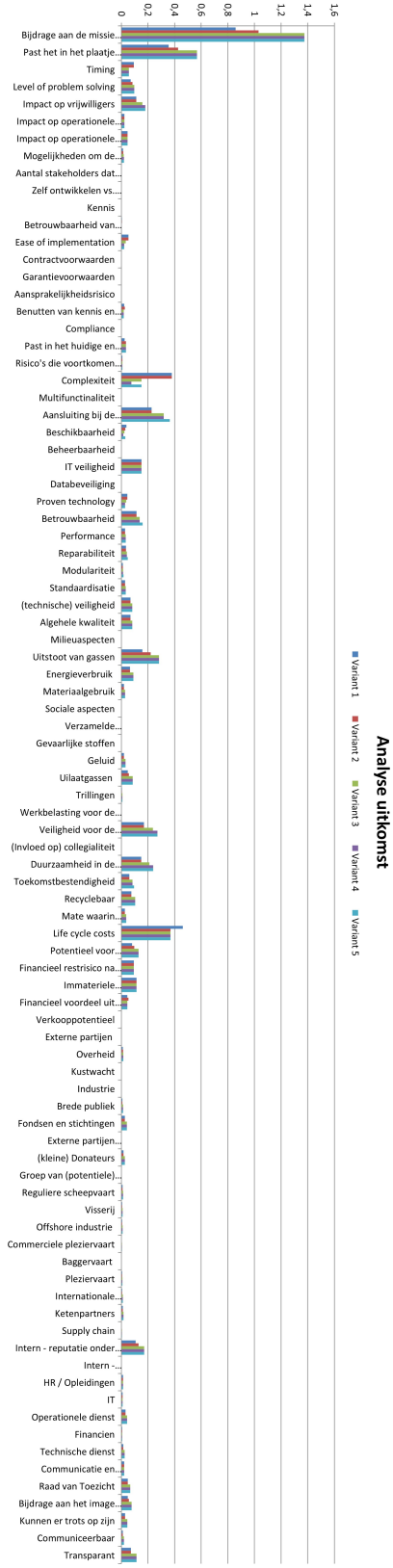


Figure N.3: The choice amongst variants as resulted from the interview with the CEO.

there is a clear case to use it.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the CEO.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the CEO.

Figure N.4: The weights as obtained from the interview with the CEO.

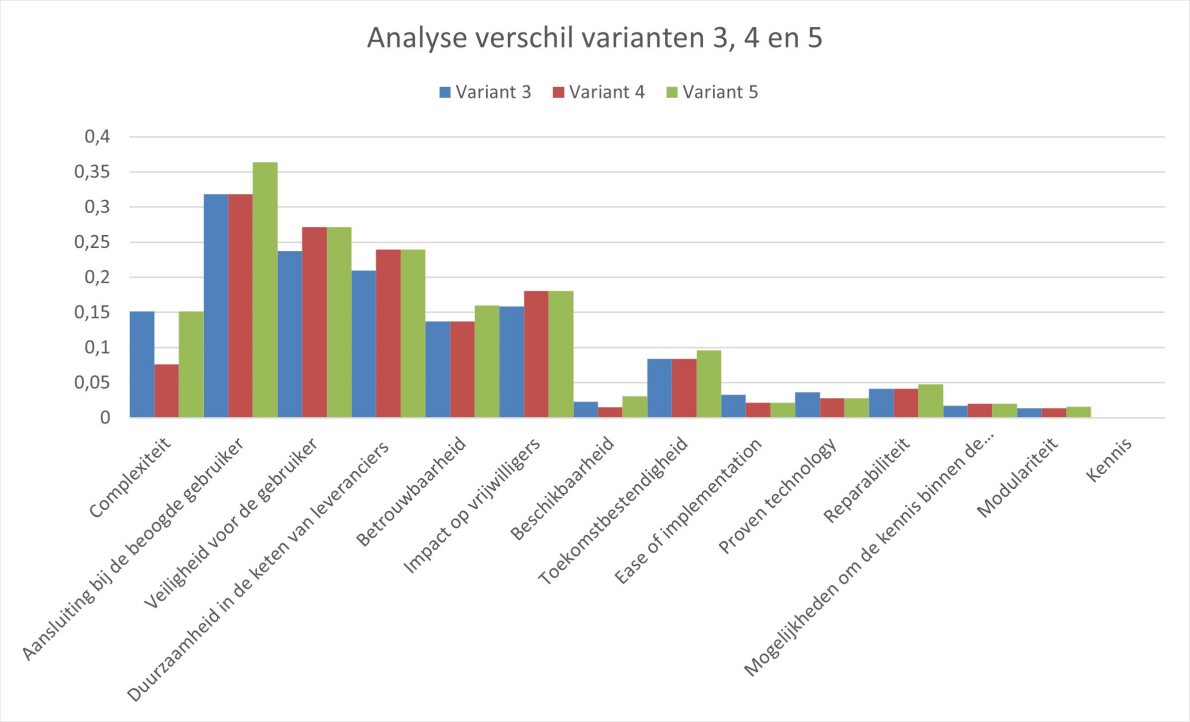


Figure N.5: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

O

Interview on the weights with the CTO

This appendix summarises the interview held with the Chief Technology Officer (CTO) of the Koninklijke Nederlandse Reddingmaatschappij (KNRM) on the 15^{th} of March 2021, which lasted approximately four hours.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter

At the start of the interview, the interviewee was asked for his preference amongst the variants presented in the test case, using the same method as he would when such a decision was presented to the Board of Executives (BOE). Since no systematic method is yet in place, the CTO chose the third variant, based on two main arguments:

1. This variant doesn't include a remote control, therefore negating any risks in relation to interference. Furthermore, he expects the introduction of an umbilical induces hassle upon the crews.
2. Having a driver on the vehicle results in the volunteers/operators having more contact and feeling with what they are doing when operating the vehicle. This is also a feeling or emotion that is strongly felt amongst crews and drivers.

The second part of the interview consisted of filling out the worksheet to obtain the weights, as detailed in appendix M. The next part consisted of filling out the performance tab in the worksheet. The final part consisted of an evaluation of the outcome of the model, a discussion on the analysis of the outcome and an evaluation of the method. Remarks from the respective parts are detailed below.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure O.1 and table O.1.

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Link met strategie	0.045		
Bijdrage aan missie en visie		0.714	0.032
Past in de kernwaarden van de organisatie		0.214	0.010
Timing		0.071	0.003
Impact	0.053		
Level of problem solving		0.169	0.009
Impact op vrijwilligers		0,044	0.002
Impact op operationele capaciteit		0.253	0.013
Impact op operationele inzetbaarheid		0.408	0.022
Mogelijkheden om kennis binnen de organisatie te vergroten		0.126	0.007

Table O.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Project	0.254			
Aantal stakeholders betrokken		0.156		0.040
Zelf ontwikkelen / uitbesteden		0.117		
Kennis			0.333	0.010
Betrouwbaarheid			0.667	0.020
Ease of implementation		0.039		0.010
Contractvoorwaarden		0.233		
Garantie			0.8	0.047
Aansprakelijkheid			0.2	0.012
Benutten van de kennis in de organisatie		0.389		0.099
Compliance		0.067		
Past in wettelijk kader			0.833	0.014
Risico's			0.167	0.003
Operationeel	0.254			
Complexiteit		0.157		0.040
Multifunctionaliteit		0.157		0.040
Aansluiting bij de gebruiker		0.118		0.030
Beschikbaarheid		0.376		0.096
Beheerbaarheid		0.078		0.020
IT veiligheid		0.078		0.020
Databescherming (AVG)		0.035		0.009
Technisch	0.158			
Proven technology		0.226		0.036
Betrouwbaarheid		0.141		0.022
Performance		0.141		0.022
Reparabiliteit		0.141		0.022
Modulariteit		0.024		0.004
Standaardisatie		0.094		0.015
(Techn.) veiligheid		0.094		0.015
Kwaliteit		0.141		0.022
Duurzaamheid	0.106			
Milieuaspecten		0.372		
Emissie van gassen			0.589	0.023
Energieverbruik			0.071	0.003
Materiaalgebruik			0.339	0.013
Sociale aspecten		0.223		
Gezondheid			0.313	
Gevaarlijke stoffen				0.075 0.001
Geluid				0.245 0.002
Uitlaatgassen				0.245 0.002
Trillingen				0.434 0.003
Werkbelasting			0.063	0.001
(Soc.) veiligheid			0.5	0.012
Collegialiteit			0.125	0.003
Duurzaamheid in de keten		0.056		0.006
Toekomstbestendig		0.089		0.009
Recyclebaar		0.223		0.024
Stimuleren economisch gebruik		0.037		0.004
Return on investment	0.024			
Life cycle costs		0.378		0.009
Potentieel voor fondsenwerving		0.222		0.005
Restrisico		0.052		0.001
Immateriele kosten		0.148		0.004
Financieel voordeel uit samenwerking		0.111		0.003

Table O.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Verkoopbaarheid		0.089		0.002
Reputatie	0.106			
Externe partijen		0.061		
Overheid			0.074	0.000
Kustwacht			0.111	0.001
Industrie			0.222	0.001
Brede publiek			0.370	0.002
Fondsen en stichtingen			0.222	0.001
Extern - gelieerd		0.065		
Kleine donateurs			0.239	0.002
Zakelijke donateurs			0.390	
Reg. scheepvaart				0.346 0.001
Visserij				0.192 0.001
Offshore				0.192 0.001
Comm. pleziervaart				0.077 0.000
Baggervaart				0.192 0.001
Pleziervaart			0.095	0.001
Internat. zusteroganisaties			0.119	0.001
Ketenpartners			0.095	0.001
Toeleveranciers			0.061	0.000
Intern - vrijwilligers		0.081		0.009
Intern - beroeps		0.081		
HR / Opleidingen			0.085	0.001
IT			0.047	0.000
Operationele dienst			0.355	0.003
Financien			0.071	0.001
Technische dienst			0.213	0.002
C&F			0.142	0.001
RvT			0.085	0.001
Bijdrage aan het imago		0.283		0.030
Moeten er trots op kunnen zijn		0.162		0.017
Communiceerbaar		0.162		0.017
Transparant		0.108		0.011

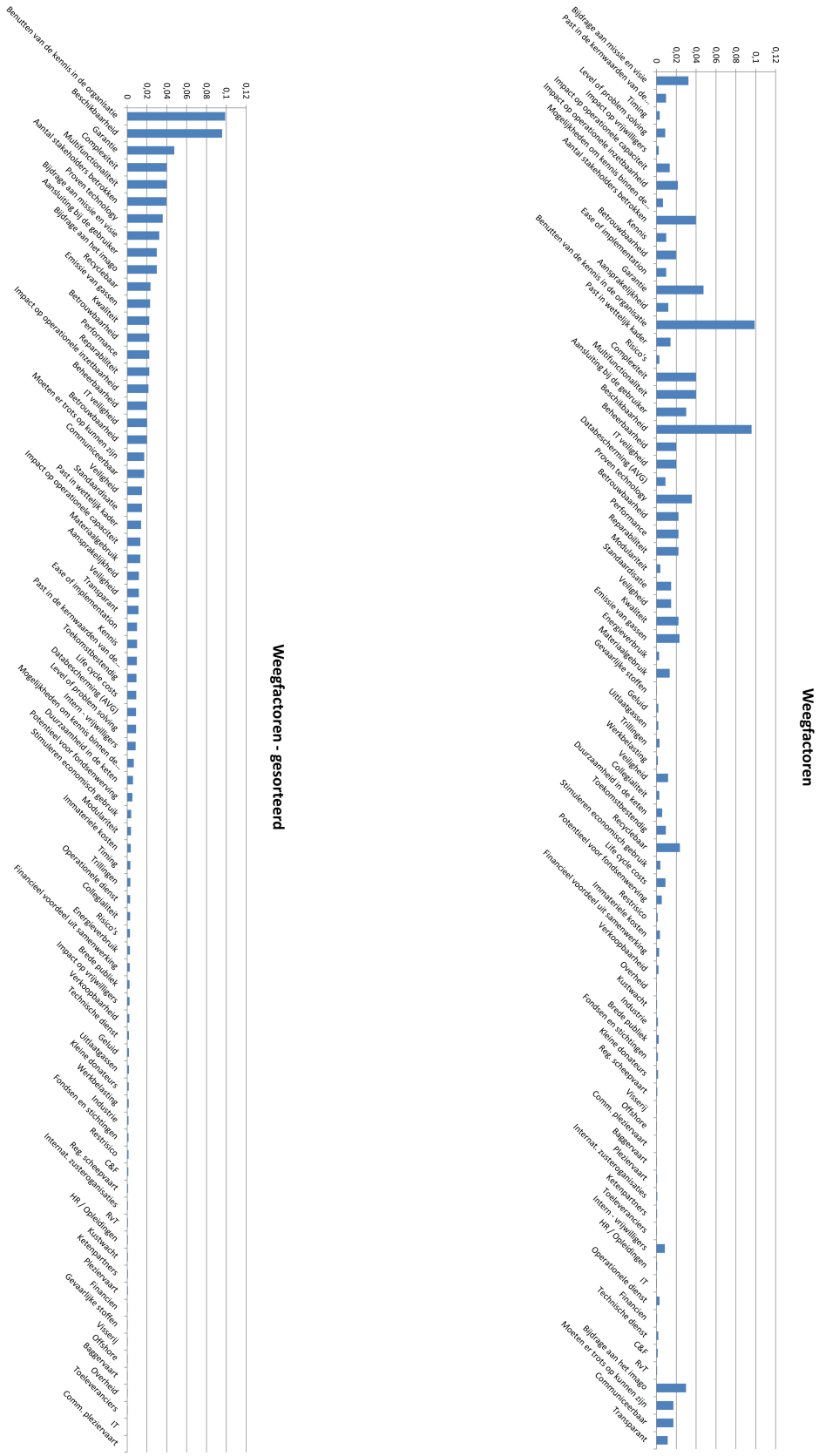
Table O.1: The weights table resulting from the interview with the CTO

Table O.2 shows the performance indicators for the CEO. This table shows only a singe inconsistency in the input-based consistency, which occurred in the sheet of the 'Sociale aspecten'. This didn't result in an invalid output-based consistency and was therefore accepted. Furthermore, the value for ψ in the sheet 'Intern - beroeps' equals zero. This is as the solver was unable to calculate the values for w_j^{max*} and w_j^{min*}. An error in the programming could not be identified, even replacing the sheet didn't sort an effect. Therefore, no valid outcome for these fields could be established.

Table O.3 and figure O.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure O.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure O.3a. Finally, the choice was analysed and the most relevant variants were selected. In the case of the CTO, this were the variants three, four and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure O.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

As can be learnt from the above, the model outcome confirms the initial choice for variant three, yet the choice is now based on over 80 criteria, rather than the three initially provided. The CTO confirmed



(a) Sorted weights as obtained from the interview with the CTO.

(b) Ordered weights as obtained from the interview with the CTO.

Figure O.1: The weights as obtained from the interview with the CTO.

	Performance indicators								
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.357	0.362	0.062	4.47	0.014	0.454	0.083	1.876	0.956
Link met strategie	0.214	0.362	0.143	4.47	0.032	0.227	0	0	0
Impact	0.262	0.282	0.098	4.47	0.022	0.373	0.032	0.966	0.967
Project	0.214	0.315	0.078	5.23	0.015	0.423	0.030	1.348	0.978
Zelf ontwikkelen / uitbesteden	0	0	0	0.44	0	0	0	0	0
Contractvoorwaarden	0	0	0	1.63	0	0	0	0	0
Compliance	0	0	0	2.3	0	0	0	0	0
Operationeel	0.286	0.341	0.094	4.47	0.021	0.438	0.050	1.630	0.970
Technisch	0.262	0.325	0.055	4.47	0.012	0.411	0.063	1.782	0.965
Duurzaamheid	0.153	0.334	0.074	5.23	0.014	0.423	0.028	1.412	0.934
Milieuaspecten	0.119	0.129	0.089	3.73	0.024	0.209	0	0	0
Sociale aspecten	0.3	0.199	0.125	4.47	0.028	0.292	0	0.52	1
Gezondheid	0.15	0.199	0.057	2.3	0.025	0.285	0.022	0.460	0.953
Return on investment	0.3	0.304	0.067	3	0.022	0.392	0.022	1.183	0.981
Reputatie	0.15	0.284	0.040	2.3	0.018	0.361	0.036	1.386	0.974
Extern	0.15	0.231	0.074	2.3	0.032	0.302	0.030	0.782	0.962
Extern - gelieerd	0.3	0.304	0.087	3	0.029	0.392	0.026	1.183	0.978
Intern - beroeps	0.3	0.314	0.071	3	0.024	0.406	0	1.427	1
(potentiele) zakelijke donateur	0.05	0.231	0.038	2.3	0.017	0.302	0.018	0.782	0.976

Table O.2: Performance indicators for establishing the weights by the CTO.

Variant	Synthesizing criterion
Variant 1	4.649
Variant 2	4.941
Variant 3	6.839
Variant 4	6.525
Variant 5	6.674

Table O.3: The outcome of scoring the performance of the variants by the CTO

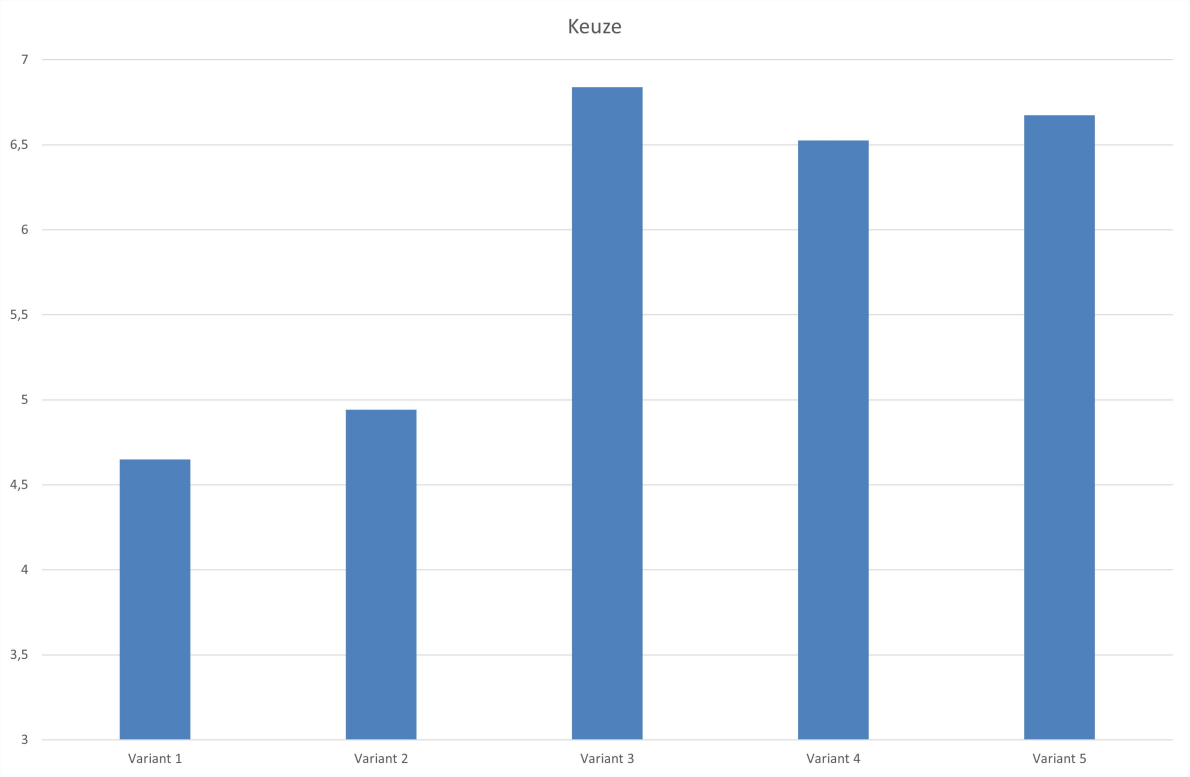
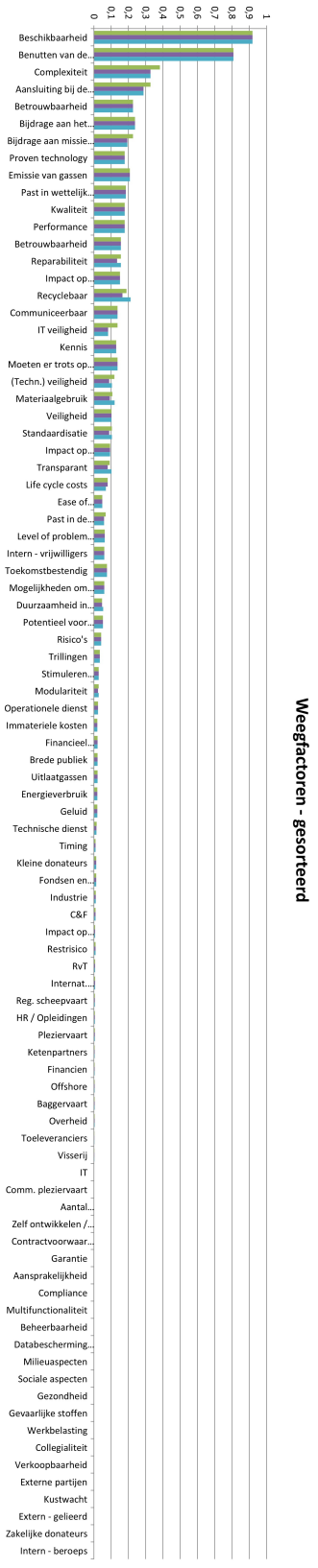
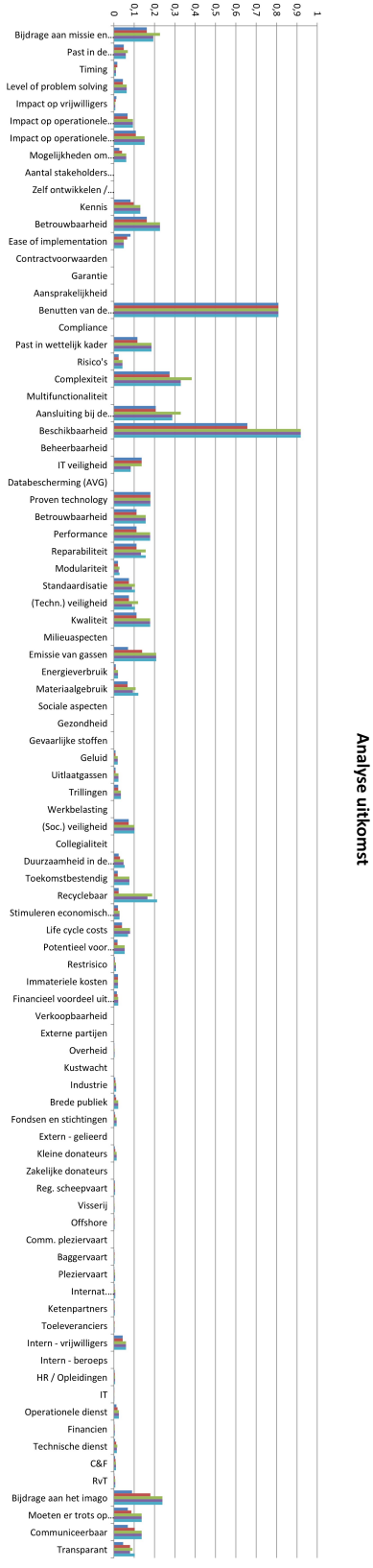


Figure O.2: The choice amongst variants as resulted from the interview with the CTO.

he valued to learn what criteria contributed to differentiate amongst the variants. Furthermore, in the evaluation he stipulated the value of having a systematic method which enforces the inclusion of many more criteria than initially came to mind.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the CTO.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the CTO.

Figure O.3: The weights as obtained from the interview with the CTO.

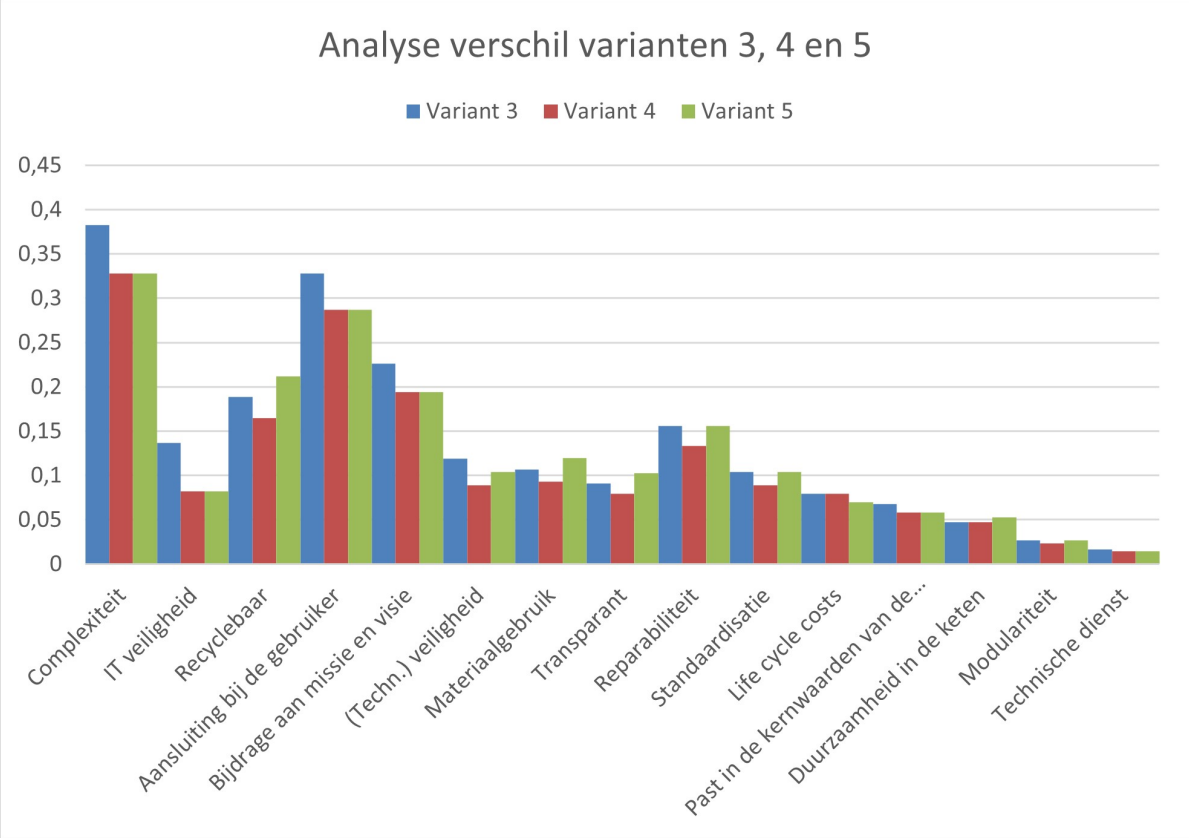


Figure O.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

P

Interview on the weights with the COO

This appendix summarises the interview held with mr. J. Geel, Chief Operations Officer (COO) of the KNRM on the 26^{th} of March 2021 and was finished on the 15^{th} of April. The first session lasted approximately two hours, the second session lasted for another huor and a half.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter
During the initial interview, the interviewee commented on the test case as being not realistic, pointing towards the financial information, in particular in respect to the maintenance. The interviewee furthermore missed an evaluation of the performance under operational conditions, such as the stability and the risk of tipping over. The author then explained the interview focussed on the process of decision making rather than the actual case, as it was partly fictional to start with. Furthermore, the study would focus on the process of making the choice, rather than on the choice itself. With these arguments, the interviewee was appeased. However, the interviewee said he wasn't able to choose amongst these variants, as neither one was realistic to him. The author asked the interviewee if he would be able to judge the variants based on the new information presented to him, he agreed and it was decided to score the performance of the variants individually and set another date for the evaluation of the outcome. Therefore, the first interview focussed on obtaining the weights only.

The interviewee then filled in the tab on scoring the performance of the variants in respect to the criteria individually and handed the file to the author, who then analysed the results. During this part of the interview, the interviewee commented on the criterion 'operationele inzetbaarheid', which he referred to as 'operationele beschikbaarheid'.

In the second interview, the interviewee was again asked to choose amongst the five variants. Having presented his argumentation, the interview continued by evaluation the outcome of the model and the analysis of the results executed by the author in preparation of the second part of the interview. Finally, the interviewee was asked to evaluate the process and asked for observations that could be relevant for the future use of the model in the decision making process of the organisation.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure P.1 and table P.1.

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Link met de strategie	0.194		
Bijdrage aan de missie en visie		0.571	0.111
Past het in het plaatje van de kernwaarden en strategische thema's		0.286	0.055
Timing		0.143	0.028
Impact van het project op de organisatie	0.332		

Table P.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Level of problem solving		0.086		0.028
Impact op vrijwilligers		0.258		0.085
Impact op operationele capaciteit		0.172		0.057
Impact op operationele beschikbaarheid		0.434		0.144
Mogelijkheden om de kennis binnen de organisatie te vergroten		0.051		0.017
Eigenschappen van het project	0.031			
Aantal stakeholders dat een rol speelt		0.128		0.004
Zelf ontwikkelen vs. uitbesteden		0.128		
Kennis			0.2	0.001
Betrouwbaarheid van externe partijen/leveranciers			0.8	0.003
Ease of implementation		0.171		0.005
Contractvoorwaarden		0.053		
Garantievoorwaarden			0.25	0.000
Aansprakelijkheidsrisico			0.75	0.001
Benutten van kennis en mogelijkheden		0.417		0.013
Compliance		0.103		
Past in het huidige en toekomstige wettelijke- en beleidskader			0.143	0.000
Risico's die voortkomen uit compliance			0.857	0.003
Operationele aspecten	0.129			
Complexiteit		0.268		0.035
Multifunctinaliteit		0.063		0.008
Aansluiting bij de beoogde gebruiker		0.268		0.035
Beschikbaarheid		0.237		0.031
Beheerbaarheid		0.032		0.004
IT veiligheid		0.079		0.010
Databeveiliging		0.053		0.007
Technische aspecten	0.065			
Proven technology		0.060		0.004
Betrouwbaarheid		0.384		0.025
Performance		0.032		0.002
Reparabiliteit		0.069		0.004
Modulariteit		0.060		0.004
Standaardisatie		0.096		0.006
(technische) veiligheid		0.240		0.016
Algehele kwaliteit		0.060		0.004
Duurzaamheid	0.055			
Milieuaspecten		0.221		
Uitstoot van gassen			0.644	0.008
Energieverbruik			0.244	0.003
Materiaalgebruik			0.111	0.001
Sociale aspecten		0.379		
Verzamelde gezondheidsaspecten			0.280	
Gevaarlijke stoffen				0.238 0.001
Geluid				0.238 0.001
Uilaatgassen				0.429 0,003
Trillingen				0.095 0.001
Werkbelasting voor de gebruiker			0.086	0.002
Veiligheid voor de gebruiker			0.495	0.010
(Invloed op) collegialiteit			0.140	0.003
Duurzaamheid in de keten van leveranciers		0.089		0.005
Toekomstbestendigheid		0.148		0.008
Recyclebaar		0.053		0.003
Mate waarin economisch gebruik gestimuleerd kan worden.		0.111		0.006
Return on investment	0.097			
Life cycle costs		0.379		0.037
Potentieel voor fondsenwerving		0.111		0.011
Financieel restrisico na mitigerende acties		0.089		0.009
Immateriele kosten/investeringen		0.221		0.021
Financieel voordeel uit samenwerking		0.148		0.014
Verkooppotentieel		0.053		0.005
Reputatie	0.097			
Externe partijen		0.069		
Overheid			0.130	0.001

Table P.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Kustwacht		0.435		0.003
Industrie		0.070		0.000
Brede publiek		0.104		0.001
Fondsen en stichtingen		0.261		0.002
Externe partijen gelieerd aan de KNRM	0.086			
(kleine) Donateurs		0.150		0.001
Groep van (potentiele) zakelijke donateurs		0.225		
Reguliere scheepvaart			0.342	0.001
Visserij			0.184	0.000
Offshore industrie			0.184	0.000
Commerciele pleziervaart			0.105	0.000
Baggervaart			0.184	0.000
Pleziervaart		0.112		0.001
Internationale zusterorganisaties / IMRF		0.053		0.000
Ketenpartners		0.385		0.003
Supply chain		0.075		0.001
Intern - reputatie onder vrijwilligers	0.173			0.017
Intern - beroepsorganisatie. Effecten op de beroepsorganisatie	0.173			
HR / Opleidingen		0.121		0.002
IT		0.121		0.002
Operationele dienst		0.224		0.004
Financien		0.121		0.002
Technische dienst		0.121		0.002
C&F		0.224		0.004
RvT		0.069		0.001
Bijdrage aan het image van de organisatie	0.292			0.028
Kunnen er trots op zijn	0.058			0.006
Communiceerbaar	0.034			0.003
Transparant	0.115			0.011

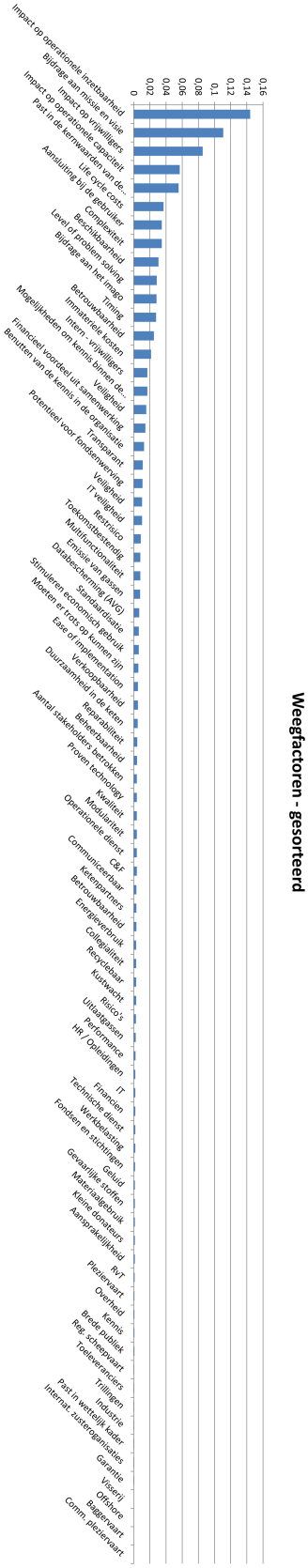
Table P.1: The weights table resulting from the interview with the COO.

Table P.2 provides an overview of the performance parameters of the interview with the COO. It shows, that on three occasions an input-based consistency was accepted which exceeded the threshold value. In neither case, this resulted in an output-based consistency exceeding the threshold. This supports that the input-based consistency is more restrictive than the output-based value.

Table P.3 and figure P.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure P.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure P.3a. Finally, the choice was analysed and the most relevant variants were selected. In the case of the COO, this were the variants two, three and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure P.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

With respect to his initial choice, the interviewee commented on variant one that it was the same as they currently had. He commented on variant two that it was still the same solution, yet it contributed to the sustainability. With regards to the third variant he commented that the sustainability of the variant was perfect, yet the availability was low, most profoundly because the vehicle would not be able to assist another vehicle from a nearby lifeboat station. He also commented the modularity was low due to the fact the tractor could not be disconnected from the trailer. The same was commented in respect to the fourth variant, along with the fact that the high voltage was another significant disadvantage. In respect to the fifth variant, the interviewee commented that it lacked a match with the designated user, as he wouldn't be present on the vehicle itself. It would definitely take time to get accustomed, but even then the interviewee had his doubt as to whether or not the designated users would like it.



(a) Sorted weights as obtained from the interview with the COO.

(b) Ordered weights as obtained from the interview with the COO.

Figure P.1: The weights as obtained from the interview with the COO.

	Performance indicators								
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.153	0.362	0.056	5.23	0.011	0.459	0.039	1.990	0.981
Link met strategie	0	0.112	0	1.63	0	0.158	0	0	0
Impact	0.190	0.282	0.081	3.73	0.022	0.373	0.025	0.966	0.974
Project	0.333	0.304	0.096	3	0.032	0.392	0.023	1.183	0.980
Zelf ontwikkelen / uitbesteden	0	0	0	1.63	0	0	0	0	0
Contractvoorwaarden	0	0	0	1	0	0	0	0	0
Compliance	0	0	0	3	0	0	0	0	0
Operationeel	0.214	0.314	0.047	3.73	0.013	0.404	0.081	1.550	0.948
Technisch	0.361	0.362	0.096	5.23	0.018	0.459	0.051	1.990	0.974
Duurzaamheid	0.2	0.304	0.063	3	0.021	0.392	0.021	1.183	0.945
Milieuaspecten	0.2	0.135	0.089	2.3	0.039	0.211	0	0	0
Sociale aspecten	0.15	0.199	0.065	2.3	0.028	0.285	0	0.460	1
Gezondheid	0.167	0.153	0.048	1.63	0.029	0.235	0.019	0.395	0.953
Return on investment	0.2	0.304	0.063	3	0.021	0.392	0.021	1.183	0.982
Reputatie	0.214	0.325	0.054	3.73	0.015	0.411	0.046	1.782	0.974
Extern	0.2	0.264	0.087	3	0.029	0.357	0.025	0.890	0.972
Extern - gelieerd	0.2	0.304	0.064	3	0.021	0.392	0.021	1.183	0.982
Intern - beroeps	0.167	0.167	0.017	1	0.017	0.209	0.014	0.749	0.982
(potentiele) zakelijke donateur	0.167	0.167	0.026	1	0.026	0.209	0.013	0.480	0.972

Table P.2: Performance indicators for establishing the weights by the COO.

Variant	Synthesizing criterion
Variant 1	4.889
Variant 2	5.357
Variant 3	5.586
Variant 4	5.051
Variant 5	5.316

Table P.3: The outcome of scoring the performance of the variants by the COO

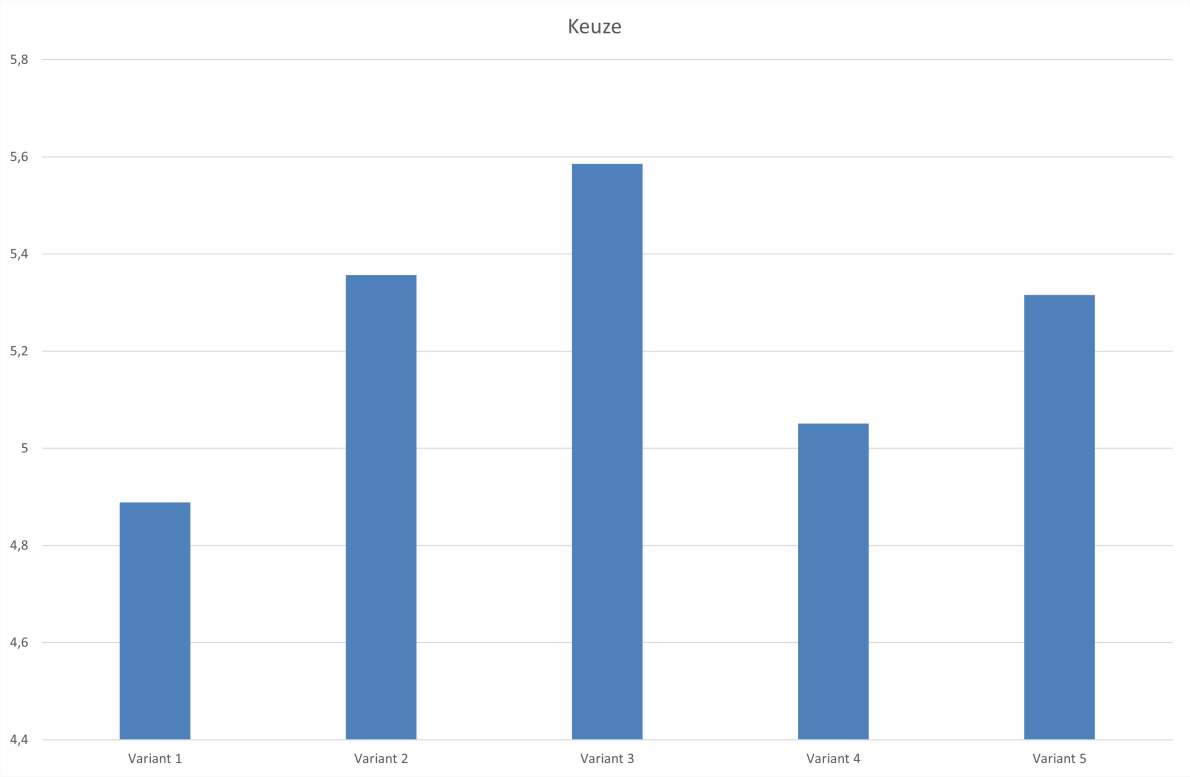


Figure P.2: The choice amongst variants as resulted from the interview with the COO.

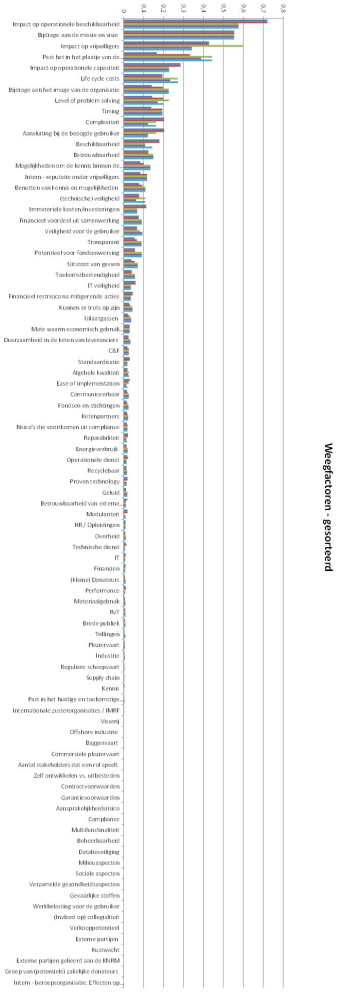
Although the interviewee presented his personal preference towards an electrification of the current vehicle, he favoured variants two and three. Initially he favoured variant 3, but he later amended this to be variant two, with his main argument being the operational perspective and the operational possibilities the vehicles offered, in particular in respect to assist vehicles at neighbouring lifeboat stations.

An important lesson learnt from the past is that it is highly recommended to have a solution that is able to detach the tractor from the trailer, otherwise both would not be available if one component fails.

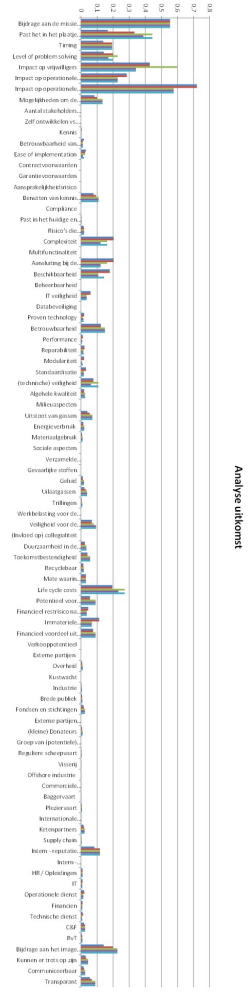
With regards to the process, the interviewee mentioned that in his opinion, all decision makers involved should fill in the entire performance scoring for themselves, to be able to compare outcomes during a group session. Yet, the most knowledgeable person or persons should present their outcome as a leading basis for the discussion. This would also enabling the inclusion of out-of-the-box opinions.

The interviewee stipulated a number of conditions for the use of the model:

- The model should be used on board level
- The model is a support system
- The model should function as a tool to confirm the choice you have already made based on arguments and argumentation.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the COO.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the COO.

Figure P.3: The weights as obtained from the interview with the COO.

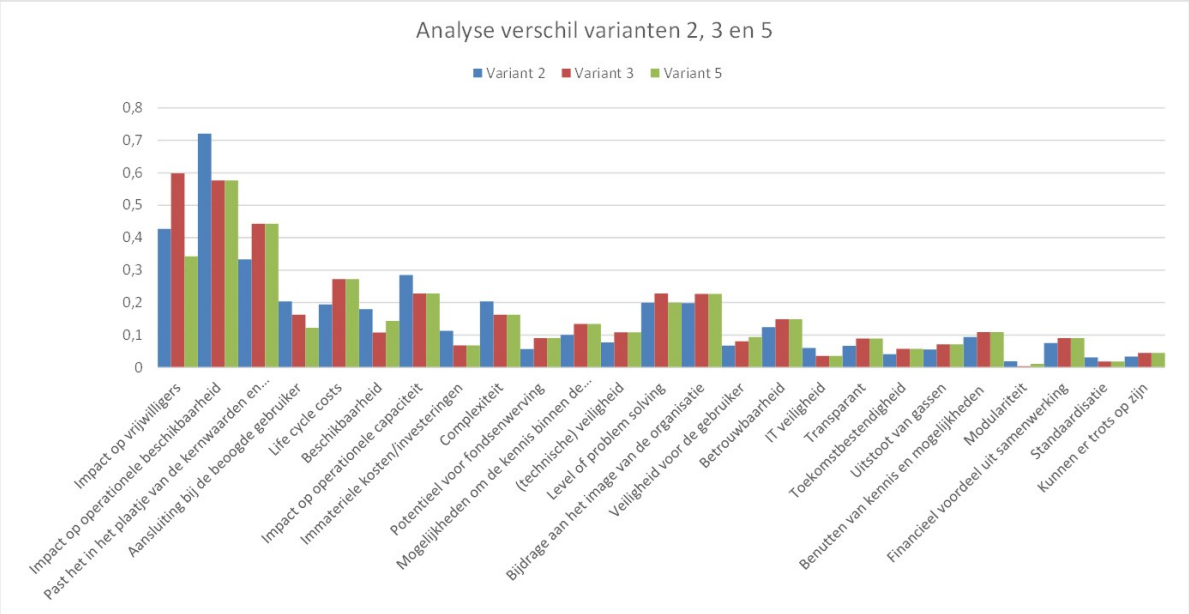


Figure P.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

- The model should be able to compare dissimilar variants[1]

The interviewee mentioned he regretted not taking part in the first interview round. This resulted, amongst others, in unclarity over the exact meaning and scope of some criteria.

Then, the interviewee also mentioned he saw an unbalance in the criteria, which may also originate from him not taking part in the initial round of interviews. He mentioned he saw for instance a rather large number of criteria relating to the reputation, while there was only a limited number of operational criteria, where he would like to have seen more. He mentioned, for instance, the operational fit for the task, the quality of the task execution and manoeuvrability. Overall, he thought there were too many criteria and the number should be reduced.

[1]This was set to be one of the conditions for choosing the model; see chapter 2.

Q

Interview on the weights with a project engineer

This appendix summarises the interview held with mr. Walter Schol, project engineer of the KNRM on the 16^{th} of March 2021, which lasted approximately three hours. Because there was just insufficient time to finish the interview during this appointment, the interview was finished the next day, lasting an additional hour.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter
The interview then continued to evaluate the weights, score the performance of the variants in relation to the criteria. Finally, the interviewee was presented with the analysis of the outcome and asked to evaluated the process.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure Q.1 and table Q.1.

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Link met strategie	0.244			
Bijdrage aan missie en visie		0.644		0.157
Past in de kernwaarden van de organisatie		0.244		0.060
Timing		0.111		0.027
Impact	0.090			
Level of problem solving		0.5		0.045
Impact op vrijwilligers		0.196		0.018
Impact op operationele capaciteit		0.098		0.009
Impact op operationele inzetbaarheid		0.147		0.013
Mogelijkheden om kennis binnen de organisatie te vergroten		0.059		0.005
Project	0.054			
Aantal stakeholders betrokken		0.093		0.005
Zelf ontwikkelen / uitbesteden		0.093		
Kennis			0.5	0.003
Betrouwbaarheid			0.5	0.003
Ease of implementation		0.043		0.002
Contractvoorwaarden		0.384		
Garantie			0.333	0.007
Aansprakelijkheid			0.667	0.014
Benutten van de kennis in de organisatie		0.232		0.013
Compliance		0.155		

Table Q.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Past in wettelijk kader		0.667		0.006
Risico's		0.333		0.003
Operationeel	0.136			
Complexiteit		0.315		0.043
Multifunctionaliteit		0.130		0.018
Aansluiting bij de gebruiker		0.034		0.005
Beschikbaarheid		0.195		0.026
Beheerbaarheid		0.130		0.018
IT veiligheid		0.098		0.013
Databescherming (AVG)		0.098		0.013
Technisch	0.136			
Proven technology		0.051		0.007
Betrouwbaarheid		0.257		0.035
Performance		0.030		0.004
Reparabiliteit		0.153		0.021
Modulariteit		0.153		0.021
Standaardisatie		0.102		0.014
Veiligheid		0.153		0.021
Kwaliteit		0.102		0.014
Duurzaamheid	0.136			
Milieuaspecten		0.128		
Emissie van gassen		0.708		0.012
Energieverbruik		0.083		0.001
Materiaalgebruik		0.208		0.004
Sociale aspecten		0.436		
Gezondheid		0.188		
Gevaarlijke stoffen			0.095	0.001
Geluid			0.238	0.003
Uitlaatgassen			0.429	0.005
Trillingen			0.238	0.003
Werkbelasting		0.475		0.028
Veiligheid		0.282		0.017
Collegialiteit		0.055		0.003
Duurzaamheid in de keten		0.128		0.017
Toekomstbestendig		0.128		0.017
Recyclebaar		0.051		0.007
Stimuleren economisch gebruik		0.128		0.017
Return on investment	0.068			
Life cycle costs		0.419		0.028
Potentieel voor fondsenwerving		0.130		0.008
Restrisico		0.104		0.007
Immateriele kosten		0.130		0.009
Financieel voordeel uit samenwerking		0.045		0.003
Verkoopbaarheid		0.173		0.012
Reputatie	0.136			
Externe partijen		0.159		
Overheid		0.158		0.003
Kustwacht		0.237		0.005
Industrie		0.158		0.003
Brede publiek		0.047		0.001
Fondsen en stichtingen		0.4		0.009
Extern - gelieerd		0.159		
Kleine donateurs		0.096		0.002
Zakelijke donateurs		0.191		
Reg. scheepvaart			0.346	0.001

Table Q.1 continued from previous page

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Visserij		0.192	0.001
Offshore		0.192	0.001
Comm. pleziervaart		0.077	0.000
Baggervaart		0.192	0.001
Pleziervaart	0.191		0.004
Internat. zusteroganisaties	0.058		0.001
Ketenpartners	0.128		0.003
Toeleveranciers	0.336		0.007
Intern - vrijwilligers	0.106		0.014
Intern - beroeps	0.106		
HR / Opleidingen	0.041		0.001
IT	0.070		0.001
Operationele dienst	0.105		0.002
Financien	0.209		0.003
Technische dienst	0.139		0.002
C&F	0.353		0.005
RvT	0.084		0.001
Bijdrage aan het imago	0.257		0.035
Moeten er trots op kunnen zijn	0.028		0.004
Communiceerbaar	0.079		0.011
Transparant	0.106		0.014

m the interview with a project engineer

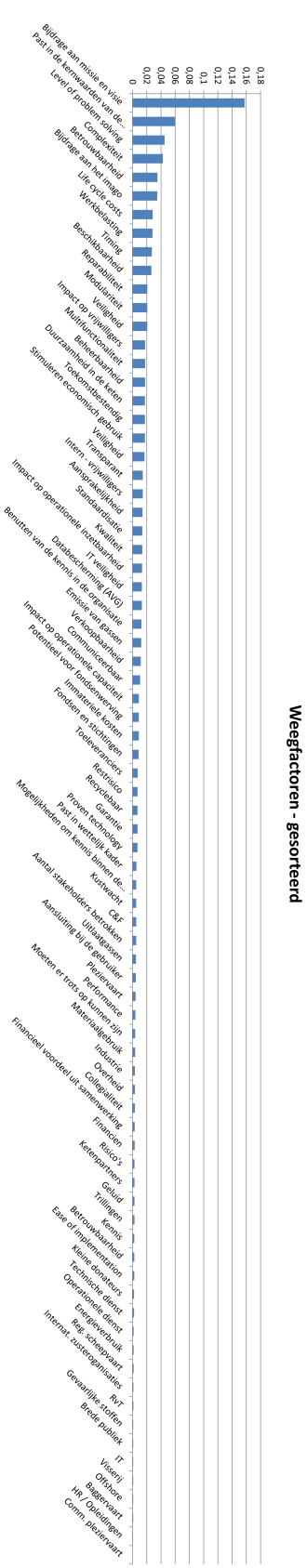
Table Q.2 shows the performance statistics for the set of criteria as they were established by the project engineer. The tables shows five cases where the input-based consistency exceeded its threshold value, of which in three cases the value exceeded the threshold only marginally. Neither case resulted in exceeding the outcome-based consistency. In one case, the interviewee expressed an equal weight for all criteria in the set, which was in the sheet of 'zelf ontwikkelen / uitbesteden'. This resulted in some particular outcomes.

Table Q.3 and figure Q.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

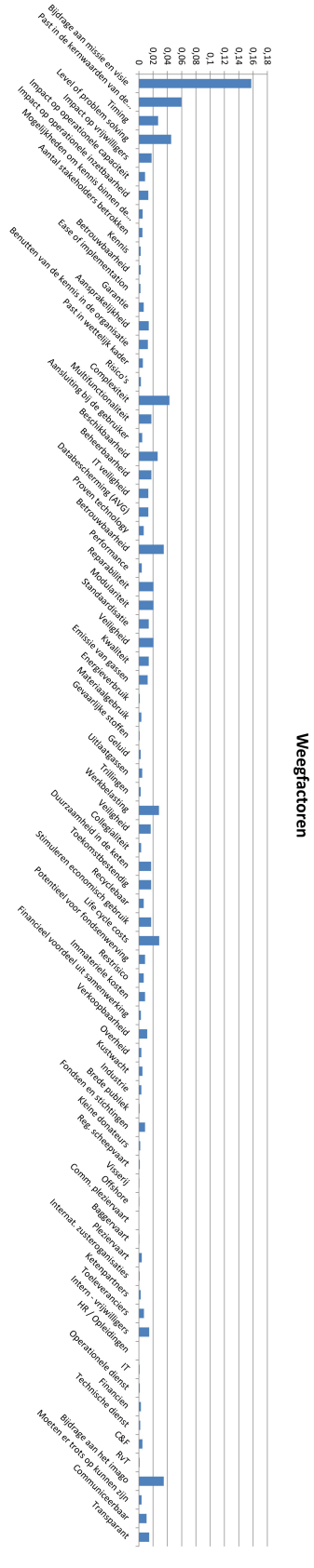
Figure Q.2 shows the outcome of the model also reflects the initial choice of the interviewee. However, the model shows a strong preference of the electric variants over variants one and two. Even while the interviewee initially stated to prefer variants one and two for their modularity, being more important then the propulsion technology. As such, the interviewee stated to value the criterion 'modularity' over the effects of the propulsion technology.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure Q.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure Q.3a. Finally, the choice was analysed and the most relevant variants were selected. In the case of the project engineer, this were the variants three, four and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure Q.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

Figure Q.4 shows the relative importance of the criterion 'modularity', significantly contributing to the performance of both variant three and five, but five in particular. Furthermore, the criteria 'complexity', 'level of problem solving', 'availability' and 'life cycle costs' contribute significantly to the performance of variant 5. The strong preference of variant tree over variant four can be attributed to the performance scoring of the criteria 'modularity', 'repairability' and 'standardisation'.



(a) Sorted weights as obtained from the interview with a project engineer.



(b) Ordered weights as obtained from the interview with a project engineer.

Figure Q.1: The weights as obtained from the interview with a project engineer.

	Performance indicators								
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.167	0.258	0.027	1.63	0.017	0.315	0.031	1.157	0.973
Link met strategie	0.2	0.135	0.089	2.3	0.039	0.211	0	0	0
Impact	0.214	0.282	0.088	3.73	0.024	0.373	0.017	0.966	0.982
Project	0.310	0.303	0.080	3.73	0.022	0.393	0.026	1.283	0.980
Zelf ontwikkelen / uitbesteden	0	0	0	0	1*	0	0	0	0
Contractvoorwaarden	0	0	0	0.44	0	0	0	0	0
Compliance	0	0	0	0.44	0	0	0	0	0
Operationeel	0.310	0.314	0.075	3.73	0.020	0.404	0.057	1.550	0.963
Technisch	0.262	0.325	0.048	3.73	0.013	0.411	0.049	1.782	0.972
Duurzaamheid	0.214	0.303	0.077	3.73	0.021	0.393	0.017	1.283	0.956
Milieuaspecten	0.214	0.129	0.125	3.73	0.034	0.209	0	0	0
Sociale aspecten	0.190	0.246	0.088	3.73	0.024	0.331	0.025	0.566	0.955
Gezondheid	0.167	0.153	0.048	1.63	0.029	0.235	0.019	0.395	0.953
Return on investment	0.310	0.303	0.100	3.73	0.027	0.393	0.024	1.283	0.981
Reputatie	0.262	0.325	0.061	3.73	0.016	0.411	0.058	1.782	0.967
Extern	0.190	0.282	0.074	3.73	0.020	0.373	0.026	0.966	0.973
Extern - gelieerd	0.2	0.255	0.046	2.3	0.020	0.331	0.020	1.026	0.981
Intern - beroeps	0.214	0.314	0.066	3.73	0.018	0.404	0.022	1.550	0.986
(potentiele) zakelijke donateur	0.167	0.190	0.038	1.63	0.024	0.274	0.019	0.656	0.971

Table Q.2: Performance indicators for establishing the weights by a project engineer.

Variant	Synthesizing criterion
Variant 1	5.097
Variant 2	5.691
Variant 3	6.572
Variant 4	6.496
Variant 5	6.779

Table Q.3: The outcome of scoring the performance of the variants by a project engineer

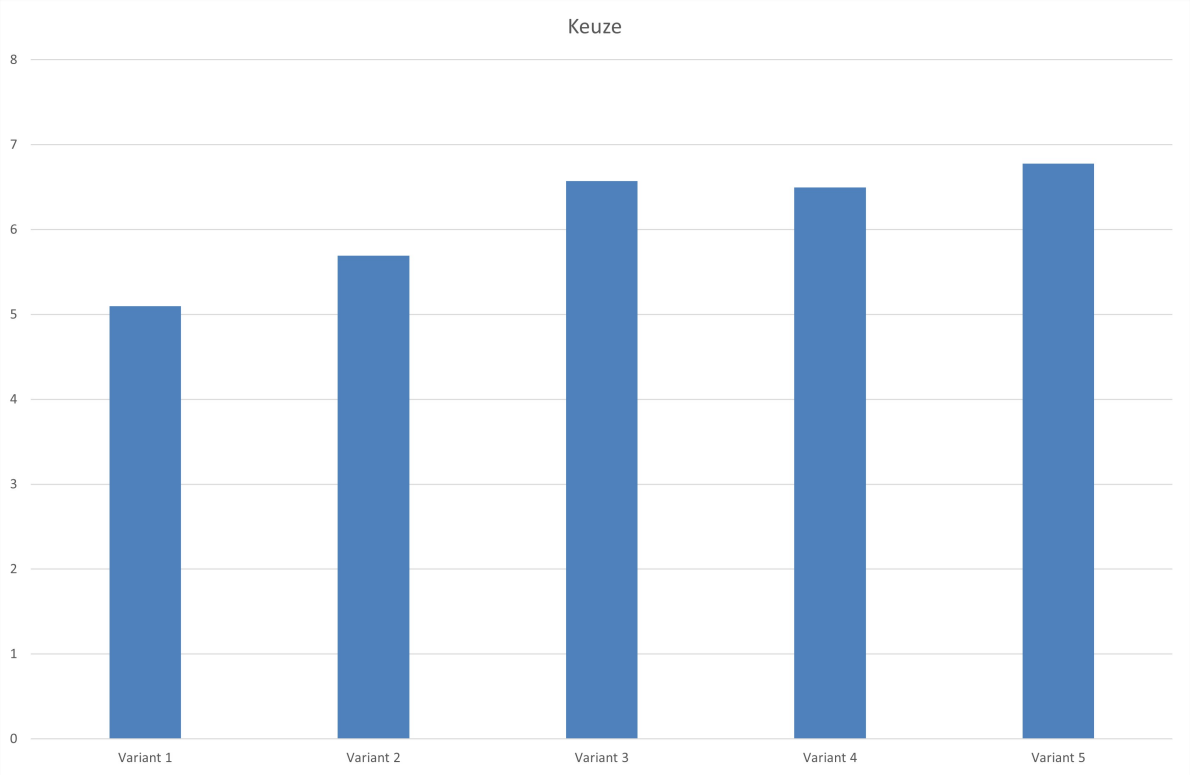
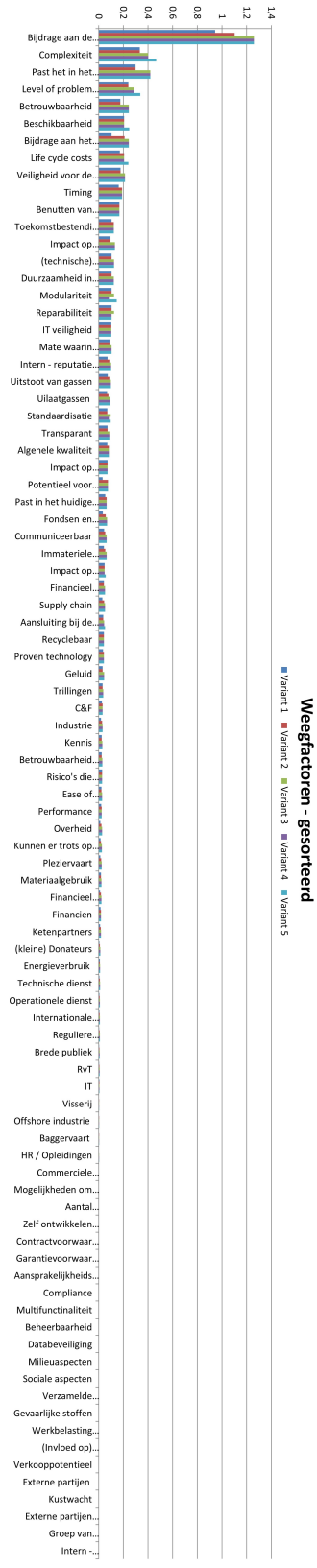


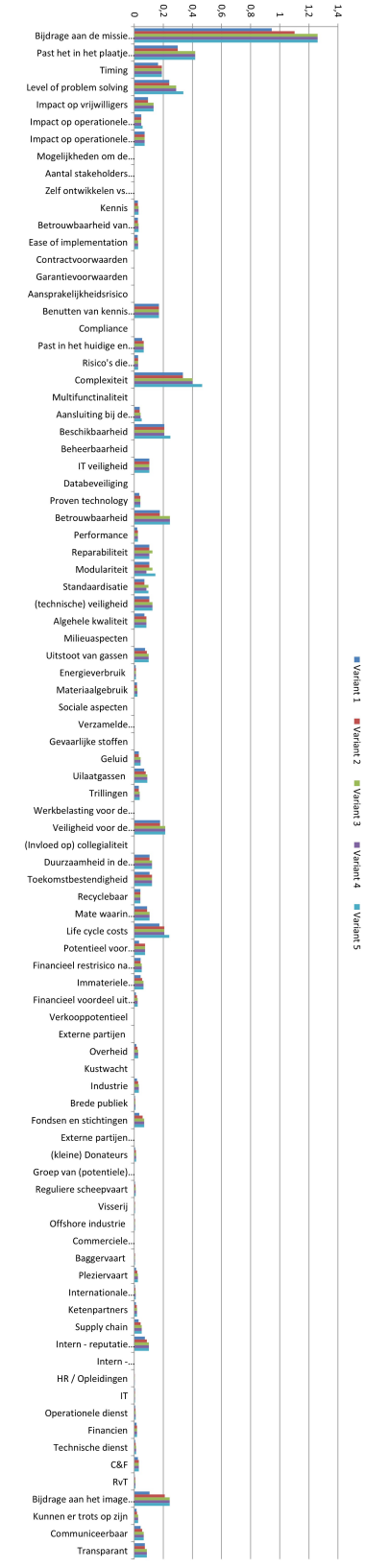
Figure Q.2: The choice amongst variants as resulted from the interview with a project engineer.

The project engineer focused, in line with his background, on relevant technical considerations to be taken into account when deciding on a replacement for the beach recovery vehicle. For instance, he proposed to use the frame of the trailer for storing batteries, and worried about the weight to volume ration of the machine, as the current solution tends to float in high water levels. Albeit very important when considering the decision, these performance characteristics are too specific to be included in the model or would have to be included in the requirements (to have sufficient downward pressure to have traction on the surface) when taking any variant into consideration in the first place.

On the other hand, seeing the outcome of the model, the project engineer valued the use of the model, as he concluded he had taken many additional criteria into account, which he would normally not do. Furthermore, he valued the insights the model provided through the analysis of the outcome and confirmed it was an addition to the decision making process. The project engineer also commented he valued the insight in these kind of methods, but he found it hard to grasp the outcome immediately and needed the explanation I provided him to understand the analysis. This lead him to the conclusion the model would be better suited to be used on a higher level in the organisation, where people would have less difficulty interpreting the outcomes.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the project engineer.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the project engineer.

Figure Q.3: The weights as obtained from the interview with the project engineer.

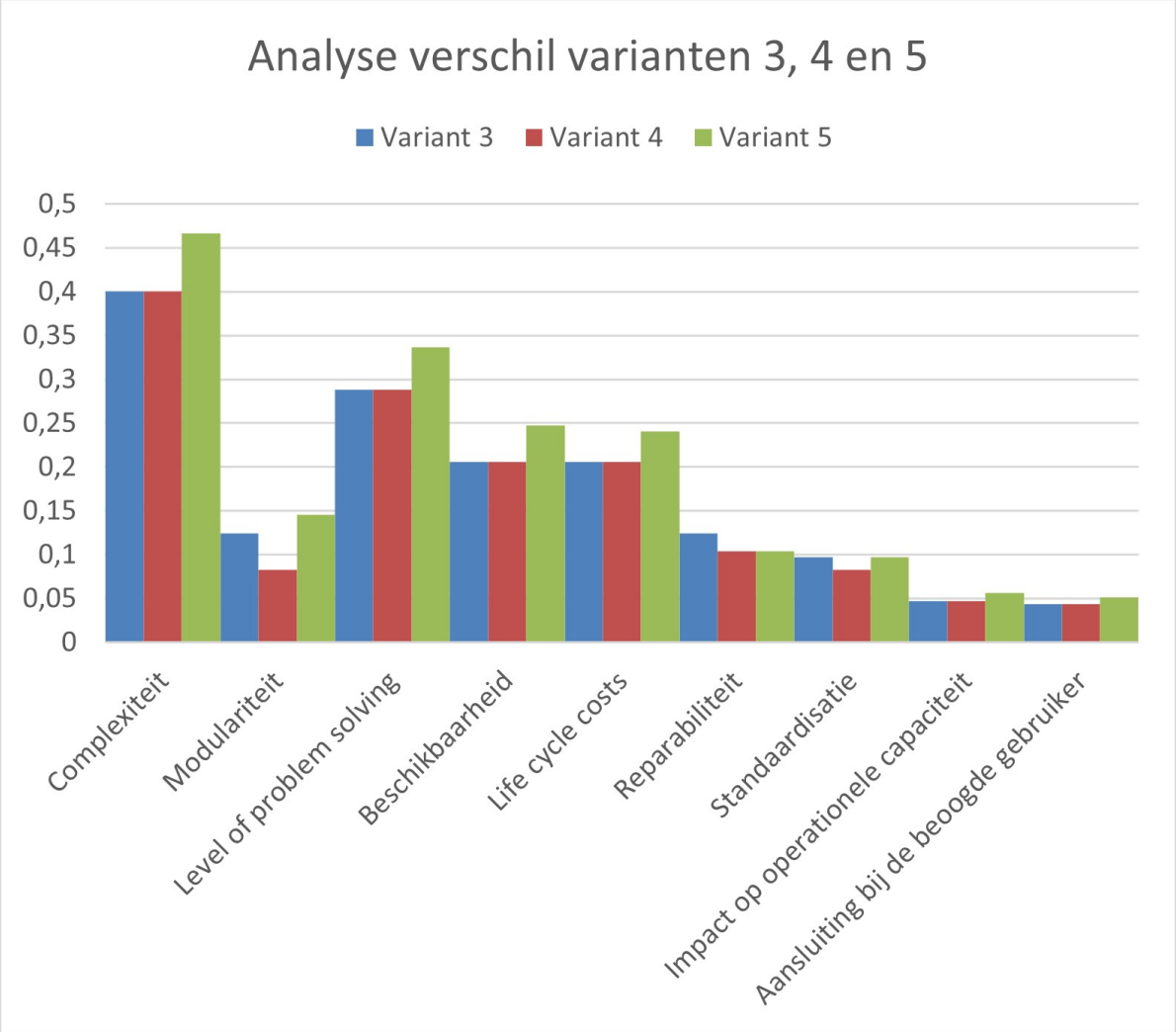


Figure Q.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

R

Interview on the weights with a communications and fund raising specialist

This appendix summarises the interview held with a specialist from the communications and fund raising department of the KNRM on the 19^{th} of March 2021, which lasted approximately three and a half hours.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter
The interview started off asking the interviewee for his choice amongst variants based on his normal procedure of making such choice. The interviewee stated variant one and two were discarded because of them not being sustainable. Variant four scored poorly on redundancy, safety and an electrical system not practical for usage in the context under scrutiny. When talking about the usage of cobalt in batteries, the interviewee stated the use of cobalt in the batteries of variant four was another important argument not to choose this variant.

Although variants three and five were rather close to one another, the interviewee stated a small preference for variant five, based on the modularity and the tractor being easily interchangeable, which would be practical for maintenance purposes. Furthermore, variant five takes the full supply chain into consideration, which is a major step forward in relation to the current offerings taken into consideration.

Then, the interview continued with establishing the weights and scoring the performance of the variants for each criterion. Finally, the outcome was evaluated and the process of decision making was analysed.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure R.1 and table R.1.

Weights overview

Criterion	Gross weight		Nett weight
Link met strategie	0.197		
Bijdrage aan missie en visie		0.412	0.081
Past in de kernwaarden van de organisatie		0.471	0.093
Timing		0.118	0.023
Impact	0.075		
Level of problem solving		0.295	0.022
Impact op vrijwilligers		0.159	0.012
Impact op operationele capaciteit		0.159	0.012
Impact op operationele inzetbaarheid		0.295	0.022

Table R.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Mogelijkheden om kennis binnen de organisatie te vergroten		0.091		0.007
Project	0.034			
Aantal stakeholders betrokken		0.105		0.004
Zelf ontwikkelen / uitbesteden		0.158		
Kennis			0.25	0.001
Betrouwbaarheid			0.75	0.004
Ease of implementation		0.158		0.005
Contractvoorwaarden		0.263		
Garantie			0.25	0.002
Aansprakelijkheid			0.75	0.007
Benutten van de kennis in de organisatie		0.158		0.005
Compliance		0.158		
Past in wettelijk kader			0.75	0.004
Risico's			0.25	0.001
Operationeel	0.112			
Complexiteit		0.227		0.025
Multifunctionaliteit		0.065		0.007
Aansluiting bij de gebruiker		0.039		0.004
Beschikbaarheid		0.086		0.010
Beheerbaarheid		0.129		0.014
IT veiligheid		0.227		0.025
Databescherming (AVG)		0.227		0.025
Technisch	0.112			
Proven technology		0.064		0.007
Betrouwbaarheid		0.207		0.023
Performance		0.112		0.013
Reparabiliteit		0.112		0.013
Modulariteit		0.112		0.013
Standaardisatie		0.074		0.008
Veiligheid		0.207		0.023
Kwaliteit		0.112		0.013
Duurzaamheid	0.197			
Milieuaspecten		0.267		
Emissie van gassen			0.542	0.029
Energieverbruik			0.292	0.015
Materiaalgebruik			0.167	0.009
Sociale aspecten		0.082		
Gezondheid			0.419	
Gevaarlijke stoffen				0.351 0.002
Geluid				0.108 0.001
Uitlaatgassen				0.351 0.002
Trillingen				0.189 0.001
Werkbelasting			0.226	0.004
Veiligheid			0.226	0.004
Collegialiteit			0.129	0.002
Duurzaamheid in de keten		0.144		0.028
Toekomstbestendig		0.096		0.019
Recyclebaar		0.267		0.053
Stimuleren economisch gebruik		0.144		0.028
Return on investment	0.075			
Life cycle costs		0.346		0.026
Potentieel voor fondsenwerving		0.192		0.014
Restrisico		0.128		0.010
Immateriele kosten		0.128		0.010
Financieel voordeel uit samenwerking		0.128		0.010

Table R.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Verkoopbaarheid		0.077		0.006
Reputatie	0.197			
Externe partijen		0.052		
Overheid			0.105	0.001
Kustwacht			0.184	0.002
Industrie			0.184	0.002
Brede publiek			0.342	0.004
Fondsen en stichtingen			0.184	0.002
Extern - gelieerd		0.091		
Kleine donateurs			0.289	0.005
Zakelijke donateurs			0.156	
Reg. scheepvaart				0.342 0.001
Visserij				0.184 0.001
Offshore				0.184 0.001
Comm. pleziervaart				0.105 0.000
Baggervaart				0.184 0.001
Pleziervaart			0.156	0.003
Internat. zusteroganisaties			0.089	0.002
Ketenpartners			0.156	0.003
Toeleveranciers			0.156	0.003
Intern - vrijwilligers		0.169		0.033
Intern - beroeps		0.169		
HR / Opleidingen			0.135	0.004
IT			0.077	0.003
Operationele dienst			0.135	0.004
Financien			0.135	0.004
Technische dienst			0.135	0.004
C&F			0.135	0.004
RvT			0.25	0.008
Bijdrage aan het imago		0.091		0.018
Moeten er trots op kunnen zijn		0.169		0.033
Communiceerbaar		0.091		0.018
Transparant		0.169		0.033

m the interview with a fundraiser

Table R.2 shows the performance criteria obtained from the results of the interview with the fund raising expert.

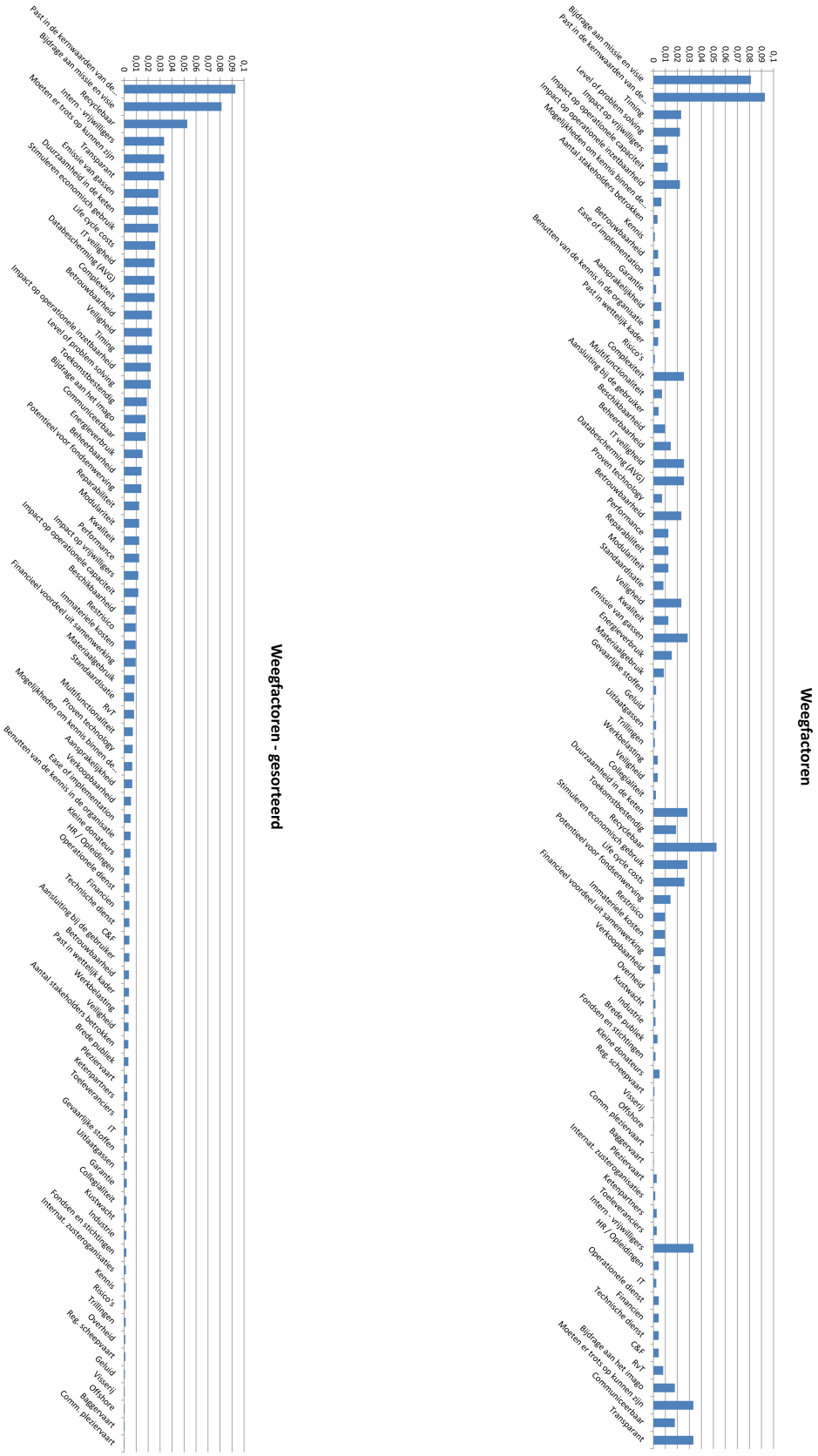
Table R.3 and figure R.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

The outcome shows a preference for variants three and five, which is in line with the preference of the interviewee prior to using the Decision Support System (DSS). This constitutes evidence the model works in this specific case, e.g. for this person for this decision.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure R.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure R.3a.

Finally, the choice was analysed and the most relevant variants were selected. In the case of the fund raiser, this were the variants three and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure R.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

The interviewee also stated he found it difficult to score the performance of criteria, since they were



(a) Sorted weights as obtained from the interview with a fund raiser.

(b) Ordered weights as obtained from the interview with a fund raiser.

Figure R.1: The weights as obtained from the interview with a fund raiser.

Performance indicators									
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.2	0.284	0.027	2.3	0.012	0.361	0.051	1.386	0.963
Link met strategie	0.083	0.112	0.059	1.63	0.036	0.158	0.032	0	0
Impact	0.167	0.167	0.023	1	0.023	0.209	0.017	0.480	0.965
Project	1	N/B	0.053	0.44	0.120	N/B	0.032	0.326	0.901
Zelf ontwikkelen / uitbesteden	0	0	0	1	0	0	0	0	0
Contractvoorwaarden	0	0	0	1	0	0	0	0	0
Compliance	0	0	0	1	0	0	0	0	0
Operationeel	0.2	0.272	0.031	2.3	0.014	0.348	0.057	1.223	0.953
Technisch	0.167	0.167	0.016	1	0.016	0.209	0.026	0.844	0.969
Duurzaamheid	0.167	0.167	0.021	1	0.021	0.209	0.015	0.630	0.927
Milieuaspecten	0.167	0.167	0.042	1	0.042	0.209	0	0	0
Sociale aspecten	0.167	0.167	0.032	1	0.032	0.209	0.013	0.283	0.952
Gezondheid	0.167	0.167	0.027	1	0.027	0.209	0.018	0.283	0.936
Return on investment	0.167	0.221	0.038	1.63	0.024	0.293	0.015	0.861	0.982
Reputatie	0.167	0.167	0.013	1	0.013	0.209	0.029	0.844	0.965
Extern	0.167	0.167	0.026	1	0.026	0.209	0.013	0.480	0.972
Extern - gelieerd	0.167	0.167	0.022	1	0.022	0.209	0.013	0.630	0.980
Intern - beroeps	0.167	0.167	0.019	1	0.019	0.209	0.012	0.749	0.984
(potentiele) zakelijke donateur	0.167	0.167	0.026	1	0.026	0.209	0.013	0.480	0.972

Table R.2: Performance indicators for establishing the weights by a fund raising expert.

Variant	Synthesizing criterion
Variant 1	3.720
Variant 2	4.168
Variant 3	6.211
Variant 4	4.378
Variant 5	7.022

Table R.3: The outcome of scoring the performance of the variants by a fund raiser

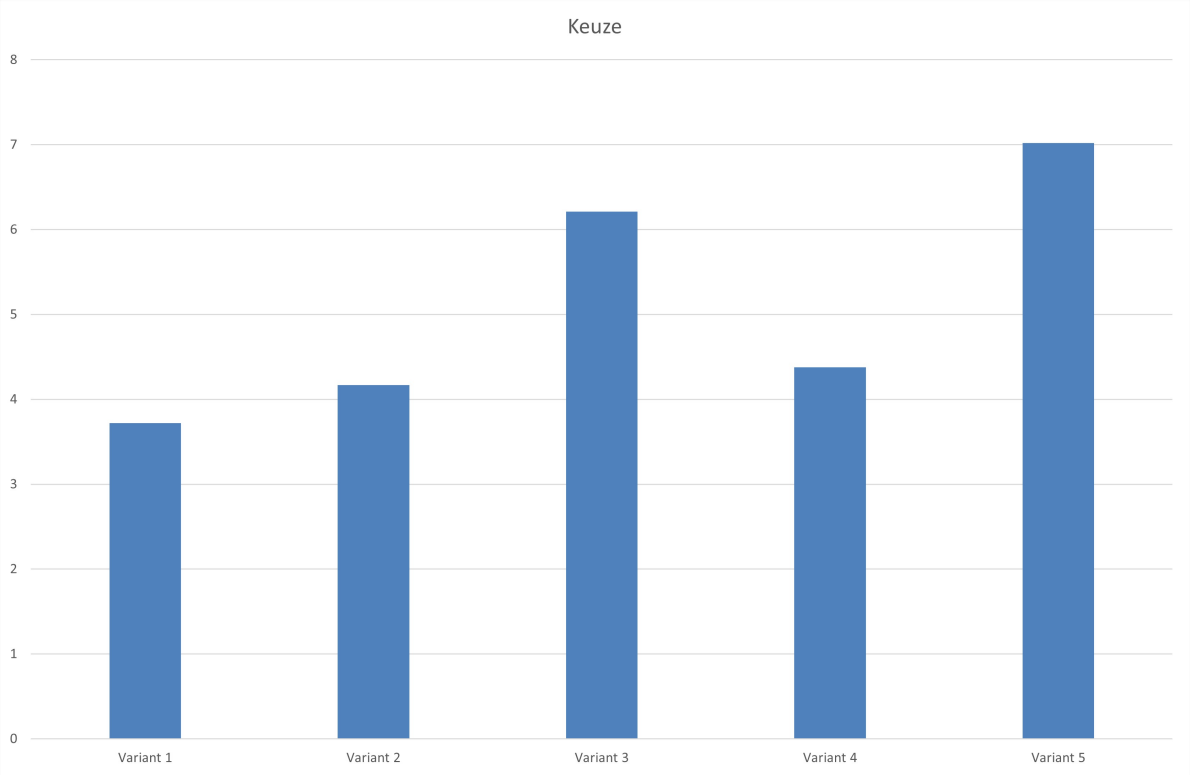
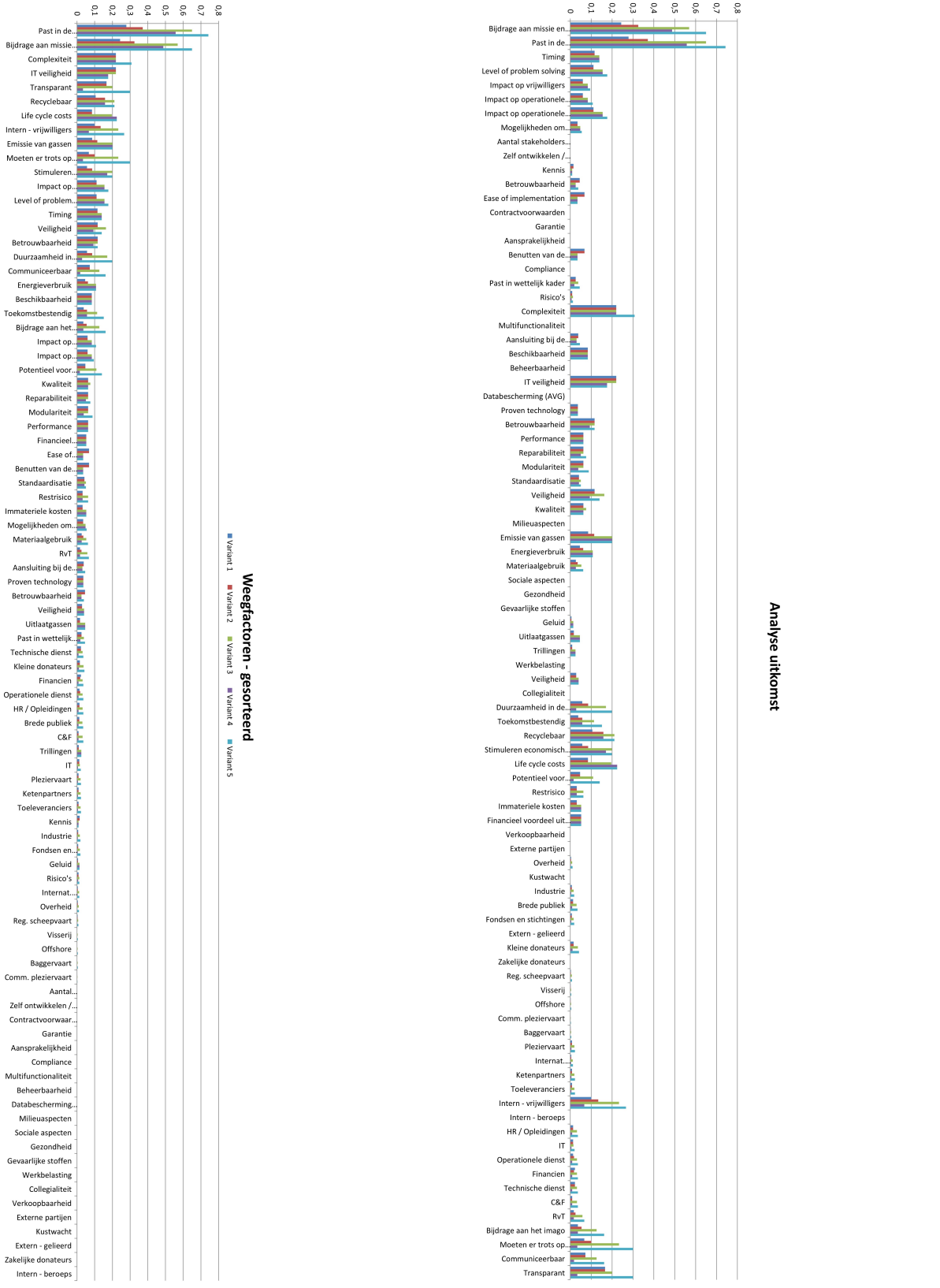


Figure R.2: The choice amongst variants as resulted from the interview with a fund raiser.

quite far from the daily practise of the fund raising department. He would therefore recommend to implement the model in a way that the performance of variants on groups of criteria is evaluated by the respective expert. The interviewee also mentioned a group session to be a value addition to the decision making process, for instance for a collective evaluation of the model outcomes and sensitivity. The interviewee also confirmed it's important to note that the decision making process is a group effort and it's important to go through the process together.

The interviewee confirmed the added value of using the DSS, as it contributed to the consciousness, rigour and the thoroughness of the decision making process.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the fund raiser.

(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the fund raiser.

Figure R.3: The weights as obtained from the interview with the fund raiser.

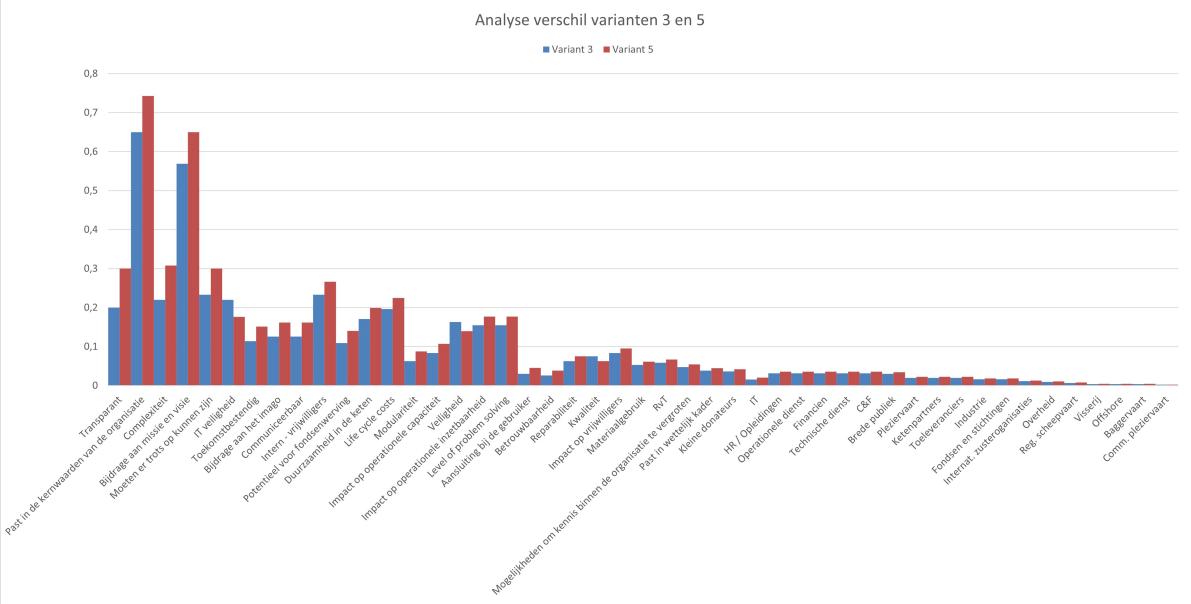


Figure R.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

S

Interview on the weights with the policy advisor

This appendix summarises the interview held with a policy advisor for the KNRM on the 19^{th} of March 2021, which lasted approximately two hours. The interview was finished on Friday 26^{th} of March 2021, which lasted another hour.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter
The interview started off with establishing the choice of the interviewee without using the model, using the as-is decision making process. The interviewee mentioned no specific process being in place and decision were made based on rational argumentations. Using this method, the interviewee selected the third variant, because of a multitude of criteria, such as the costs, the sustainability, in particular the variant being future proof and the choice of battery technology. Other criteria mentioned were the standardisation, in relation to the Beach Assistance Vehicle (BAV), the maintenance, the boathouses and, last but not least, the driver being accommodated on the vehicle, which contributes to volunteer motivation and retainment.

Having established the initial choice, the interview continued with establishing the weights for the criteria. Then, the performance of the variants from the test case were scored in respect to the criteria. Finally, the decision making process was evaluated.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure S.1 and table S.1.

Weights overview

Criterion	Gross weight		Nett weight
Link met strategie	0.268		
Bijdrage aan missie en visie		0.563	0.151
Past in de kernwaarden van de organisatie		0.125	0.033
Timing		0.313	0.084
Impact	0.165		
Level of problem solving		0.372	0.061
Impact op vrijwilligers		0.212	0.035
Impact op operationele capaciteit		0.212	0.035
Impact op operationele inzetbaarheid		0.141	0.023
Mogelijkheden om kennis binnen de organisatie te vergroten		0.064	0.011
Project	0.165		
Aantal stakeholders betrokken		0.128	0.021

Table S.1 continued from previous page

Weights overview

Criterion	Gross weight			Nett weight
Zelf ontwikkelen / uitbesteden		0.096		
Kennis			0.2	0.003
Betrouwbaarheid			0.8	0.013
Ease of implementation		0.191		0.032
Contractvoorwaarden		0.191		
Garantie			0.2	0.006
Aansprakelijkheid			0.8	0.025
Benutten van de kennis in de organisatie		0.058		0.010
Compliance		0.336		
Past in wettelijk kader			0.667	0.037
Risico's			0.333	0.018
Operationeel	0.110			
Complexiteit		0.284		0.031
Multifunctionaliteit		0.043		0.005
Aansluiting bij de gebruiker		0.155		0.017
Beschikbaarheid		0.103		0.011
Beheerbaarheid		0.103		0.011
IT veiligheid		0.155		0.017
Databescherming (AVG)		0.155		0.017
Technisch	0.110			
Proven technology		0.036		0.004
Betrouwbaarheid		0.184		0.020
Performance		0.122		0.013
Reparabiliteit		0.092		0.010
Modulariteit		0.073		0.008
Standaardisatie		0.092		0.010
Veiligheid		0.309		0.034
Kwaliteit		0.092		0.010
Duurzaamheid	0.066			
Milieuaspecten		0.119		
Emissie van gassen			0.333	0.003
Energieverbruik			0.333	0.003
Materiaalgebruik			0.333	0.003
Sociale aspecten		0.497		
Gezondheid			0.313	
Gevaarlijke stoffen				0.184 0.002
Geluid				0.102 0.001
Uitlaatgassen				0.184 0,002
Trillingen				0.531 0.005
Werkbelasting			0.313	0.010
Veiligheid			0,313	0.010
Collegialiteit			0.063	0.002
Duurzaamheid in de keten		0.099		0.007
Toekomstbestendig		0.149		0.010
Recyclebaar		0.085		0.006
Stimuleren economisch gebruik		0.050		0.003
Return on investment	0.082			
Life cycle costs		0.450		0.037
Potentieel voor fondsenwerving		0.163		0.013
Financieel restrisico na mitigerende acties		0.068		0.006
Immateriele kosten/investeringen		0.098		0.008
Financieel voordeel uit samenwerking		0.123		0.010
Verkooppotentieel		0.098		0.008
Reputatie	0.034			
Externe partijen		0.030		

Table S.1 continued from previous page

Weights overview

Criterion	Gross weight			Nett weight
Overheid		0.165		0.000
Kustwacht		0.123		0.000
Industrie		0.048		0.000
Brede publiek		0.416		0,000
Fondsen en stichtingen		0.247		0.000
Extern - gelieerd	0.060			
Kleine donateurs		0.175		0.000
Zakelijke donateurs		0.175		
Reg. scheepvaart			0.298	0.000
Visserij			0.170	0.000
Offshore			0.255	0.000
Comm. pleziervaart			0.106	0.000
Baggervaart			0.170	0.000
Pleziervaart		0.307		0.000
Internat. zusteroganisaties		0.116		0.000
Ketenpartners		0.175		0.000
Toeleveranciers		0.053		0.000
Intern - vrijwilligers	0.100			0.003
Intern - beroeps	0.075			
HR / Opleidingen		0.143		0.000
IT		0.143		0.000
Operationele dienst		0.143		0.000
Financien		0.143		0.000
Technische dienst		0.143		0.000
C&F		0.143		0.000
RvT		0.143		0.000
Bijdrage aan het imago	0.254			0.009
Moeten er trots op kunnen zijn	0.254			0.009
Communiceerbaar	0.075			0.003
Transparant	0.151			0.005

Table S.1: The weights table resulting from the interview with the policy advisor

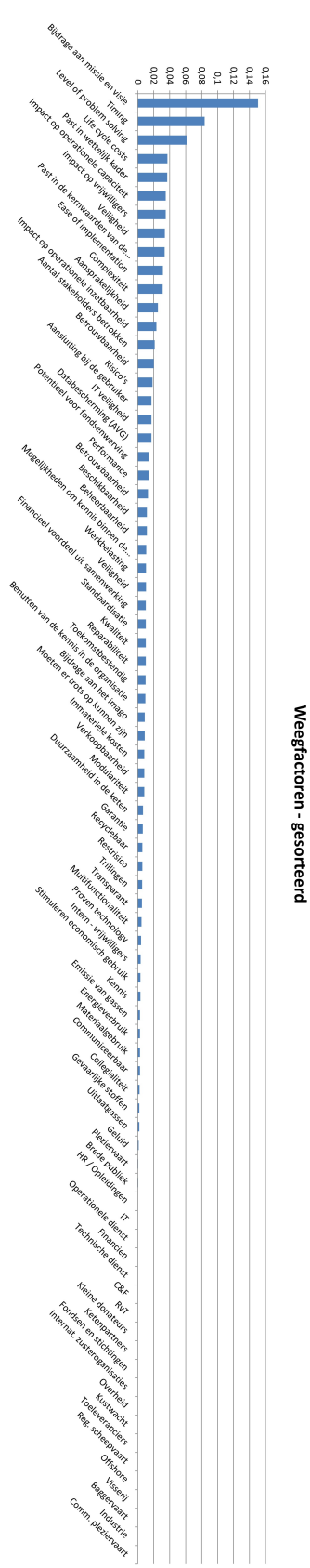
Table S.2 shows the performance criteria calculated from the results on the interview with the policy advisor. The table shows only one instance in which the input-based consistency exceeded its threshold. This couldn't be circumvented while representing the viewpoints of the policy advisor. And since it didn't result in the output-based consistency exceeding its threshold, it was accepted.

Furthermore, in two instances, the interviewee judged all criteria to be of equal importance. This was in the categories 'Milieuaspecten' and 'Intern - beroeps'. This impacted the performance indicators.

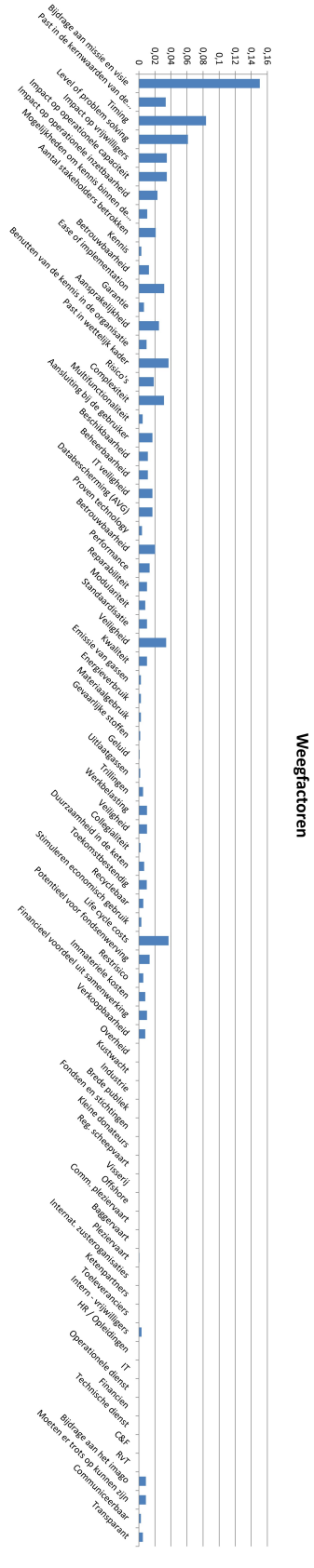
Table S.3 and figure S.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

The outcome confirms the choice for an electric variant, but the distinction between the variants is minimal.

The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure S.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure S.3a. Finally, the choice was analysed and the most relevant variants were selected. In the case of the policy advisor, this were the variants three, four and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure S.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.



(a) Sorted weights as obtained from the interview with the policy advisor.



(b) Ordered weights as obtained from the interview with the policy advisor.

Figure S.1: The weights as obtained from the interview with the policy advisor.

	Performance indicators								
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.3	0.322	0.062	3	0.021	0.417	0.056	1.638	0.966
Link met strategie	0.167	0.112	0.063	1.63	0.038	0.158	0	0	0
Impact	0.2	0.231	0.051	2.3	0.022	0.302	0.022	0.782	0.972
Project	0.2	0.255	0.046	2.3	0.020	0.331	0.020	1.026	0.980
Zelf ontwikkelen / uitbesteden	0	0	0	1.63	0	0	0	0	0
Contractvoorwaarden	0	0	0	1.63	0	0	0	0	0
Compliance	0	0	0	0.44	0	0	0	0	0
Operationeel	0.1	0.314	0.026	3	0.009	0.406	0.027	1.427	0.981
Technisch	0.214	0.325	0.058	3.73	0.015	0.411	0.042	1.782	0.977
Duurzaamheid	0.214	0.315	0.099	4.47	0.022	0.423	0.016	1.348	0.963
Milieuaspecten	0	0	0	0	1*	-	0	0	0
Sociale aspecten	0	0.199	0	2.3	0	0.285	0	0.460	1
Gezondheid	0.05	0.199	0.020	2.3	0.009	0.285	0	0.460	1
Return on investment	0.133	0.304	0.041	3	0.014	0.392	0.009	1.183	0.992
Reputatie	0.214	0.325	0.047	3.73	0.013	0.411	0.063	1.782	0.965
Extern	0.214	0.282	0.077	3.73	0.021	0.373	0.025	0.966	0.974
Extern - gelieerd	0.2	0.255	0.042	2.3	0.018	0.331	0.021	1.026	0.979
Intern - beroeps	0	0	0	0	1*	-	0	0	0
(potentiele) zakelijke donateur	0.167	0.167	0.043	1	0.043	0.209	0.031	0.480	0.935

Table S.2: Performance indicators for establishing the weights by a policy advisor.

Variant	Synthesizing criterion
Variant 1	4.883
Variant 2	4.903
Variant 3	6.960
Variant 4	6.861
Variant 5	7.035

Table S.3: The outcome of scoring the performance of the variants by the policy advisor

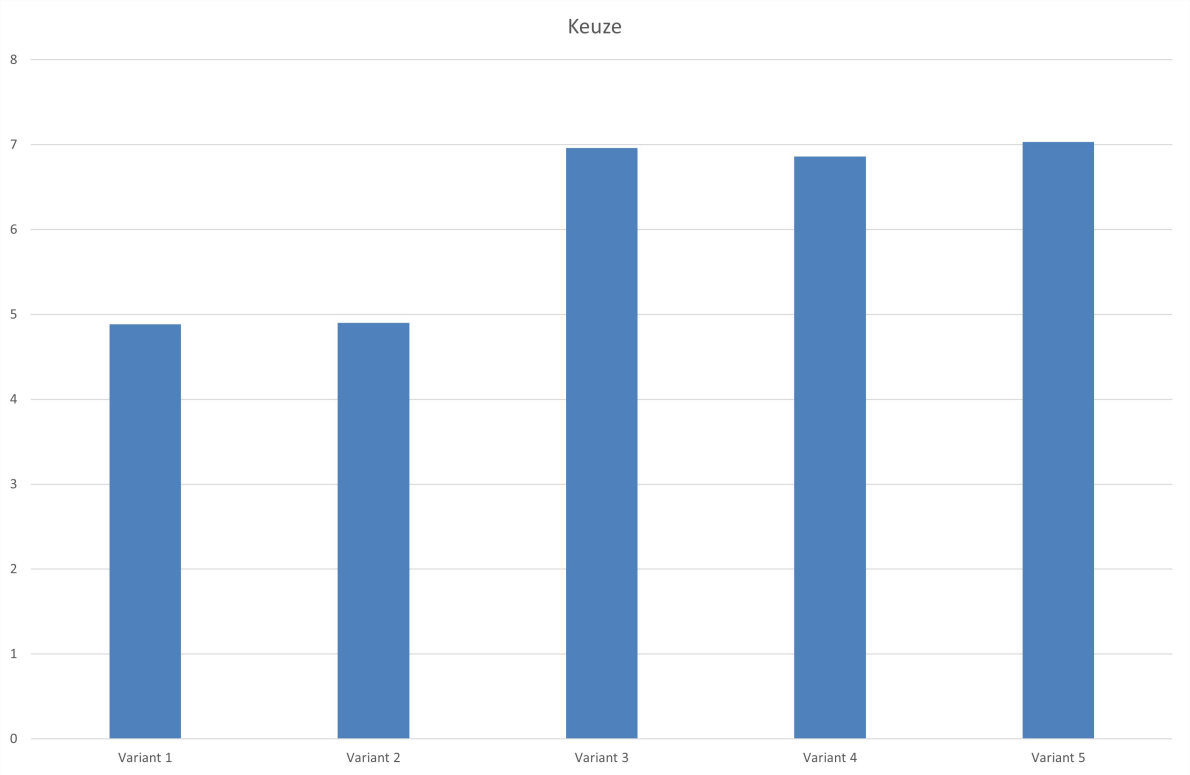
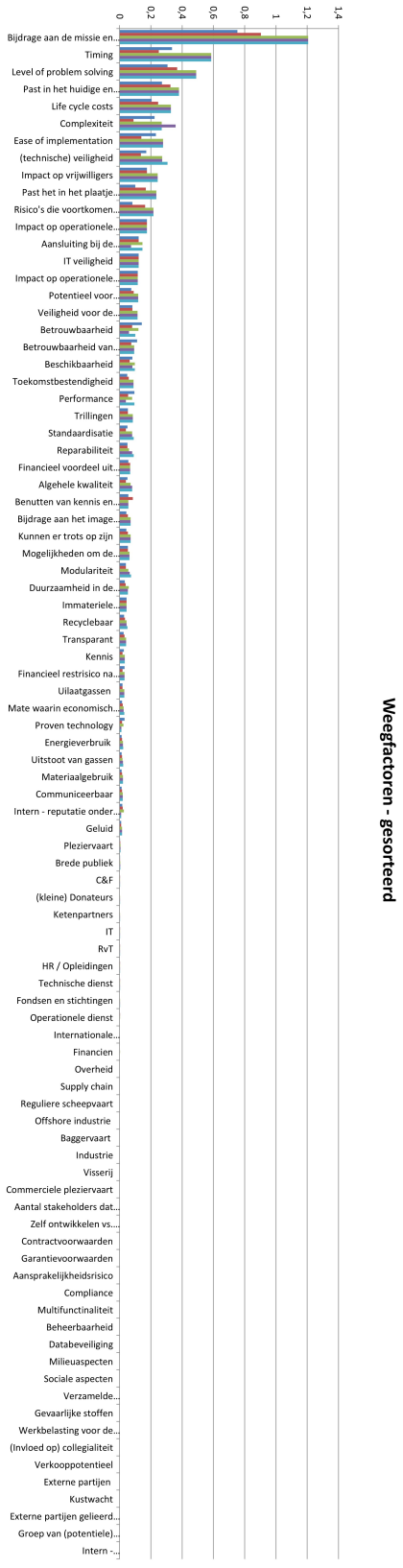


Figure S.2: The choice amongst variants as resulted from the interview with the policy advisor.

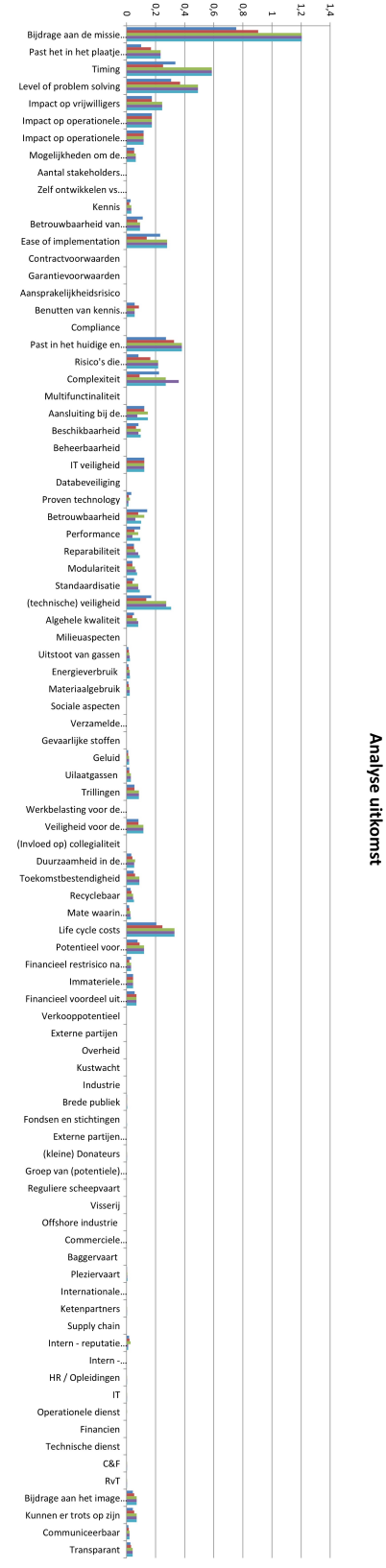
During the analysis of the outcome, the interviewee stated she initially considered the retainment of volunteers to be an important criteria. But the analysis thought it may have been overrated. On the other hand, financial- and sustainability criteria were under weighted.

The interviewee also commented on her ability to judge criteria that were further from her field of expertise. The interviewee stated she found it in particular difficult to score operational and technical criteria. On the other hand, the model forces all involved to do their research and prepare offerings more thoroughly. It also enforces the organisation to do better research before taking any option into consideration as a variant and later to ensure sufficient information allowing the Decision Maker (DM)s involved to properly evaluate the scores.

The interviewee also mentioned the model may provide a means to support the organisations interests in other arena's, as the model illustrates the corporate values and contributes to the transparency of the organisation.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the policy advisor.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the policy advisor.

Figure S.3: The weights as obtained from the interview with the policy advisor.

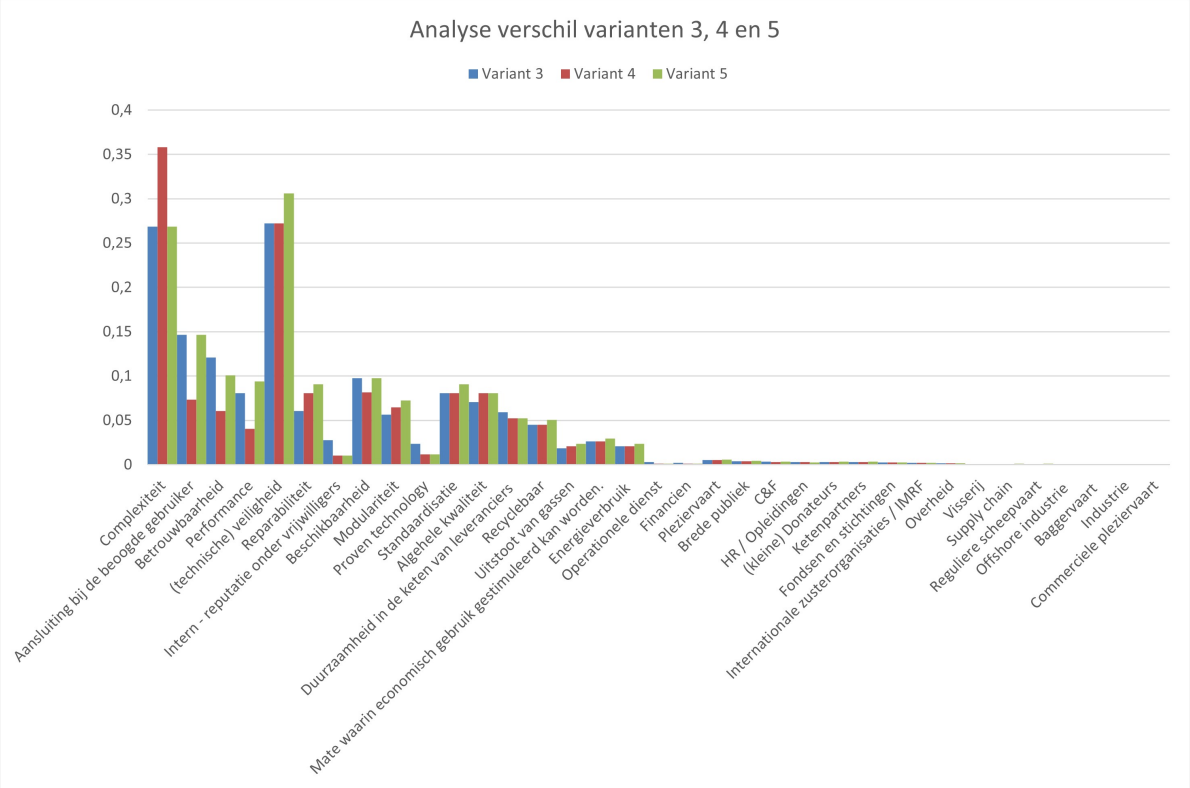


Figure S.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

T

Interview on the weights with a financial expert

This appendix summarises the interview held with mr. Nancy Barten, who works in the financial department of the KNRM on the 26^{th} of March 2021, which lasted approximately three hours. Since there wasn't enough time that day to finish the full interview, the interviewee filled out the remainder of the workfile on her own occasion. The interview was finished on the 30^{th} of March and lasted another hour.

Before the interview, the interviewee was presented an overview of all criteria for the organisation, as established in chapter

The interviewee was asked to formulate a choice from the five options and build a case why the choice was made, which he didn't find time to do prior to the interview.

The interviewee stated her preference towards variants four and five, assessing them to be more or less equal. Having asked the interviewee to narrow her choice down to a single variant, she stated her preference for variant five, commenting on the recycle-ability of the batteries and the modular build-up to be the main arguments leading up to her choice. The interviewee reassured herself all electric variants had sufficient power for their task. The researcher explained the choice of the capacity and the rationale behind it. Whether or not this was deemed sufficient, was for the organisation to decide.

Having finished the conversation on the initial choice, the interview continued with establishing the weights, the scoring of the performance of the variants in respect to the criteria. Finally, the results were analysed, the analysis was discussed, along with the process of decision making.

The outcome, which consists of the weights and the performance of the five variants in the test case, is shown below. First of all, the weights are shown in figure T.1 and table T.1.

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Link met de strategie	0.123		
Bijdrage aan de missie en visie		0.1	0.012
Past het in het plaatje van de kernwaarden en strategische thema's		0.157	0.019
Timing		0.742	0.091
Impact van het project op de organisatie	0.123		
Level of problem solving		0.162	0.020
Impact op vrijwilligers		0.243	0.030
Impact op operationele capaciteit		0.416	0.051
Impact op operationele beschikbaarheid		0.121	0.015
Mogelijkheden om de kennis binnen de organisatie te vergroten		0.058	0.007
Eigenschappen van het project	0.123		
Aantal stakeholders dat een rol speelt		0.332	0,041

Table T.1 continued from previous page

Weights overview				
Criterion	**Gross weight**			**Nett weight**
Zelf ontwikkelen vs. uitbesteden	0.136			
Kennis		0.714		0.012
Betrouwbaarheid van externe partijen/leveranciers		0.286		0.005
Ease of implementation	0.043			0.005
Contractvoorwaarden	0.082			
Garantievoorwaarden		0.714		0.007
Aansprakelijkheidsrisico		0.286		0.003
Benutten van kennis en mogelijkheden	0.204			0.025
Compliance	0.204			
Past in het huidige en toekomstige wettelijke- en beleidskader		0.333		0.008
Risico's die voortkomen uit compliance		0.667		0.017
Operationele aspecten	0.195			
Complexiteit	0.171			0.033
Multifunctinaliteit	0.286			0.056
Aansluiting bij de beoogde gebruiker	0.046			0.009
Beschikbaarheid	0.086			0.017
Beheerbaarheid	0.069			0.013
IT veiligheid	0.171			0.033
Databeveiliging	0.171			0.033
Technische aspecten	0.061			
Proven technology	0.045			0.003
Betrouwbaarheid	0.146			0.009
Performance	0.073			0.004
Reparabiliteit	0.073			0.004
Modulariteit	0.097			0.006
Standaardisatie	0.097			0.006
(technische) veiligheid	0.254			0.016
Algehele kwaliteit	0.216			0.013
Duurzaamheid	0.224			
Milieuaspecten	0.362			
Uitstoot van gassen		0.571		0.046
Energieverbruik		0.143		0.012
Materiaalgebruik		0.286		0.023
Sociale aspecten	0.217			
Verzamelde gezondheidsaspecten		0.116		
Gevaarlijke stoffen			0.495	0.003
Geluid			0.140	0.001
Uilaatgassen			0.280	0.002
Trillingen			0.086	0.000
Werkbelasting voor de gebruiker		0.186		0.009
Veiligheid voor de gebruiker		0.512		0.025
(Invloed op) collegialiteit		0.186		0.009
Duurzaamheid in de keten van leveranciers	0.145			0.032
Toekomstbestendigheid	0.109			0.024
Recyclebaar	0.109			0.024
Mate waarin economisch gebruik gestimuleerd kan worden.	0.058			0.013
Return on investment	0.123			
Life cycle costs	0.359			0.044
Potentieel voor fondsenwerving	0.102			0.013
Financieel restrisico na mitigerende acties	0.062			0.008
Immateriele kosten/investeringen	0.136			0.017
Financieel voordeel uit samenwerking	0.136			0.017
Verkooppotentieel	0.204			0.025
Reputatie	0.029			
Externe partijen	0.279			
Overheid		0.082		0.001
Kustwacht		0.137		0.001
Industrie		0.205		0.002
Brede publiek		0.370		0.003
Fondsen en stichtingen		0.205		0.002
Externe partijen gelieerd aan de KNRM	0.171			
(kleine) Donateurs		0.350		0.002
Groep van (potentiele) zakelijke donateurs		0.210		
Reguliere scheepvaart			0.2	0.000

Table T.1 continued from previous page

Weights overview			
Criterion	**Gross weight**		**Nett weight**
Visserij		0.2	0.000
Offshore industrie		0.2	0.000
Commerciele pleziervaart		0.2	0.000
Baggervaart		0.2	0.000
Pleziervaart	0.140		0.001
Internationale zusterorganisaties / IMRF	0.105		0.001
Ketenpartners	0.140		0.001
Supply chain	0.056		0.000
Intern - reputatie onder vrijwilligers	0.036		0.001
Intern - beroepsorganisatie	0.057		
HR / Opleidingen	0.143		0.000
IT	0.143		0.000
Operationele dienst	0.143		0.000
Financien	0.143		0.000
Technische dienst	0.143		0.000
C&F	0.143		0.000
RvT	0.143		0.000
Bijdrage aan het imago van de organisatie	0.114		0.003
Kunnen er trots op zijn	0.114		0.003
Communiceerbaar	0.114		0.003
Transparant	0.114		0.003

om the interview with a financial expert

Table T.2 shows the performance statistics derived from the outcome of the interview with the financial expert. The table shows three categories for which the input-based consistency exceeded its threshold, of which in one case this was only marginally. In the two remaining cases, the interviewee sought an additional nuance to the weights. Neither a 1/3-2/3 nor a 1/4-3/4 division matched her standpoint and she wanted to obtain weights in the middle. These were obtained at the cost of the formal consistency, but in line with the standpoint of the interviewee.

Furthermore, in two cases the interviewee assessed all criteria to have an equal weight. This occurred for the categories 'Intern - beroeps' and '(potentiele) zakelijke donateurs'.

The interviewee stated she found it difficult to score the performance of the variants on criteria that were far from her area of expertise and argued this should be reflected in the method proposed for implementation.

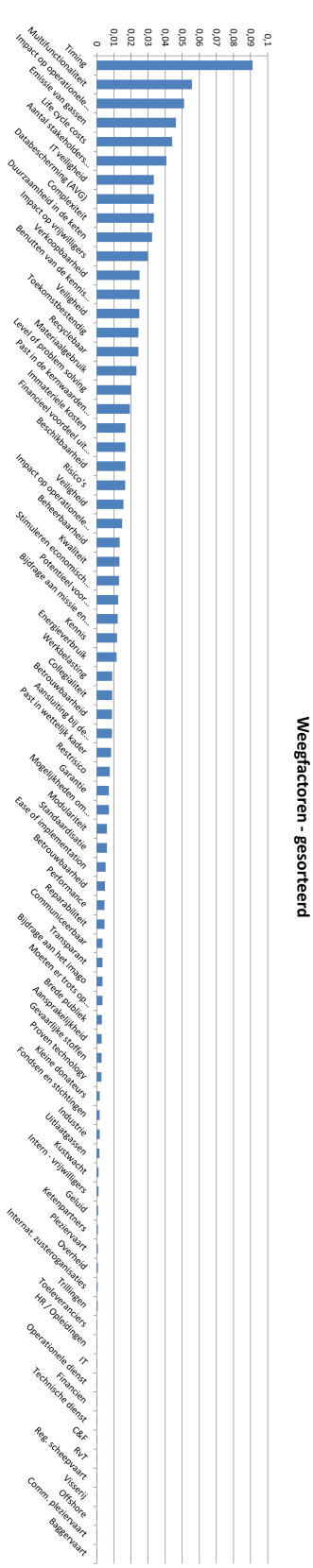
Table T.3 and figure T.2 show the outcome of scoring the performance of the variants in respect to the criteria. The table gives the synthesizing criteria for each variant.

The choice reflects also the initial choice of the interviewee and therefore the model outcome aligns with her personal preference.

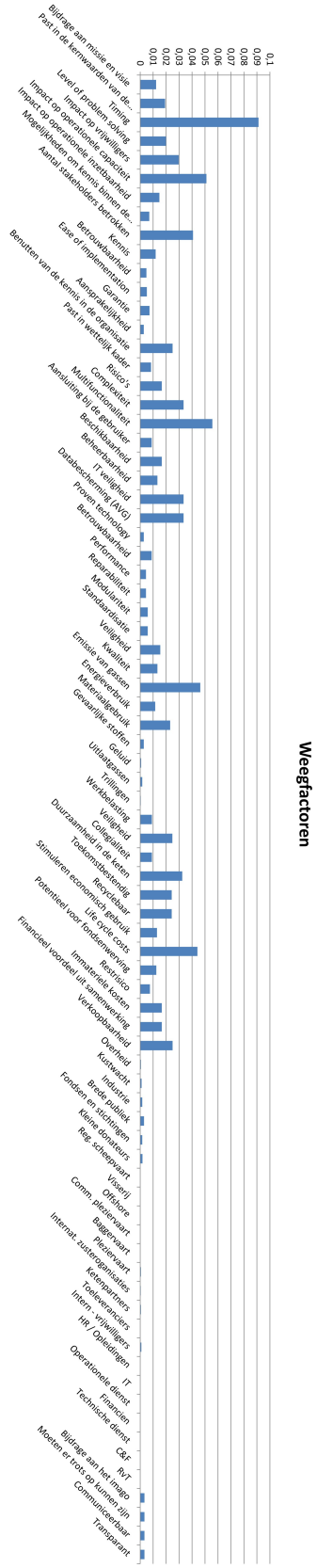
The outcome of the performance scoring is further analysed. First of all, the contribution of all criteria has been calculated, shown in figure O.3b. Then, the contribution was sorted, ordering the criteria from a high average contribution to a minor average contribution, shown in figure O.3a.

Finally, the choice was analysed and the most relevant variants were selected. In the case of the CTO, this were the variants three, four and five. Then the criteria were sorted according to their decisiveness and relative contribution to the outcome and visualised in figure O.4. The decisiveness is defined as the difference between the maximum contribution and the minimum contribution to the synthesizing criterion.

During the evaluation, the interviewee commented on the analysis as being very useful and insightful as to what aspects are involved in the decision making and what influences the outcome most. Therefore, she appreciate the insights provided by the tool and considers it useful and valuable for future use.



(a) Sorted weights as obtained from the interview with a financial expert.



(b) Ordered weights as obtained from the interview with a financial expert.

Figure T.1: The weights as obtained from the interview with a financial expert.

	Performance indicators								
	Global consistency (CR^I)	**Threshold**	ξ	**Consistency Index (ξ^{max})**	**Consistency ratio**	**Threshold**	ψ	**Max(ψ)**	κ
Hoofdcategorieen	0.2	0.322	0.051	3	0.017	0.417	0.080	1.638	0.951
Link met strategie	0.071	0.129	0.043	3.73	0.011	0.209	0	0	0
Impact	0.2	0.264	0.069	3	0.023	0.357	0.023	0.890	0.974
Project	0.3	0.304	0.077	3	0.026	0.392	0.032	1.183	0,973
Zelf ontwikkelen / uitbesteden	0.167	0	0.143	1	0.143	0	0	0	0
Contractvoorwaarden	0.167	0	0.143	1	0.143	0	0	0	0
Compliance	0	0	0	0.44	0	0	0	0	0
Operationeel	0.133	0.314	0.057	3	0.019	0.406	0.055	1.427	0.961
Technisch	0.2	0.284	0.037	2.3	0.016	0.361	0.051	1.386	0.963
Duurzaamheid	0.25	0.255	0.072	2.3	0.032	0.331	0.025	1.026	0.923
Milieuaspecten	0	0.112	0	1.63	0	0.158	0	0	0
Sociale aspecten	0.167	0.153	0.047	1.63	0.029	0.235	0	0.395	1
Gezondheid	0.15	0.199	0.065	2.3	0.028	0.285	0	0.460	1
Return on investment	0.2	0.255	0.050	2.3	0.022	0.331	0.019	1.026	0.982
Reputatie	0.3	0.322	0.064	3	0.021	0.417	0.053	1.638	0.967
Extern	0.167	0.190	0.041	1.63	0.025	0.274	0.018	0.656	0.973
Extern - gelieerd	0.25	0.255	0.070	2.3	0.030	0.331	0.026	1.026	0.975
Intern - beroeps	0	0	0	0	1*	-	0	0	0
(potentiele) zakelijke donateur	0	0	0	0	1*	-	0.000	0	0

Table T.2: Performance indicators for establishing the weights by a financial expert.

Variant	Synthesizing criterion
Variant 1	4.871
Variant 2	5.722
Variant 3	6.817
Variant 4	7.586
Variant 5	7.829

Table T.3: The outcome of scoring the performance of the variants by a financial expert

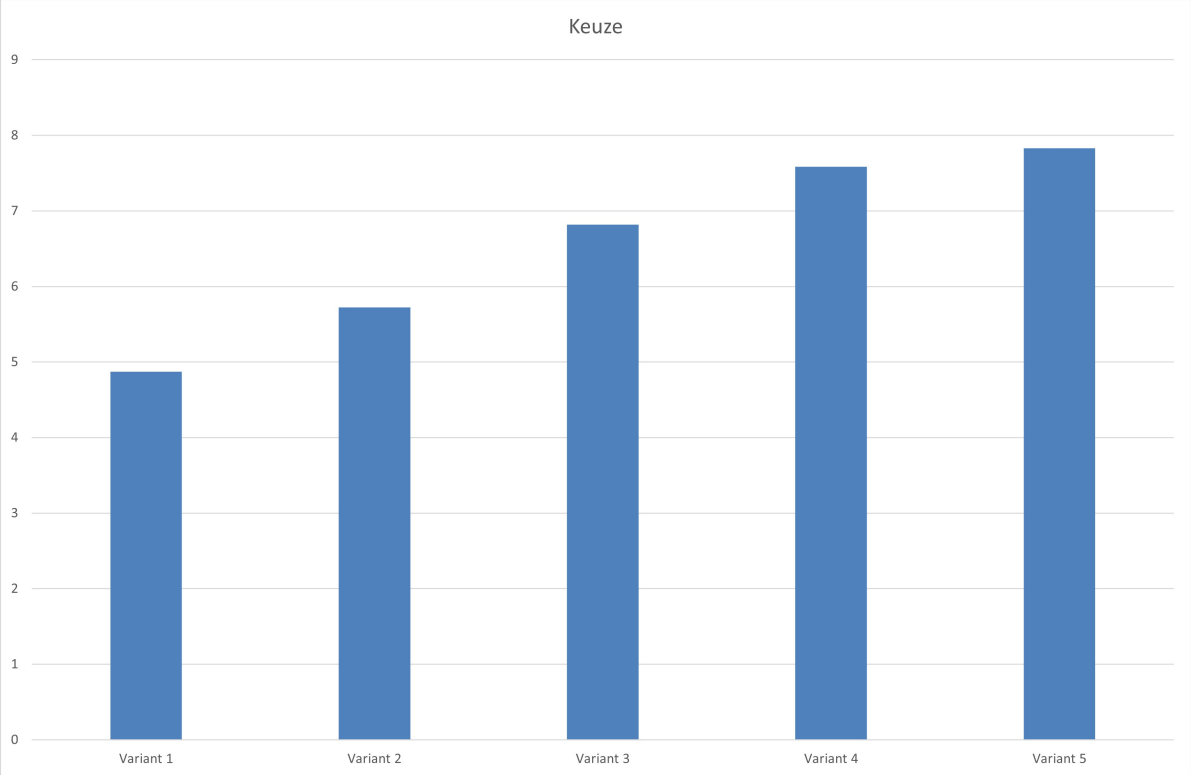
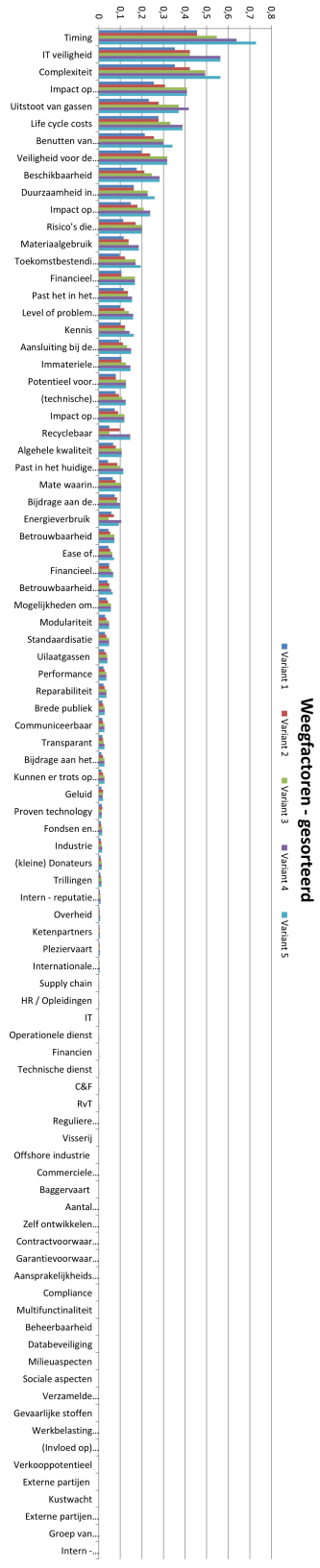
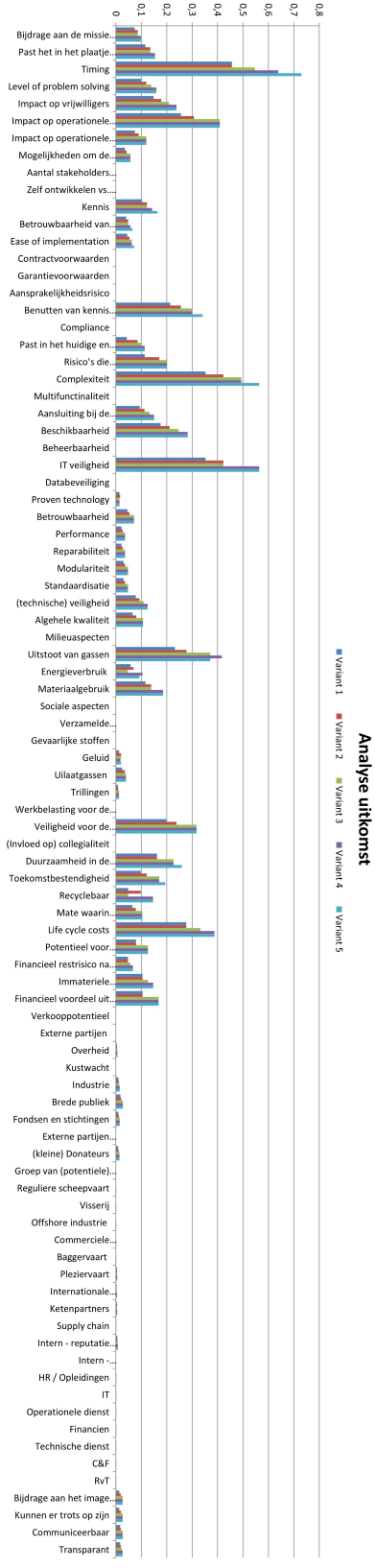


Figure T.2: The choice amongst variants as resulted from the interview with a financial expert.



(a) Contribution of the performance of each criteria to the synthesizing criterion, sorted, as obtained from the interview with the financial expert.



(b) Contribution of the performance of each criteria to the synthesizing criterion, as obtained from the interview with the financial expert.

Figure T.3: The weights as obtained from the interview with the financial expert.

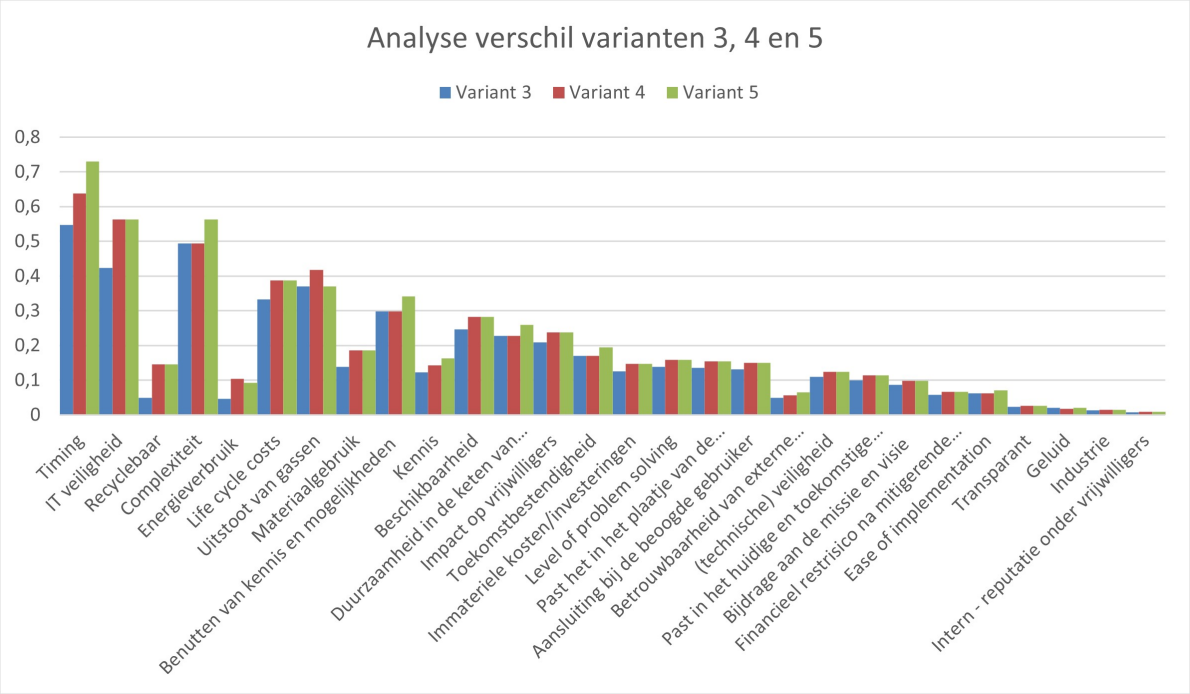


Figure T.4: The criteria sorted to their decisiveness in their contribution to the synthesizing outcome.

Acronyms

AHP Analytical Hierarchy Process. 24, 28, 29, 32–36, 39, 90, 91, 101

AI Artificial Intelligence. 28

AIP Aggregation of Individual Priorites. 55, 56

ANP Analytic Network Process. 24, 34

BAV Beach Assistance Vehicle. 107, 201, 243

BOE Board of Executives. 5, 6, 11, 13, 14, 16, 21, 22, 34, 47, 73, 79, 81, 82, 84, 85, 90, 94, 101, 208, 211

BWM Best-Worst method. 35–37, 39, 40, 43, 45–47, 51, 54, 55, 67, 89, 91, 97, 101, 139, 153, 155, 157, 159, 161, 163

CEO Chief Executive Officer. 213

CEO Chief Executive Officer. 6, 11, 13–15, 22, 33, 36, 48–50, 70, 84, 105, 111, 153, 154, 201, 203, 207, 208

CFO Chief Financial Officer. 84

CI Consistency Index. 43

COO Chief Operations Officer. 11, 48, 70, 84, 219, 221

CR Consistency Ratio. 43

CTO Chief Technology Officer. 6, 11, 13–15, 48–51, 56, 70, 84, 90, 121, 130, 155, 156, 171, 201, 211, 213, 253

DEMATEL Decision Making Trial and Evaluation Laboratory. 34, 97, 102

DM Decision Maker. 3, 17, 22–24, 33, 34, 36, 37, 39, 40, 43, 45, 53–56, 58, 61–63, 65, 67, 73, 74, 77, 78, 81–86, 88, 90–94, 97–99, 101–103, 245

DMP Decision Making Problem. 23, 39, 74

DMS Decision Making Situation. 3, 7, 21–23, 33, 34, 40, 47, 69, 79

DP Decision Problem. 13, 16, 19, 79, 81–84, 87, 88

DSS Decision Support System. 5–9, 11, 13, 14, 17–19, 21, 25, 26, 34, 35, 47, 55, 61, 63, 65, 69, 72, 74, 75, 77–79, 81, 83–91, 93, 94, 97–99, 101, 102

DST Decision Support Tool. 237

EIA Environmental Impact Assessment. 21

ELECTRE Elimination et Choix Traduisant la Realité. 24

HVO Hydrotreated Vegetable Oil. 105, 113

IMRF International Maritime Rescue Federation. 4, 108

IT Information Technology. 165, 167, 168

KNRM Koninklijke Nederlandse Reddingmaatschappij. iii, 1–8, 11–18, 21, 22, 25, 33, 35–37, 40, 45–47, 49, 50, 56, 70, 72, 73, 77–83, 86, 88–94, 98, 101–103, 105, 107, 108, 112, 113, 115, 116, 121, 153, 155, 157, 159, 161, 163, 171, 173, 201, 208, 211, 219, 227, 235, 243, 251

LNG Liquified Natural Gas. 115

MACBETH Measuring Attractiveness by a Categorical Based Evaluation Technique. 24, 34

MADM Multi-attribute decision making. 28, 32

MAUT Multi-Attribute Utility Theory. 24, 34

MAVT Multi-Attribute Value Theory. 24, 34

MCAP Multicriterion Aggregation Process. 23, 24, 34, 35, 53, 54, 67, 91, 97, 102

MCDA Multi-criteria Decision Analysis. 26

MCDM Multi-criteria Decision Making. 3, 4, 6, 15, 17, 18, 21, 24–28, 30–32, 53, 54, 89, 90, 94, 101, 102

MODM Multi-objective decision making. 28

MT Management Team. 11, 40

NGO Non-Governmental Organisation. 1, 2

PROMETHEE Preference Ranking Organisation Method for Enrichment of Evaluations. 24, 31, 33

R&D Research and Develpoment. 3

REMBRANDT Ratio Estimation in Magnitudes or deci-Bells to Rate Alternatives which are Non-Dominated. 34

RHIB Rigid Hull Inflatable Boat. 2, 109, 111

RNLI Royal National Lifeboat Institution. 109, 119

SAR Search and Rescue. 5, 171

SAS Special Air Service. 111

SAW Simple Additive Weighting. 34

SBS Special Boat Service. 111

SDG Sustainable Development Goal. 108

SEA Strategic Environmental Assessment. 21

SMART Simple Multi-Attribute Rating Technique. 24, 34

TOPSIS Technique for Order Performance by Similarity to Ideal Solution. 24, 34

TUD Delft University of Technology. 11

UTA Utility Theory Additive. 34

VIKOR Višekriterijumska Optimizacija i Kompromisno Rešenje. 34

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