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Multi-criteria reasoning models for value aggregation in wind power permit application assessment

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ABSTRACT

Assessment of an application for wind power establishment is a multi-criteria problem including the core problem: whether to grant permission or not. In Sweden, County Administrative Boards decide the outcomes of these kinds of applications. Five permit officers were interviewed to investigate the difficulties and the type of value aggregation in this work, and to test reasoning models as possible decision support tools. The commonly used type of aggregation was condition-based aggregation. Aggregation based on value differences, which means weighing together aspects for and against the wind power establishment, was considered difficult to apply by the respondents. Most of them agreed that some of the aspects that speak against granting permission could be aggregated but that aggregation of all aspects would be hard due to differences between aspects. In addition, the value of the main aspect that speaks for permission, climate friendly energy supply, is very difficult to estimate. Thus, aggregation based on value differences is a difficult question and how it could be performed is discussed in the paper. If policymakers wish to make it possible to take both positive and negative aspects into consideration and to discuss the trade-offs transparently, the investigated method can be a way forward.

1. Introduction

Wind power is an important renewable energy source and one of the key components in the effort to decrease CO_2 emissions. However, wind power establishment may lead to other negative effects, such as disturbance of local wildlife and/or reduction of biodiversity, problems for the reindeer industry, disturbance of inhabitants or decreased value of landscape image. The processes evaluating the negative effects of wind power establishment often take a long time which has been seen as a problem (e.g. [2,13,8]). In line with this, Thygesen and Agarwal [26] point out the importance of clear permission and assessment requirements. Cardoso and Hoffmann [4] emphasize the importance of including environmental planning early in the planning and licensing process in the energy sector.

A central part in decision-making regarding new wind power establishment is the evaluation of the environmental impact assessment. Even if the procedures for permission evaluation differ between different countries, the core problem is the same: should the location be granted an environmental permit for wind power establishment or not. The problem is a multi-criteria problem and thus multi-criteria decision analysis could be used to aid the handling of the problem. How multi-criteria decision analysis (MCDA) could be applied to facilitate the permission process is a central question in this paper. In the Swedish context it is permit officers who, with the help of other experts, evaluate if an application of wind power establishment should be given a permit or not, but the decision is made by the Environmental Assessment Delegation. The decision can be appealed but focus in this study is on the first stage of permission process, i.e., before any appeals. One central question is whether the value of wind power establishment is larger, or at least large enough, compared to other values that are decreased if the wind power establishment is permitted. These questions are important, both to increase transparency of the decisions and to lay a groundwork for a decision support tool for this kind of work.

1.1. Aims

The aim of this paper is to study if a tool, in the form of a decision support model, could support decision-making in the permitting process. More specifically, the aim is to study, from the point

of view of permit officers, the work process with applications of larger, land-based wind power parks[1] and what difficulties there may be. Furthermore, the aim is to study if the permit officers use condition-based aggregation, value difference-based aggregation or a combination of those two, and to discuss how Odelstad's the seven-step decision support model including both aggregation types [17,19], or some parts of the model, could support the work with applications.

2. Background

2.1. Process of licensing

In Sweden, as in many other countries, one of the goals of the energy sector is to substantially increase wind power as a renewable energy source, and one part of the work is the licensing process. Applications by companies concerning larger wind power establishments on land are evaluated in specific permitting processes in Sweden. It is a question of an activity requiring authorization, i.e., building and operating large-scale wind energy facilities is not allowed without a permit (license). The municipalities have a veto power and may thus hinder a wind power establishment (see more about the municipal veto in Darpö [5]. Most applications of wind power establishments are managed by County Administrative Boards (CABs). A permit officer works with permit applications and the Environmental Assessment Delegation (EAD, in Swedish Miljöprövningsdelegation MPD) decides if the application is accepted or not. The permit officer and the EAD are in communication during the process, but their roles are different. The permit officer prepares the decision basis for the case and the EAD decides it. Other experts on CABs help the permit officer, e.g., in questions concerning species that could be affected or effects on landscape image, and external experts can also be used. The Swedish Environmental Code (1998:808, MB) is one of the bases for this work, together with for example the territorial planning system [25] and the legal rules for the possibilities for public participation [20]. The EADs are independent and impartial decision-making units within the CABs that, in court-like forms, examine cases concerning permits. An EAD consists of a chairman, who has judicial competence, and an environmental expert who has technical competence. The work with permit applications is based on specific laws, recommendations, and praxis having a basis in cases that have been appealed and decided by the courts. The ruling from an EAD can be appealed to the Land and Environment Court and possibly further to the Land and Environment Court of Appeal (see more about Swedish permission procedure in Darpö [5]. The Swedish system has been described as complicated, slow, and bureaucratic without possibility to produce binding national or regional plans [14]. There is also a high level of uncertainty regarding politics and how the laws and rules will be applied in the permit process [21]. However, the question of planning on a national and regional level is intended to be changed (see [23]).

In Germany, the permission procedure is regulated mainly by the planning law based on federal state legislation and guidelines [3]. However, there are differences between the federal states in how the planning law is framed and applied [3]. In Denmark, the main legal framework for wind power establishment is physical planning that includes for example localization issues [21]. This is different compared to Sweden and Norway, where the Swedish Environmental Code and Norwegian Energy Act, respectively, are central in licensing procedures regarding wind power establishment [21]. In Norway, the final decisions about licensing cases are political, thus different from the situation in in Sweden [2]. The decisions of the licenses in Norway are taken by the Norwegian Water Resources and Energy Directorate, i.e., not by local administrators, after the benefits of the project have been weighed against the negative impact [8]. Blindheim [2] describes the Norwegian processes as time-consuming, with uncertainty about the outcome, creating risk for investors. Blindheim [2] emphasizes that, in addition to a faster pace, a clarification of the relevant criteria is needed when different interests are evaluated, and they request guidelines to separate "good" projects from "bad" projects early in the process. Inderberg et al. [8] studied influence of different formal and informal practices on the wind power licensing process in Norway. They argue that some stakeholders may have more influence than expected. Furthermore, wind power applications in Norway 2000–2019 were investigated using statistical methods by Inderberg et al. [9]. They found that both environmental impact and local perspectives have a big impact on the final licensing decisions concerning wind power establishment. They conclude that the municipalities have almost a veto power in licensing questions.

2.2. Environmental impact assessment

An important part of the permit application is the environmental impact assessment (EIA). In Sweden, it is normally made by consultants for the company applying for permission. When a company plans an application, it contacts EAD to discuss what should be included in an EIA and to get support or suggestions for organization of consultation with administrative authorities and with local citizens. An EIA should consider all aspects that are relevant to permit evaluation, and it is an important part of the evaluative work for county administrators. The quality of an EIA must be high enough to be evaluated. High quality here means that all relevant aspects are investigated and described in an adequate manner for evaluation. If it is not, the EIA must be completed. This can result in several iterations before the application is regarded as complete. If satisfactory quality is not reached, the case will be closed, and the application is not processed further. In addition, CABs may also carry out investigations concerning environmental questions.

3. Theoretical framework

Being a multi-criteria decision problem, a permit application case involves several aspects, such as value with respect to contribution to climate friendly energy supply, consideration for landscape image and consideration for protection of endangered species, such as the golden eagle. An aspect may also be called a *factor*, an *attribute*, a *criterion*, or a *dimension*. A decision maker, in this case a permit officer, needs to aggregate the aspects to be able to decide for or against permission. Other examples of aspects, in totally different contexts, are area, temperature, loudness, and archeological value (see [18]). Aspects can be classified for example as categorical and comparative aspects. Another categorization is descriptive, normative and intermediate aspects. From a measurement theoretical point of view, aspects are characterized by different kinds of *relations* [22], for example 'equality' and 'non-equality' and, if the aspect is comparative, relations 'greater-than' and 'lesser-than'. For example, areas of two locations can be of equal size, and the archeological value of one location can be greater than the archeological value of another location. As is clear from these examples, not all aspects are descriptive (like area and temperature). Some aspects, like archeological value, are normative (evaluative) aspects or neither purely descriptive nor purely normative aspects. The latter are so-called *intermediate aspects* (see [18]). An intermediate aspect or an intermediate concept functions as a

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[1] The process is somewhat different when it comes to offshore wind power establishment, but this is not included in the paper.

conceptual bridge or link between factual grounds for the concept, and its normative consequences. See for example Lindahl and Odelstad [12] for an overview of the theory of intermediate concepts.

A central part of the decision process in a multi-criteria decision problem is to aggregate the different factors (i.e., aspects) that determine the value of the different outcomes [18]. As the name suggests, *aggregation theory* deals with aggregation (and the converse activity of decomposition) of factors. To aggregate means to weigh together different factors, by means of trading off pros against cons, and to decompose means to split up aggregate factors in subfactors [17]. In the following, the concept of aggregation is presented more formally.

Assume that we consider two alternatives a and b (it is straightforward to generalize to an arbitrary number of alternatives). Somewhat simplified, the typical aggregation consists of the following procedure [17]: Determine how a and b compare with respect to the set of n aspects $\alpha_1, \alpha_2, \ldots, \alpha_n$. Based on this, decide how a and b compare with respect to an aspect α_0 which is an aggregation of $\alpha_1, \alpha_2, \ldots, \alpha_n$. For example, α_0 may represent how good an alternative is, taking all relevant factors (i.e., the aspects $\alpha_1, \alpha_2, \ldots, \alpha_n$) into consideration. Note (see [19]) that one or more of the factors of the aggregation α_0 may in turn be an aggregation of a number of (sub-) factors. It is common that the aggregation of the factors $\alpha_1, \alpha_2, \ldots, \alpha_n$ is carried out in steps by using intermediate factors $\beta_1, \beta_2, \ldots, \beta_m$ such that some of the factors $\alpha_1, \alpha_2, \ldots, \alpha_n$ are aggregated to β_1, some to β_2, and so on. Finally, $\beta_1, \beta_2, \ldots, \beta_m$ are aggregated to α_0. Note that $\beta_1, \beta_2, \ldots, \beta_m$ are intermediate aspects whose meaning is determined jointly by their respective grounds $\alpha_1, \alpha_2, \ldots, \alpha_n$ and their consequence α_0. The *aggregation tree* (see for example [18]) in Fig. 1 illustrates the structure of the following aggregation: α_0 (the main aggregation) is an aggregation of β_1, β_2, and α_7. β_1 is an aggregation of $\alpha_1, \alpha_2, \alpha_3$, and α_4. β_2 is an aggregation of α_5 and α_6.

For a brief discussion of the formal properties of aspects and their representation as relational structures, see Odelstad [18] with references. The application of aggregation theory within decision-making, known under names such as multi-attribute decision theory or multi-criteria decision analysis, is discussed for example in Keeney and Raiffa [10] and in Belton and Stewart [1]. The relationship between these concepts is discussed in depth (in Swedish) in Odelstad [16].

3.1. Condition-based vs. Value Difference-based Aggregation

Odelstad [16] discusses two basic models, a one-sided and a two-sided model, for reasoning about complex decision problems in the context of planning and building. Odelstad describes the one-sided model as a spring balance model where one or several disadvantages are "weighed," i.e., evaluated to see if the effect is too large, as opposed to a two-sided balance scale model where both advantages and disadvantages are "weighed" using a balance scale, i.e., compared with each other (Fig. 2). These models were later adapted and applied to wind power application situations [17,19].

The first basic model is so-called *condition-based aggregation*, in which the decision alternatives are viewed from several aspects. One possible decision about a permit application is the following: If an alternative is good enough (accepted) with respect to each aspect, the alternative as a whole is accepted. If an alternative is not good enough (rejected) with respect to at least one aspect, then the alternative as a whole is rejected. Note that there may be leeway between being accepted and rejected. What this may mean is discussed in more detail, and from a formal point of view, in Odelstad [19].
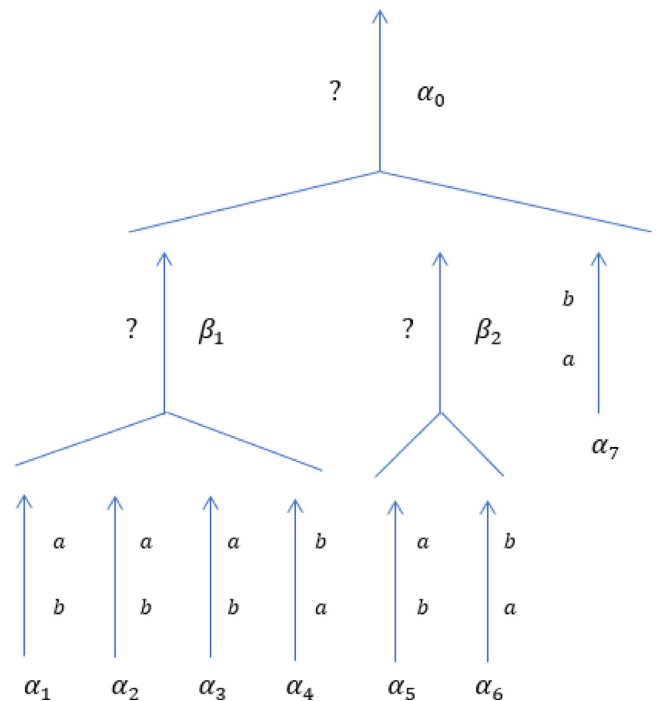

Fig. 1. An example of aggregation of aspects $\alpha_1, \alpha_2, \alpha_3$, and α_4 to aspect β_1, aspects α_4 and α_5 to aspect β_2 and aggregation of aspects β_1, β_2, and α_7 to α_0, the main aggregation. According to the figure, a is better than b with respect to each of the aspects $\alpha_1, \alpha_2, \alpha_3$, and α_5 while b is better than a with respect to α_4, α_6, and α_7. The question mark illustrate that deciding which of a and b is best with respect to β_1, β_2, and α_0, requires weighing together (i.e., aggregating) the aspects below.
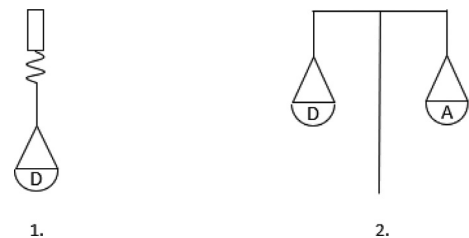

Fig. 2. Part 1 shows a spring balance model where one or several disadvantages (D) are evaluated to see if the effect is too large. Part 2 shows a balance scale model where both advantages (A) and disadvantages are compared with each other. Redrawn from Odelstad [16].

Another basic model, *value difference-based aggregation*, is (as the name suggests) based on the notion of value differences. Suppose that we are to determine for two alternatives a and b how good they are relative to each other with respect to an aspect α_0 that is an aggregation of the aspects $\alpha_1, \alpha_2, \ldots, \alpha_n$. Value difference-based aggregation intends to compare how good a and b are with respect to the different aspects, and then add together what speaks for a (i.e., those aspects in which a has an advantage over b) and what speaks for b (i.e., those aspects in which b has an advantage over a). These added pros and cons are then traded off against each other in a balance scale-like fashion. This requires a completely different formalism than for condition-based aggregation. A very brief account of this formalism, which is presented in detail in Odelstad [19], is given here.

The value difference between a and b with respect to an aspect α_i is denoted $\Delta_i(a, b)$. If a is better than b with respect to α_i, then $\Delta_i(a, b)$ is a *positive* difference. In other words, α_i is an aspect that speaks for a over b. If a and b are equally good with respect to α_i, then $\Delta_i(a, b)$ is a *zero* difference, and α_i speaks for neither a nor

b. If b is better than a with respect to α_i, then $\Delta_i(a, b)$ is a *negative* difference, and α_i speaks for b over a. The *concatenation* of two value differences $\Delta_i(a, b)$ and $\Delta_j(a, b)$ is denoted $\Delta_i(a, b) \oplus \Delta_j(a, b)$. If for example both $\Delta_i(a, b)$ and $\Delta_j(a, b)$ are positive differences, $\Delta_i(a, b) \oplus \Delta_j(a, b)$ represents taking together the two advantages for a over b with respect to aspects α_i and α_j. The aggregation tree in Fig. 3 illustrates a situation in which the two advantages for a over b in α_i and α_j add up to an advantage for a over b regarding the aggregated aspect β_k.

The concept of value difference (in the literature also often referred to as utility difference or preference difference) is a central notion in decision analysis (see for example Köbberling [11]). How to put this concept and the formalism presented here to practical use will be demonstrated in the following section, which presents a seven-step model for the permit decision process that is based on a mixture of both condition-based and value difference-based aggregation. In this model, value differences are treated explicitly and qualitatively, meaning that the approach in this methodology is based on qualitative comparisons of differences in single aspects or differences in several aspects taken together.

3.2. Seven-step model with an example

Based on the reasoning models described in the previous section, Odelstad [17] proposed a seven-step model for permit decisions. The model is presented in Fig. 4 and described below in detail using the same example that was used in the second interviews of the study. The example is hypothetical but based on actual cases. It is about an application concerning a wind power park of 50 wind power plants, and the problem is whether permission is to be granted or not. We assumed that the hypothetical permit officer has read all the material in the permit application, including the comprehensive EIA. The comparisons below are between wind power establishment ($\mathcal{W}$) and the so-called zero alternative ($\mathcal{Z}$), i.e., the alternative to refrain from $\mathcal{W}$.

$\mathcal{W}$ – wind power establishment

$\mathcal{Z}$ – zero alternative

Further, we suppose that during this work the permit officer has identified the following aspects to be central in the case:

$\mathcal{R}$ – consideration for reindeer industry

$\mathcal{L}$ – consideration for landscape image

O – consideration for outdoor life

$\mathcal{T}$ – consideration for wilderness tourism

$\mathcal{B}$ – consideration for protection of golden eagle[2]

$\mathcal{G}$ – geoscientific value

$\mathcal{E}$ – value of contribution to climate friendly energy supply

Step 1. Investigate if there is an aspect level that makes the establishment of wind power according to the suggested location not acceptable (see Fig. 5). The aspect levels of $\mathcal{W}$ concerning each aspect are compared to an acceptable level which we will refer to as the *threshold level* or simply *threshold*. The meaning of a threshold level in this context may be intuitively clear, but (as will be further discussed in Section 6) we do not assume that the threshold can be easily reduced to or represented by some numerical quantity. In general, it must be evaluated in each specific situation using the relevant legal framework and other regulations. If there are one or more aspect levels below the respective threshold, reject the permission application for $\mathcal{W}$. Otherwise, go to step 2.

t^i – threshold with respect to aspect *i*.

t^R – threshold below which reindeer industry is affected too negatively.

t^B – threshold below which golden eagles are affected too much.

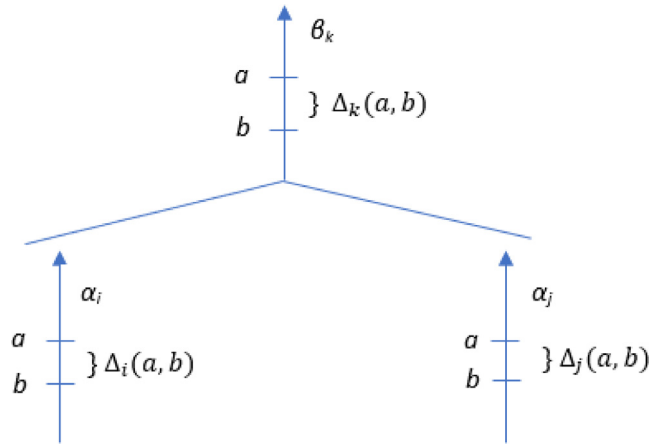[2] We use the letter B, bird, because both G and E are already in use.

Fig. 3. An aggregation tree showing two value differences between alternatives a and b, $\Delta_i(a, b)$ and $\Delta_j(a, b)$ taken together, resulting in a value difference $\Delta_k(a, b)$ with respect to aspect β_k.
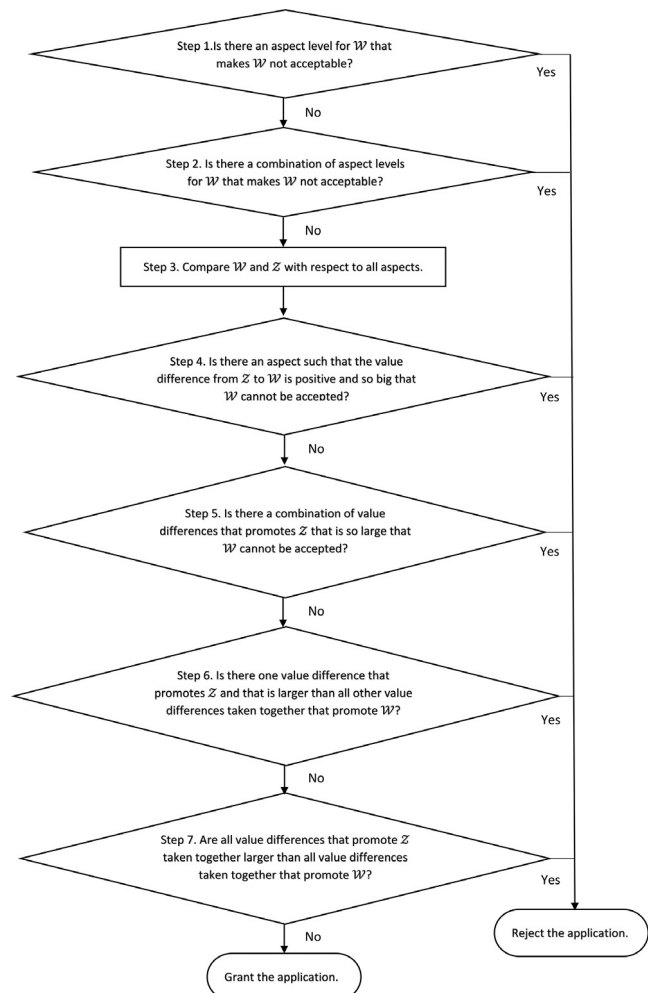
Fig. 4. A diagram of the 7-step model for investigation if a wind power permit application should be accepted or not. Alternatives: $\mathcal{W}$ – wind power establishment, $\mathcal{Z}$ – zero alternative.

In step 1, it is a sufficient condition for accepting the permit application that each aspect level of $\mathcal{W}$ is above the respective threshold. However, there may be other circumstances where an alternative could be accepted even if all thresholds are not
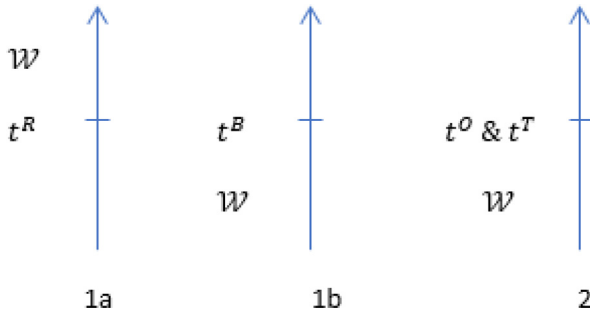
Fig. 5. Parts 1a and 1b belong to step 1 and part 2 belongs to step 2. 1a) Wind power establishment $\mathcal{W}$ is acceptable with respect to consideration for reindeer industry because it is better than the threshold t^R; 1b) Wind power establishment $\mathcal{W}$ is not acceptable with respect to consideration for protection of golden eagle because it is worse than the threshold t^B; 2) Wind power establishment $\mathcal{W}$ is not acceptable with respect to aspects outdoor life and wilderness tourism taken together, because when evaluating the acceptance of $\mathcal{W}$, the joint threshold $t^O\&t^T$ (also written t^{OT}) represents a limit below which these two taken together are affected too negatively.

achieved, for example via a compensation. This means that the thresholds do not need to be absolute. In addition, there may be absolute thresholds without any possibility for compensation.

Step 2. Investigate if there is a combination of aspect levels for $\mathcal{W}$ that makes the establishment of wind power according to the suggested location not acceptable. If there is such a combination, reject the permission application. Otherwise, go to step 3.

The thresholds used to exemplify step 2 (Fig. 5):

t^O – threshold below which outdoor life is affected too negatively.

t^T – threshold below which wilderness tourism is affected too negatively.

t^{OT}(in the figures denoted $t^O\&t^T$) – joint threshold for the aspect OT, i.e., the aggregation of outdoor life and wilderness tourism.

The rationale behind Step 2 is that there may be a combination effect such that $\mathcal{W}$ may lie under the joint threshold t^{OT} even if $\mathcal{W}$ lies above the individual thresholds t^O and t^T when aspects O and $\mathcal{T}$ are evaluated separately in Step 1.

Step 3. Compare the alternative of wind power establishment ($\mathcal{W}$) and the zero alternative ($\mathcal{Z}$), i.e., no wind power establishment, with respect to all relevant aspects. This step is a preparation for the following steps. The aim is to clarify the grounds for judgments. Fig. 6 shows an aggregation tree of the hypothetical case used in this study. The aggregation tree represents the decision problem: to approve the permission, which means choosing $\mathcal{W}$, or not to approve the permission, which means choosing $\mathcal{Z}$.

As examples, let us consider two comparisons that the aggregation tree shows:

(1) $\mathcal{Z} \succ_\mathcal{R} \mathcal{W}$, meaning that $\mathcal{Z}$ is better than $\mathcal{W}$ with respect to the aspect consideration for the reindeer industry. It also means that there is a positive difference with respect to consideration for the reindeer industry between the zero alternative and the wind power establishment, i.e., $\Delta_\mathcal{R}(\mathcal{Z}, V)$ is positive.

(2) $\mathcal{W} \succ_\mathcal{E} \mathcal{Z}$, meaning that $\mathcal{W}$ is better than $\mathcal{Z}$ with respect to the aspect contribution to climate friendly energy supply. It also means that there is a positive difference with respect to value of contribution to climate friendly energy supply between the wind power establishment and the zero alternative, i.e., $\Delta_\mathcal{E}(\mathcal{W}, \mathcal{Z})$ is positive.

where

$\succ$ means 'better than' and for example

$\succ_\mathcal{R}$ means 'better with respect to reindeer industry than'.
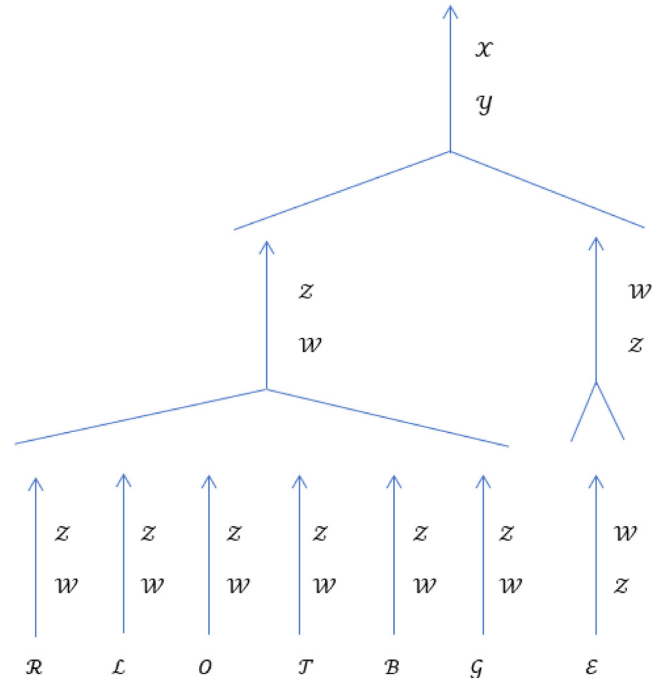
Fig. 6. Aggregation tree with the following aspects: consideration for reindeer industry, $\mathcal{R}$, consideration for landscape image, $\mathcal{L}$, consideration for outdoor life, O, consideration for wilderness tourism, $\mathcal{T}$, consideration for protection of golden eagle, $\mathcal{B}$, geoscientific value, $\mathcal{G}$, and value of contribution to climate friendly energy supply, $\mathcal{E}$. Wind power establishment is represented by $\mathcal{W}$ and zero alternative by $\mathcal{Z}$. On the highest level of the aggregation tree, x and y represent the 'total goodness' of the alternatives but in this case, it is not clarified which of the alternatives $\mathcal{W}$ and $\mathcal{Z}$ is the best one.

Step 4

Investigate if there is an aspect such that the value difference from $\mathcal{Z}$ to $\mathcal{W}$ is positive, which means that this aspect speaks for $\mathcal{Z}$ over $\mathcal{W}$, and that this (value) difference is so big that $\mathcal{W}$ cannot be accepted.

If there is such an aspect, reject the permission application. Otherwise, go to step 5.

Example of a value difference in Step 4.

Investigate if the difference between $\mathcal{Z}$ and $\mathcal{W}$ when it comes to protection of golden eagle is positive, and so large that $\mathcal{W}$ cannot be accepted. In other words, investigate if $\mathcal{Z}$ is so much better than $\mathcal{W}$ with respect to protection of golden eagles that $\mathcal{W}$ cannot be accepted. In Step 3 we saw that the zero alternative is better than the wind power establishment with respect to consideration for the reindeer industry, i.e., $\mathcal{Z} \succ_\mathcal{R} \mathcal{W}$. Now we need to assess if the difference $\Delta_\mathcal{R}(\mathcal{Z}, \mathcal{W})$ is too large to allow the acceptance of $\mathcal{W}$. The difference between step 1 and step 4 is that in step 1 we do not consider the alternative $\mathcal{Z}$ but we simply compare $\mathcal{W}$ with a threshold condition that is independent of $\mathcal{Z}$.

Step 5. Investigate if there is a combination of value differences that promotes $\mathcal{Z}$ that is so large, i.e., forms a hindrance, that $\mathcal{W}$ cannot be accepted. If there is such a combination, reject the permission application. Otherwise, go to step 6.

Example of a combination of value differences in Step 5.

In Step 3 we saw that $\mathcal{Z} \succ_O \mathcal{W}$ and $\mathcal{Z} \succ_\mathcal{T} \mathcal{W}$, i.e., that the zero alternative is better than the wind power establishment with respect to consideration for outdoor life and wilderness tourism. This means that $\Delta_O(\mathcal{Z}, \mathcal{W})$ and $\Delta_\mathcal{T}(\mathcal{Z}, \mathcal{W})$ are positive differences. The question is now if $\Delta_O(\mathcal{Z}, \mathcal{W}) \oplus \Delta_\mathcal{T}(\mathcal{Z}, \mathcal{W})$, the two differences taken together, is big enough to lead to a rejection of the permis-

sion application. In other words, investigate if $\mathscr{Z}$ is so much better than $\mathscr{W}$ when taking consideration for outdoor life and wilderness tourism together that $\mathscr{W}$ cannot be accepted.

Steps 6 and 7. The last two steps include comparisons of value differences. We use $\sqsupset$ for 'larger than' when comparing differences.

Step 6. Investigate if there is one value difference that promotes $\mathscr{Z}$ and that is larger than all other value differences taken together that promote $\mathscr{W}$. In this case, $\mathscr{W}$ cannot be accepted. If there is such a value difference, reject the permission application. Otherwise, go to step 7.

For example, as can be seen in Fig. 6, $\mathscr{Z}$ is better than $\mathscr{W}$ with respect to geoscientific value. That means that the value difference $\Delta_{\mathscr{G}}(\mathscr{Z}, \mathscr{W})$ is positive. $\mathscr{W}$ is on the other hand better than $\mathscr{Z}$ with respect to the aspect contribution to climate friendly energy supply. That means that the value difference $\Delta_{\mathscr{E}}(\mathscr{W}, \mathscr{Z})$ is positive. The question is now if the value difference with respect to geoscientific value is so much bigger than the value difference with respect to contribution to climate friendly energy supply, i.e., if $\Delta_{\mathscr{G}}(\mathscr{Z}, \mathscr{W})$ is so much bigger than $\Delta_{\mathscr{E}}(\mathscr{W}, \mathscr{Z})$, that $\mathscr{W}$ cannot be accepted.

Step 7. Investigate if all value differences that promote $\mathscr{Z}$ taken together are larger than all value differences taken together that promote $\mathscr{W}$. If this holds true, $\mathscr{W}$ cannot be accepted. Otherwise, $\mathscr{W}$ can be accepted, and permission is granted.

The following positive value differences promote alternative $\mathscr{Z}$: $\Delta_{\mathscr{R}}(\mathscr{Z}, \mathscr{W})$, $\Delta_{\mathscr{L}}(\mathscr{Z}, \mathscr{W})$, $\Delta_{O}(\mathscr{Z}, \mathscr{W})$, $\Delta_{\mathscr{T}}(\mathscr{Z}, \mathscr{W})$, $\Delta_{\mathscr{B}}(\mathscr{Z}, \mathscr{W})$ and $\Delta_{\mathscr{G}}(\mathscr{Z}, \mathscr{W})$

The following positive value difference promotes alternative $\mathscr{W}$: $\Delta_{\mathscr{E}}(\mathscr{W}, \mathscr{Z})$.

We need to take together all the positive value differences promoting $\mathscr{Z}$ and compare the result to the value difference promoting $\mathscr{W}$. If the following is true, $\mathscr{W}$ can be accepted, otherwise not.

$$\Delta_{\mathscr{E}}(\mathscr{W}, \mathscr{Z}) \sqsupset \Delta_{\mathscr{R}}(\mathscr{Z}, \mathscr{W}) \oplus \Delta_{\mathscr{L}}(\mathscr{Z}, \mathscr{W}) \oplus \Delta_{O}(\mathscr{Z}, \mathscr{W}) \oplus \Delta_{\mathscr{T}}(\mathscr{Z}, \mathscr{W})$$
$$\oplus \Delta_{\mathscr{B}}(\mathscr{Z}, \mathscr{W}) \oplus \Delta_{\mathscr{G}}(\mathscr{Z}, \mathscr{W})$$

Steps 1 and 2 are based on formulating conditions on aspect levels meaning that the proposed wind power establishment, $\mathscr{W}$, needs to be good enough with respect to each aspect to go further in the permission process. In the following steps, $\mathscr{W}$ is compared to the zero alternative, $\mathscr{Z}$, by means of comparing value differences between $\mathscr{W}$ and $\mathscr{Z}$ with respect to relevant aspects.

Steps 1 and 2 have their basis chiefly in condition-based aggregation, including investigation of the alternative $\mathscr{W}$ with respect to relevant aspects to assess if $\mathscr{W}$ is possible to accept. If $\mathscr{W}$ is on an acceptable level with respect to all aspects, it is not rejected. If it is not on an acceptable level with respect to one or more aspects, it is not accepted, and the application is rejected. Steps 4 and 5 can be seen as being based on a hybrid between condition-based and value difference-based aggregation, since we are dealing with conditions on the sizes of value differences. In these steps, the value differences of disadvantages are evaluated but no comparisons are made with advantage(s), i.e., these steps focus on disadvantages of $\mathscr{W}$, investigating if they are too large. In other words, for the aspects in which $\mathscr{W}$ is worse than $\mathscr{Z}$, it must be decided if the difference from $\mathscr{W}$ up to $\mathscr{Z}$ is too big or not.

In value difference-based aggregation, two or more alternatives are compared using value differences with respect to different aspects. In this study, we focus on two alternatives that are relevant for permit officers: to accept the application or to reject it. In steps 6 and 7, value differences are taken together, i.e., added together, in different ways. In these steps, as opposed to the earlier steps, the benefits of $\mathscr{W}$ are also taken into consideration and they are compared to benefits of $\mathscr{Z}$.

4. Methodology

The empirical part of this study was performed using semi-structured interviews. Respondents have insight in the processes that lead to a decision on whether a proposed facility is granted permission or not. Five interviews[3] were performed with respondents working as permit officers at a county board with responsibility to gather and process the necessary information from the applicant (the company) and the experts within the county board, discuss with the EAD and write the proposed decision document.

The respondents were selected with an aim to include representation of different types of challenges regarding wind power and a spread in geographical location. Both male and female respondents were interviewed.

Before the first interview, we had asked each permit officer to send us documentation of a wind energy case they were familiar with. These cases were discussed during the interviews to clarify the working process and problems in this work. One aim was to identify the uncertainties and difficulties that they encounter. Another aim was to ask some preliminary questions about aggregation based on value differences. After each interview we asked if we could come back with clarifying questions and all respondents said yes to this. The first interviews were held in person at the respondents' office and took about 1.5–2 hours. All interviews were recorded, transcribed, and analyzed before preparing for the second round of interviews.

A few months later a second interview was scheduled with each of the five permit officers, and these interviews were conducted as web meetings. The purpose of the second interviews was to provide feedback on the first interviews and to test the possible decision support model based on Odelstad's seven-step method. For this we had constructed a hypothetical example to discuss inspired by an actual case. This case that was discussed during the second interviews is the same case that is presented in the Theoretical Framework section. Even if a permit application must include several alternatives, i.e., alternative localizations, we focus in this study on two alternatives: to grant the permission or not. Alternative localizations seldom play a role in practice in decision-making on a permission case for wind power establishment and their role is not studied in this study. The second interviews took a little less than one hour each. The interviews were recorded, transcribed, and analyzed.

5. Results

In the first interviews, the respondents answered questions about their working process with wind power applications and how they involve other experts in the work when necessary. In Sweden, it is permit officers who prepare the basis of decisions for wind power applications. An application for wind power establishment in Sweden is a large document with relevant attachments, including EIA. The permit officer who has responsibility to prepare the decision basis of the case often already has knowledge of the case because the company has contacted the County Administrative Board (CAB) to get advice on what is needed for the application or if there are serious obstacles to establishment (see Fig. 6). The permit officer has in most cases contributed information to the company about organization of mandatory consultations, both with administrative authorities and with citizens. One of the goals with these consultation occasions is to find out which aspects need to be thoroughly investigated for EIA. For example, if it is known by experts in a CAB that the planned area includes golden eagle nests, it is important input for the company to try to plan the park with-

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[3] In one interview there were two permit officers.

out disturbing them. Another important goal is attempts to find agreement and acceptance among those who are going to be affected by the wind power establishment. Sometimes it is possible to find acceptance but not always. If the consultation with citizens is performed badly it may be very difficult to make corrections, "to heal" as one of the respondents expressed it.

Fig. 7 shows a generalized schema of a permit officer's work with a permit process. The final deliverable of a permit officer is a statement about the application to be used as a decision basis by EAD (Environmental Assessment Delegation). Note that at some CABs, one person may work with the case both as a permit officer and as a permit officer of EAD (however, without taking part in decision-making). Each interview included a specific case that the permit officer had been working with, and a general discussion about the process and problems with it.

Permit officers focus on permissibility. After identification of the relevant aspects, using EIA (Environmental Impact Assessment) and the competence in the CABs, they mainly work focusing on one aspect at a time to see if the suggested wind power park is acceptable with respect to it, either directly or if it could be accepted with mitigation measures that can be included in a permit. Some of the permit officers recalled cases where several disadvantages were added together against a wind power park, but some of them did not see this kind of addition as a possible way to evaluate wind power park applications.

When it comes to the value of the aspect $\mathscr{E}$, contribution to climate friendly energy supply, in a specific case, the permit officers explained that there are political goals to increase the production of climate friendly energy supply but that they do not estimate any value for alternatives with respect to this aspect.

The second round of interviews had focus on feedback and on a discussion of Odelstad's seven-step method. For the discussion, we used a hypothetical example presented in the introduction section. The case is described in detail in the Theoretical Framework section.

Referring to steps 1–7 below, we discuss the response from the respondents after showing them figures from the steps and discussing the steps with them. The same figures as those in the introduction session were shown to the respondents but in Swedish instead of English.

Step 1. Step 1 and parts 1a and b in Fig. 5 are feasible according to all permit officers. If it is clear that $\mathscr{W}$ is not good enough, i.e., it is below the threshold level, with respect to one of the criteria, the permission cannot be approved. It is most often the case that one single aspect is the reason why an application by a wind power park does not get a permit. However, it is difficult if $\mathscr{W}$ is close to the acceptable level. In those cases, it may be a relevant question to find out if there are protective measure(s) that can change the situation by making $\mathscr{W}$ acceptable.

Step 2. There were different opinions among permit officers how this step (see Fig. 5, part 2) could be implemented in practice. Some of them thought that it could be possible to combine two aspects, at least if it is possible to see that they naturally belong together, as is the case with outdoor life and wilderness tourism. However, they found it difficult to combine aspects that do not have much in common, such as reindeer industry and geoscientific value. Some of the permit officers were skeptical of the idea of combining aspects in this way, even though they knew that it has been done.

Step 3. Most of the permit officers found the aggregation tree (Fig. 6) a good way to represent the decision problem. The aggregation tree which was shown to the permit officers did not have X and Y on the highest level, and neither $\mathscr{W}$ or $\mathscr{Z}$ on the level in the middle as in Fig. 6. However, these symbols were discussed during the second interview with each of the permit officers, and

the symbols have been added in Fig. 6 to make the figure clear for all readers. Some of the permit officers pointed out that there may be a large difference between $\mathscr{Z}$ and $\mathscr{W}$, i.e., that the negative impact of $\mathscr{W}$ is large compared with $\mathscr{Z}$, but that this difference can be diminished by some protective measure(s). Observe that in Fig. 6, the 'goodness' of the alternatives $\mathscr{W}$ and $\mathscr{Z}$ with respect to each aspect is represented ordinally, i.e., it is possible to see whether $\mathscr{W}$ or $\mathscr{Z}$ is better with respect to each aspect, but it is not possible see how big a difference there is between $\mathscr{W}$ and $\mathscr{Z}$.

Some of the permit officers suggested an additional aspect: benefit in the form of continued possibility to drive reindeer industry because of diminished climate change. However, the effect of one wind power park on climate change is practically zero. The question has to do with cumulative effects of large numbers of actions to increase renewable energy sources. It is not possible to promise reindeer breeders that if they abandon their land the climate will not change too much for the reindeer industry. As in the first interviews, the difficulty to assess value with respect to aspect $\mathscr{E}$ was discussed.

Step 4. All five permit officers felt that this step reminds them of a way they work, or a way one could work, i.e., that they consider if the (value) difference between $\mathscr{Z}$ and $\mathscr{W}$ is large enough not to be accepted.

Step 5. The question in this step is if the value differences taken together are large enough to lead to a rejection of the permission application. Most of the permit officers thought that it could be possible to take value differences together, at least if they are near to each other (for example outdoor life and wilderness tourism). However, there was one permit officer who expressed strong doubt about considering any of the value differences together.

Steps 6 and 7. A large problem with these steps is how to assess the value for the aspect $\mathscr{E}$, value of contribution to climate friendly energy supply. There are national goals to increase the amount of wind power to increase renewable energy production. It is not possible to translate this to a value for a certain wind power park. Another problem is to take all value differences together that are against the wind power establishment. As we have seen earlier, some of the permit officers were open to the idea of aggregating (similar) aspects, i.e., to consider the combined impact with respect to two or more aspects taken together. One suggestion was that it could be possible to take value differences together for wilderness tourism, $\mathscr{T}$, outdoor life, O and landscape image $\mathscr{L}$. Further, it could be possible to take value differences together for protection of golden eagle, $\mathscr{B}$, and geoscientific value, $\mathscr{G}$.

6. Discussion

To lay the groundwork for a decision-making tool it is important to know how the decision-making process proceeds and what kind of problems decision-makers face during the process. Furthermore, factors regulating the decision-making need to be considered. In this study, the focus is on a decision-making model that could be useful in the context of wind power establishment, and specifically for permit officers when they evaluate permit applications. From an MCDA point of view, we investigated if permit officers use condition-based aggregation, value difference-based aggregation or a combination of both when evaluating permit applications. When Swedish permit officers interviewed in this study evaluate an application with its EIA, in most cases they inspect each aspect separately to assess if it is on an acceptable level for a wind power establishment or not, i.e., they do not combine aspects and add up pros and cons. It can be described, using the concepts in Odelstad [16], as a spring balance model where each disadvantage is "weighed," i.e., evaluated separately to see if the effect is too large as opposed to a balance scale model where

Consultations

Contribute with local knowledge about local interests to the consultation with administrative authorities and the consultation with citizens that the company organizes before its work with the application, including EIA.

$\downarrow$

Application arrives

EAD sends the company's application to CAB. Assess the need for completion. If necessary, organize referral in suitable entities in Swedish CAB.

*If the permit officer works for EAD, ask if County Administrative Board, municipality, and other relevant parties identify a need for supplementary information.

$\downarrow$

Inform EAD

In many cases the application needs to be complemented. Inform EAD about it. EAD has the contact with the company.

*If the permit officer works for EAD, have contact with the company.

$\downarrow$

Evaluation of the application

When the application is complete, evaluate it. Organize referral in suitable entities in CAB and if necessary, even with other experts.

$\downarrow$

Statement

Write a statement about the application for EAD.

$\downarrow$

Possible re-evaluation of the application and a new statement

If EAD needs more information a re-evaluation of the application may be needed.

Fig. 7. Main stages of the permission process from the perspective of permit officers in Swedish County Administrative Boards (CABs). During most steps, a permit officer has contact with the Environmental Assessment Delegation (EAD) that makes the final decision. If the permit officer works for EAD, write the EAD's decision and inform the company.

both advantages and disadvantages are compared with each other (Fig. 2). Thus, when an application is rejected, it is in most cases due to a single aspect. If the level of a certain aspect is near a level that can be accepted, the respondents consider if protective measures may improve the plan in the application so that permission could be granted, i.e., they consider if there are some protective measures that can be performed to change the current level to an acceptable level. In other words, they consider if there are some protective measures that can be performed to change the current level to an acceptable level, i.e., to raise the level of $\mathscr{W}$ above the

threshold. The condition that alternative $\mathscr{W}$ must fulfil with respect to each aspect is that its performance is above the threshold level, either with or without protective measures. As mentioned in Section 3.2, it is not a general assumption that the threshold level can be easily represented by a numerical quantity. In some cases, a simple comparison with a numerical representation of the threshold level may be all that is needed, but in general the comparison may require non-trivial evaluations based on the relevant legal framework and other regulations. One possibility is to represent the threshold level for a certain aspect by the level

of another (real or fictitious) alternative U that is considered to be "just barely acceptable" as regards this aspect. To compare $\mathscr{W}$ to the threshold level for this aspect then means to compare $\mathscr{W}$ to U with respect to this aspect: If the performance of $\mathscr{W}$ is better than the performance of U, then $\mathscr{W}$ is above the threshold for this aspect.

Steps 4 and 5 of the 7-step model require the decision maker to assess value differences to see if one difference (step 4) or some combination of them (step 5) that speaks for $\mathscr{Z}$ is too large to allow the acceptance of $\mathscr{W}$. For this, the levels of $\mathscr{W}$ and $\mathscr{Z}$ with respect to relevant aspects must be assessed. Even if the interviewed permit officers recognize the approach in the step 4 as being near the evaluation they perform in practice, it is not an approach that they actually use. They describe that their chief task is to examine if there are enough reasons to reject an application or, otherwise, to grant it, i.e., they apply condition-based aggregation.

The last two steps of the seven-step model by Odelstad [16–19] are based on comparisons of value differences between $\mathscr{W}$ and $\mathscr{Z}$. To apply these steps, it is necessary to compare the value of renewable energy with disadvantages with a wind power establishment. We observed difficulties when we asked the permit officers about applying these steps, for two reasons. First, the permit officers found it very difficult to estimate the value of renewable energy. From their perspective, there are political intentions and regulatory documents that show a general importance of wind power establishment. However, these are difficult to use to estimate the value of renewable energy in specific cases. Second, the permit officers found it difficult to take together disadvantages of a wind power establishment, i.e., combine them, which is needed in steps 5 and 7. Some of the permit officers thought that aspects that speak against a wind power establishment could be taken together, at least if the aspects are of a similar kind, such as "consideration for outdoor life" and "consideration for wilderness tourism". Thus, they were open to reasoning about joint thresholds that take into account a possible combination effect of two or more aspects. However, one of the permit officers was strongly against this kind of approach. The permit officers were aware that argumentation including a combination of aspects had been used for example in a case that had been appealed [15]. However, the aggregation that the permit officers described is condition-based aggregation with focus on one aspect at time. To assist the decision makers to better handle the complexity of such a task including value differences, computer support tools could be developed. To structure the aggregation problem, a simple visualization tool such as an aggregation tree may be helpful. A decision support tool for performing qualitative value difference comparisons would greatly reduce the cognitive burden of identifying positive value differences and keeping track of value difference comparisons.

Many of the permit officers interviewed hoped that there would be a national plan for wind power. That would make it possible to know which areas should be used for wind power establishments and which areas should be used for other purposes. Pettersson et al. [21] also seem to be on the same line when they discuss Swedish legislation with vague guidelines compared to Danish pre-determined standards. Söderholm et al. [24] conclude that most objections against wind power establishments are local and are based on environmental issues. The work with national plans has started and the Swedish Energy Agency and Swedish Environmental Protection Agency [23] have published a report about it (in Swedish).

Transparency and predictability are requirements that are often mentioned in the public discussion in the context of wind power establishment, and for example Gulbrandsen et al. [7] call for transparency and predictability in permission procedures in their study of the effect of political governance of Norwegian wind power establishments. The permit officers in our study also took up transparency and clear communication as important factors. The consultation with citizens needs to be performed properly. Otherwise, there may arise conflicts that are difficult to overcome. The seven-step model or part of it could be applied to help communication and increase transparency of the licensing process. The use of the model could help identify and clarify where exactly the disagreements lie. Furthermore, using the concepts in the model could increase the clarity in the discussions about conflicting interests. It could decrease vagueness and increase transparency in permit officers' work that includes different kind of judgments. A start could be using an aggregation tree (step 3) to communicate the structure of the decision problem. Furthermore, the threshold levels and the value differences could be presented and discussed.

According to Swedish law, the operator needs to show alternative localizations for an activity. This also concerns larger wind power establishments on land, i.e., companies must present other, alternative localizations for an establishment in the application. Our interpretation is that the permit officers did not see this demand as designed for wind power cases. They found it peculiar that a localization that is alternative in one application may be the main alternative in another, future application. In addition, sometimes an alternative localization can be a localization that was not granted a permit in an earlier application.

A decision to approve permission requires that the suggested location be sufficiently well suited for a wind power establishment, as regards for example the different aspects that must be considered in the environmental impact assessment. Chapter 3 Section 1 in the Swedish Environmental Code [6] states the following:

> Land and water areas shall be used for the purposes for which the areas are best suited in view of their nature and situation and of existing needs. Priority shall be given to use that promotes good management from the point of view of public interest.

Permit officers seem not to handle this question, at least not routinely. According to the respondents the permit officers consider other potential use of land only if there are some plans for other use of it. A location's *suitability for wind power plant establishment with respect to environmental impact* is an aspect that is an aggregation of other aspects such as suitability with respect to impact on the reindeer industry, suitability with respect to impact on the golden eagle, suitability with respect to impact on outdoor life, and suitability with respect to impact on wilderness tourism. The suitability for wind power plant establishment with respect to environmental impact is, in turn, one factor (of potentially several) that make up the aggregate aspect *suitability for wind power plant establishment, all things considered.*[4] The aggregated suitability aspects mentioned here are examples of intermediate aspects that, in a chain- or network-like fashion, link descriptive grounds for suitability (such as the impact on golden eagle in terms of number of birds killed or disturbed) to normative consequences of suitability (such as rejection of an application due to a location not being suitable enough for a wind power establishment). Assessing and comparing value differences is a possible way for performing an evaluation of the most suitable use of a particular location, a process that seems to more closely tied to national, regional, or municipal development planning than to granting or denying permit applications.

The method we investigated could be of help for policy- and decision-makers in cases when there is a need to include a multiple range of aspects of both positive and negative nature in an overall assessment, and at the same time a wish to discuss and transpar-

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[4] Other factors of this aspect may for example be suitability with respect to conditions for wind power production and impact on local employment and economy, but the permit officers do not consider this kind of aspects.

ently illustrate the trade-offs made. In conflict situations, the model could help identify and clarify where exactly the disagreements lie. Furthermore, using the concepts in the model could increase the clarity to the discussions about conflicting interests.

Data availability

The data that has been used is confidential.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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