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The effect of modelling expert knowledge and uncertainty on multicriteria decision making: a river management case study

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ABSTRACT

To support decision making on complex environmental issues, models are often used to explore the potential impacts of different management alternatives on the environmental system. We explored how different model outcomes affect decision making. Two topics have our particular interest, namely (1) the influence of quantification of qualitative information on decision making, and (2) the influence of reflecting uncertainty in the model outcomes on decision making. We set up a survey, in which we use a case study describing a decision making situation in strategic river management. The survey was disseminated through the Internet. From the results we conclude that the quantification of information in itself does not necessarily change preferences, although the outcomes suggest that preferences converge when based on quantified information. When confronted with uncertainty information, respondents show a preference for the alternative with the smallest chance of negative impacts. The study shows that, whereas the modelling community often strives to provide the policy process with as good, and as detailed information as is possible, their assumption that this will automatically lead to 'better' decision making is not self-evident.

1. Introduction

This article deals with the role of model-based information in environmental decision making. More in particular, we study how different representations of information (qualitative, quantitative, and quantitative including uncertainty) about the impacts of different management alternatives affect decision making. This is described in a strategic river management case study, in which a multicriteria decision needs to be made. By providing individuals with either one of the three kinds of information mentioned above, and then asking them to decide for the most favourable management alternative, we study how the nature of the information affects preference.

Now why particularly compare the effect of these kinds of information? Environmental management problems often concern parts of the environmental as well as socio-economical system, many uncertainties regarding the behaviour of these systems, and many stakeholders and interests. Modelling can be used to support decision making in such contexts. In modelling for the support of environmental management, integration of different objectives and uncertainty analysis are regarded pivotal to do justice to the typical nature of such problems (Downs and Gregory, 1991; Van Asselt and Rotmans, 2002; Pappenberger and Beven, 2006), where analytical assessments, e.g. model-based, yield information on a range of impacts of possible management alternatives, to

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support valuation of these impacts and their trade-offs in decision making. One of the first steps in modelling to support environmental management is the choice of objective indicators – or model attributes – to be included in the model. The choice of these indicators is guided by, from a modelling perspective, the tests of relevance, measurability, data-availability and simplicity (Nieuwkamer, 1995; Lorenz et al., 2001; Dale and Beyeler, 2001; Niemeijer, 2002). From a decision making perspective the indicators should be unambiguous, comprehensive, direct, operational and understandable (Keeney and Gregory, 2005). In practice, ''what the users of model outcomes appreciate as relevant and understandable'', does however not always overlap with ''what modellers perceive to match with data-availability and simplicity''. Janssen et al. (2009) demonstrate this in a Dutch river management case study De Kok and Wind (2003). As part of the solution to this mismatch Janssen et al. (2009) suggest the incorporation of qualitative knowledge in models, to be able to address objectives in terms of indicators that are comprehensive, relevant and understandable to the users of model outcomes. Integration of qualitative knowledge in models could improve the support of models to decision making. In the case study presented in this paper, we compare the respondents' preference for a management alternative based on

(a) qualitative knowledge presented as a verbal description,
(b) the same qualitative knowledge, but now described by a simulation model and presented in graphs, and
(c) the same model simulations presented in graphs, now also including an indication of the model uncertainty.

In all three cases, we asked individual respondents to indicate their preference, based on an analysis of three different decision criteria.

The main purpose of the study is, to assess the influence of representing information verbally versus graphically using quantitative modelling with or without uncertainty information on decision making. Many psychological phenomena may affect the respondents' behaviour. The following two subsections elaborate on the expected impact on preference by the nature of information, according to literature.

1.1. *Framing of information*

Models are often used to support environmental decision and policy making, because they can provide insight in the complex behaviour of environmental systems. They do so by quantitatively supporting the analysis of these systems. They can provide the advantages of flexibility and transparency (Ubbels and Verhallen, 1999) over other methods such as expert based assessments. While allowing the analysis of complex systems, modelling at the same time changes the way in which information is framed. Generally speaking it is simplified. In river management, for instance, numerous models were built in which the hydraulic aspects of measures are combined with outputs reflecting impacts on functions such as safety, water quality, spatial planning, nature, and economy (Nieuwkamer, 1995; Schielen et al., 2001; Matthies et al., 2007; Ministerie van Verkeer en Waterstaat, 2003). Modellers assume that by providing this information, users of model results make better decisions. This study investigates how the representation of information in model outcomes influences preferences of a management alternative. Earlier research in psychology and also in medicine demonstrates that the way in which information is framed may affect the decisions based on it (Tversky and Kahnemann, 1981; McGettigan et al., 1999). McGettigan et al. (1999) conclude that the interpretation of clinical information and subsequent treatment decisions were more likely to concur across specialties when data were presented in numeric, as opposed to verbal terms. This is also the distinction we are interested in. In the river management case study presented in this paper we test whether a similar effect is observed. This effect is indicated by convergence of the preferences of the individual (and independent) respondents when confronted with quantitative, rather than qualitative (verbal) statements. We hypothesize that:

H1. Quantification of qualitative knowledge does affect the convergence of individuals' preferences for management strategies.

1.2. *Dealing with uncertainty in model outcomes*

Uncertainty can be defined as '*... any deviation from the unachievable ideal of completely deterministic information*' (Walker et al., 2003). It should not merely be regarded a statistical uncertainty in input, parameters and output of the model. Rather, it comprises information about the simplifications made during the translation of a natural (socio-economical, etc.) system into a (in this case software) model. It says something about the possible alternative model outcomes, given the chosen model and the reference system. It comprises the presence of different perceptions, and refers to the highly complex, and therefore difficult to describe, system itself (Funtowicz and Ravetz, 1993). The analysis of uncertainties in a model is necessary to adequately address the conceptualization of the natural system in a software tool (e.g. Hipel and Ben-Haim, 1999; Mowrer, 2000; Haag and Kaupenjohann, 2001; Jakeman and Letcher, 2003; Brugnach et al., 2006). The question is however, whether decision makers are able to appropriately appreciate the uncertainty information. Earlier research by others has demonstrated that that the acceptability of the overall level of uncertainty is highly subjective (Mowrer, 2000) and that people are not very good at interpreting uncertainties (Tversky and Kahneman, 1974). Loewenstein et al. (2001) argue that the response to risk, which can be regarded as uncertainty concerning negative outcomes, is often driven by emotion, rather than by cognition. At the same time explicit reasoning is found to improve performance on an analytic task (McMackin and Slovic, 2000), suggesting that an emotional response to an analytical issue may not always be the best. Also, the notion that individual decision makers show a tendency towards risk-averse behaviour has been established for many years (e.g. Kahnemann and Tversky, 1979).

To address the way humans could deal with uncertainty, various strategies have been explored in literature. It has for instance been suggested to decide for the most 'robust' management alternative as a rational way of dealing with uncertainty. A decision can be labelled robust if '*...its (ex-ante assessed) effects are expected to be relatively unaffected by uncertainty*'

(Walker, 1988), i.e. if the uncertainty interval is narrow. Other principles to deal with uncertainty include (Agusdinata, 2008) Wald's maximum criterion (choosing the alternative that performs best under the worst scenario), the maximax criterion (choosing the alternative that has the highest maximum outcome), Hurwicz optimism—pessimism criterion (choosing after the decision makers have a priori assigned a weight to their attitude towards risk and Savage's minimax criterion (choosing the alternative for which regret is minimized over all scenario's, regret being defined as the difference between the outcome of a policy option and the score on the best alternative).

In the current case study, we investigate how people deal with risk intuitively, enforcing or suggesting neither a predefined uncertainty strategy nor an analytical path towards an outcome. They are not presented with any utility, regret, risk or other processed outcomes, but merely with the outcomes on criteria and the corresponding uncertainty information, as becomes increasingly common in policy studies. By asking the respondents what the underlying reasoning has been after making their decision, we can observe whether their explicit reasoning would lead to the same preference as did their initial, intuitive decision.

Based on the earlier observed behaviour under uncertainty, as described above, we hypothesize that:

H2. Uncertainty information affects individuals' preferences in a risk-averse manner.

The following section describes the method and the survey. In Section 3 the results are described. Finally we discuss the method and results and draw our conclusions in Section 4.

2. Method

We test the hypotheses in a river management case study. The case study describes a multicriteria setting, in which an individual decision maker assesses four management alternatives on three criteria. The three criteria represent the objectives over which the respondent should optimize. The decision maker is not presented with any help or guidelines to perform the multicriteria analysis. The decision maker is indicating a preference without any explicit reasoning, at least not until after the decision for a decision alternative. This allows us to test how people respond to different information formats without methodological inferences. This is expected to most clearly illustrate the impact of different information formats on the decision.

The river management case study was presented in an Internet survey. An Internet survey has several advantages over other print surveys (Boyer et al., 2002). It is likely to have fewer missing responses than regular printed surveys, it is easy to collect and process response data, and the response is usually faster. Important in the outline of the survey is extensive testing of the survey clarity and survey routing, to enhance transparency and user friendliness. Lack of testing may lead to a high number of people not finishing the survey (Boyer et al., 2002). Response further strongly depends on the way in which people are invited to participate. In this case, we chose to approach a target group familiar with the survey topic. The group consisted of three sub-groups; in the first place the members of the Netherlands Centre for River studies (NCR), second students participating in the course Integrated River Basin Management from Wageningen University, and third employees of the Water Engineering and Management group of the University of Twente. These people were invited by email to follow a link to the survey.

Before inviting respondents, testing is recommended (Hoyle et al., 2002). The survey was tested intensively by people matching the profile of the future respondents, i.e. people with a research or commercial background in river management. Testing resulted in several iterations and adjustments.

The respondents to the survey are the 'decision makers' in the river management case study. They were presented one out of three information formats to base their decision on. All respondents are to some extent familiar with river management. By comparing the responses of the three groups, we aim to test the two hypotheses. In the case study, none of the presented strategies is, a priori, the 'best'. The qualification of each management alternative depends on the weights which individual respondents assign to the three different assessment criteria, and on their assessment of the scores of the alternatives. Because none of the three strategies is *a priori* the best, the survey is not merely an exercise of multicriteria analysis, but rather allows more in-depth investigation of respondents' argumentation. Eventually, we compare

- o the decision for a management alternative;
- o the weights attached to the criteria;
- o the argumentation provided to underpin the decision;
- o answers to the control questions.

2.1. *Case study description*

The case study describes a river stretch at which safety standards are challenged. The current river cross-section is not large enough to allow the safe conveyance of very high discharges. Such discharges are anticipated to occur more often in future due to climate change. To reduce the chance that dikes are overtopped under these high discharge conditions, measures have to be taken that increase the conveying cross-section of the river. The number of potential measures is here limited to three, together forming four management alternatives.

The area reflects a typical modified lowland river: the banks have been straightened to optimize the river profile for shipping. The river is relatively shallow, has very wide floodplains and is confined by dikes. Land use in the floodplains is agriculture. To enhance future safety, the following four different management alternatives for river engineering are available:

- o summer bed (main channel) excavation (SBE);
- o relocation of dikes alongside the river (DR);
- o floodplain excavation (FPE);
- o combination of floodplain excavation and summer bed excavation (FPE+).

The respondent is asked to take the position of the decision maker and to decide for one of the management alternatives. Besides the safety interest, he is asked to consider two other important interests; agriculture and landscape. Cattle-breeding in the floodplains is an important source of income and employment for the local inhabitants and municipalities. With regard to landscape, it is considered important that the management alternative decided for fits with the geomorphologic size and scale of the landscape. The open character of the riparian zone and the specific characteristics of this river stretch are to be maintained as good as possible.

2.2. *Respondent groups and their information*

A disadvantage of the 'invitation by email'—method is that there is no exact knowledge of the response rate, since the invitation to participate was distributed through various email groups. The total number of invitations is estimated to be ~500. Eventually, 72 people made valid responses to the survey.

The four management alternatives are evaluated by the respondents on their safety impact, the impact on agriculture, and their impact on the landscape. The individual respondents are (randomly) presented with one out of the following three information formats to base their decision on:

- o Only quantitative information about safety, no uncertainty margins. The only impact given as a model output is that on 'safety'. Agriculture and landscape are addressed in terms of qualitative descriptions. This group will in the remainder of this chapter be labelled 'Only safety'.
- o Model outcomes are provided for all three criteria; the model integrates all information required. This group is addressed as 'All criteria'.
- o Model outputs, and uncertainty ranges, are provided for all three criteria. This group is referred to as the 'Uncertainty' group.

The model outcome information as it was provided to the respondents is depicted in Fig. 1. The group 'Only safety' is additionally provided with the qualitative information given

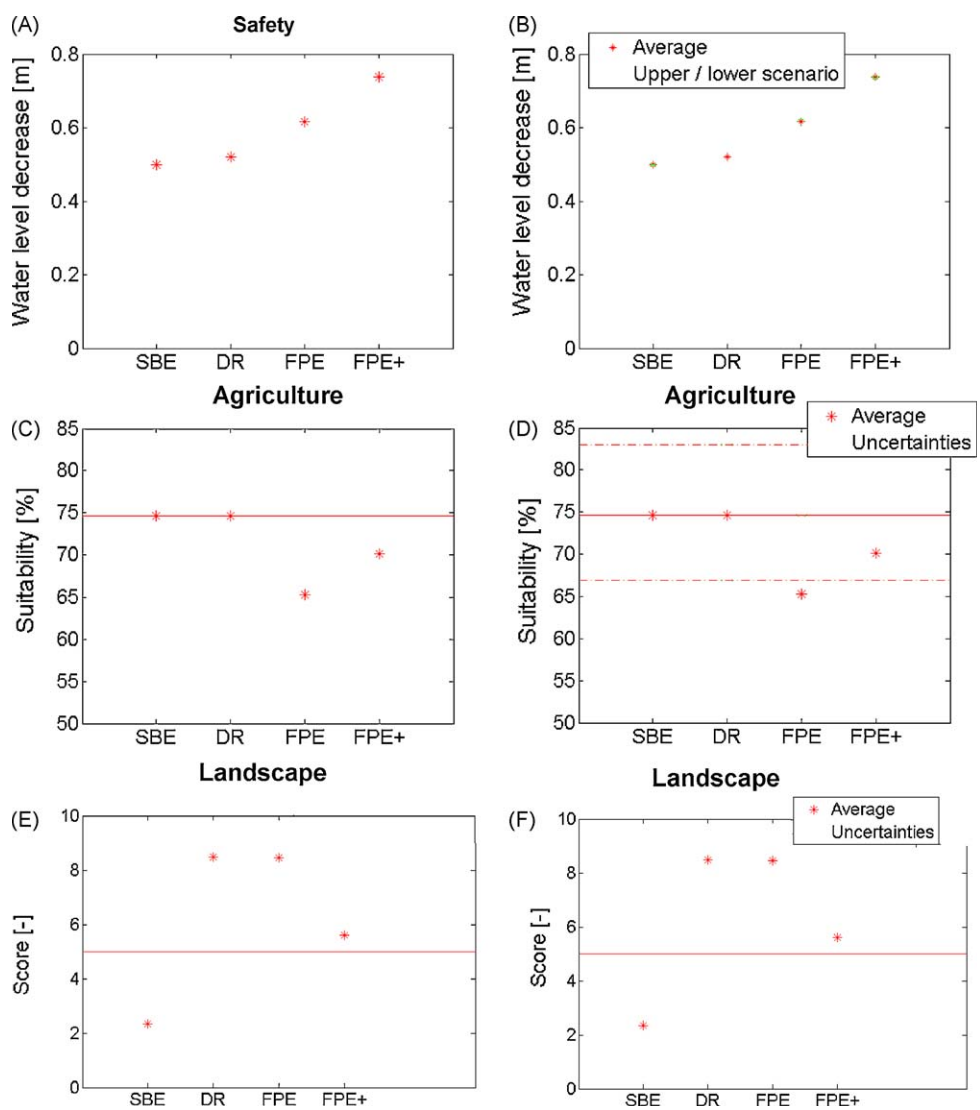

Fig. 1 – Model outcomes as provided to the three different groups of respondents. The 'Only safety' was provided with graph A and additional qualitative information, the 'All criteria' group with graphs A, C, and E, and the 'Uncertainty' group with plots B, D and F.

> The impact of a strategy on the agricultural suitability of the area is determined by the difference between the –multiple year average- river water levels, and the floodplain levels. There may be a matter of moist (water levels too high), as well as dry (water levels too low) conditions. In the current situation, agriculture suitability is good. It is especially sensitive to moist conditions.
> The river stretch is shallow and relatively flat, with wide floodplains. The area features large openness. These aspects need to be considered regarding the suitability of the strategy in the local landscape.

Fig. 2 – Qualitative description of the coherence between the river, the strategy and the 'agriculture' and 'landscape' criteria as provided to the group 'Only safety'.

in Fig. 2. The horizontal dotted lines in Fig. 1 indicate the reference situation for agriculture and landscape impact.

2.3. *Survey outline and hypotheses testing*

In the survey seven questions were asked. The first two questions concerned the respondents' backgrounds. The third question only served the purpose of generating random groups of respondents for each information format. The next three questions concerned the preference for a management alternative, ranking, and weighting of the criteria. The final question concerned the option to read background information on the model. The questions concerning the preference for a management alternative, ranking of strategies and weighing of criteria are relevant for testing the hypotheses. By first asking the respondents to decide for the management alternative of their preference, and only asking them later to indicate how they weighed the different criteria, we avoid interference of the weighing (explicit reasoning) with the actual decision. At the same time, we can observe whether or not the information format also affects the weights attributed to the criteria. The same counts for the 'grading' of strategies.

The questions relevant to the hypothesis testing read as follows:

1. Which management alternative would you decide for and why?
2. How would you grade each management alternative?
   a. (Only for the 'uncertainty'—group) Did the information about uncertainty affect your decision for a management alternative, and if yes, how?
3. How important was each criterion in your assessment (on a scale from 1 to 5)?
   a. Safety (very important—very unimportant).
   b. Agriculture (very important—very unimportant).
   c. Landscape (very important—very unimportant).

The respondents' answers provide evidence of how the information they were provided with affects their preferences. To be able to get a good insight in the question 'how' the information affects the preferences, the management alternatives have been chosen such that there is not an obvious single best option. Rather, different alternatives outrank others depending on the weighing of the criteria and on the assessment of the scores, and on possible additional considerations. The 'why' question provides valuable additional information regarding, among other things, the latter of these: it helps revealing additional factors that may have played a role in the decision.

The questions provide the tools to measure to what extent these arguments play a role in the respondents' trade-off. For the first group, the hypothesis leads to expect that their preference will be strongly guided by the model information given, i.e. the information about the alternatives' performance on safety. This means that FPE+ would be the most preferred, followed by FPE, DR and SBE. Grading of alternatives is likely to follow the same pattern. The hypothesis leads to expect that the qualitative information will play a relatively small role; the qualitative indicators' relevance will be assessed as relatively unimportant in the trade-off between different management alternatives.

In the second group of respondents, that gets information about all the criteria available, we expect that FPE and FPE+ will be less preferred because of their negative impact on agriculture. We expect that they will also be graded lower than the 'only safety' group did. We expect that DR will become more preferred than it was in the first group, because of its good performance on both qualitative criteria. FPE may be strongly preferred by people who either assess the negative impact on agriculture as small, or who find agriculture not very relevant. SBE is unlikely to be preferred at all, due to its negative impact on both safety and landscape.

In the final group, receiving information about all criteria and additional uncertainty information, we expect that the FPE+ will be less preferred than in the other two groups, because (a) its uncertainty exceeds the threshold value for landscape impact and (b) because the uncertainty bounds for agriculture are so large that it might become the worst alternative on agriculture. At the same time, we expect that FPE will be more preferred than in the other two groups, because its negative impact on agriculture is relatively small compared to the uncertainties for this criterion, and the uncertainty is much larger in the positive than in the negative direction. Under uncertainty, the FPE is – according to our definition of robustness – the most robust because it has the smallest uncertainty intervals. The DR is the best alternative when looking at the 'chance of obtaining a negative impact'; it is the only management alternative that does not (potentially) score negative on any of the three criteria.

A Chi-square goodness-of-fit test is used to test the acceptance or rejection of the hypothesis that different information formats lead to different preference. Because in Chi-square goodness-of-fit the assumption that cell values should be no smaller than 5, is in some instances violated here, we should be aware of type II errors: acceptance of the null hypothesis which should actually be rejected. Still the Chi square test is the most appropriate here, since it is the most tolerant to different types of distributions. While there are four strategies, there are three degrees of freedom. The critical value of the test statistic with $p = 0.95$ is then 7.81. This means that the chance of the Chi square test value exceeding 7.81 by coincidence is smaller than 5%, or in other words, the chance that the distributions of preference over the different strategies differ is larger than 95%.

3. Results

The results to the analysis were collected via the Internet. The results are described in the same order as the questions in the survey.

3.1. *Response and respondents' backgrounds*

The case study survey was distributed through an Internet mailing which addressed river management researchers and involved in the Netherlands Centre for River studies (NCR), the entire department of Water Engineering and Management within the University of Twente, students from the course Integrated River Basin management of Wageningen University, and several other people working in Dutch river management. The survey was open to response for two weeks.

In total, there were 72 valid responses. The majority of the respondents (65%) works in research or education or is a student, 17% of the respondents are government employees at the national or province level, 12% are working in consultancy, and 7% have a different background. The majority of the respondents indicated to have a professional or educational background in river management and engineering (50 people). In addition to, or combination with, that, ecology (11 people), landscape (20 people), administrative science (5 people) and other (24 people) were reported. The respondents were randomly assigned to either one of the three possible information groups; 'Only safety', 'All criteria' or 'Uncertainty' (Table 1). The names of the groups refer to model information they were provided with.

3.2. *Preferences for management alternatives*

To test our hypotheses, we compare the preferences for management alternatives over the three respondent groups. Fig. 3 depicts the preferences. The Chi square test gives a value of 6.98 for the comparison between the group 'Only safety' and the group 'All criteria'. The difference between the preference with and without a quantitative assessment of all criteria is hence not significant. For the comparison between the group 'All criteria' and the 'Uncertainty' group the test statistic is 9.94. This difference, between the assessment with and without uncertainty information, is significant at the 5% level, because the value of the test statistic exceeds the threshold of 7.81.

Table 1 – Distribution of the respondents over the respondents groups.

Group	# of respondents
Only safety	30
All criteria	21
Uncertainty	21

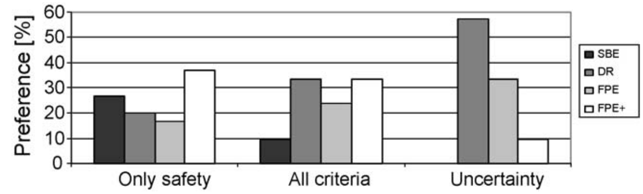

Fig. 3 – Strategy preferences per respondent group.

In the first group, which was presented with model outcomes for safety only, there was, as the hypothesis leads to expect, a preference for the management alternative which performs best on the safety criterion (FPE+; 37%). The second most preferred alternative is the SBE, which performs worst on safety; apparently, unlike we expected, the qualitative information does play an important role. In fact, all respondents who do not decide for the FPE+, provide qualitative reasoning about either landscape or agriculture or both to account for their preference. The respondents choosing SBE for instance underpinned their decision using the following arguments:

> "*The other strategies are hardly more effective on safety and probably more harmful on the qualitative criteria.*"

> "*Agriculture suitability will not deteriorate as an effect of this management alternative.*"

> "*It fits well in the landscape.*"

The respondents of the 'only safety' group draw the correct conclusions about agriculture suitability, namely that it will deteriorate as an effect of FPE and FPE+. Regarding landscape, 21% (out of the total 27% opting for the SBE) of the respondents argue that the SBE will, unlike the other alternatives, not negatively impact the river landscape. However, because the river channel is relatively shallow and wide, summer bed excavation may, as one respondent correctly argues, lead to uncontrolled erosion/sedimentation.

When the actual model outcomes for agriculture and landscape are also provided, i.e. looking at the evaluations made by the second respondent group, the preferences follow the expected pattern. The number of respondents preferring summer bed excavation shows a strong decrease. Still, a minority of the respondents still decide for SBE as the best alternative; in their evaluations they do not provide arguments for this decision. The only thing we learn from their evaluations is that they score all strategies more or less the same. It seems that the fact that they do not see much distinction leads to their decision for the first alternative. DR and the FPE+ management alternative are the most preferred in the 'All criteria' group, and also floodplain excavation shows a slightly increased preference. Arguments are, e.g. 'good score on safety' for the FPE+, and 'fits well in the landscape' for the DR.

The third respondent group, which also got information about the uncertainties in model outcomes, shows a strong preference for DR, indicating that a potential negative score prevails over robustness (in the sense of uncertainties being small) as a decision argument. The FPE is also preferred more often than in the previous two cases. It is also remarkable that less than 10% of the respondents chose one of the two other options; there is a high degree of agreement about the best alternative in this last group. Respondents use the following relevant arguments to explain their preference for the most preferred management alternative, dike relocation:

> "*It provides a considerable water level reduction, even though it remains unclear whether or not this is enough*."

> "*It scores relatively well on both landscape and agriculture*."

The eventual decision for FPE is underpinned by the respondents by two types of arguments. First, they use their own interpretation concerning additional arguments which were not provided by the questionnaire:

> "*The floodplains already are very wide, and adding more land to them doesn't seem sensible. The floodplains moreover primarily serve the river, and there is plenty of space for agriculture anyway*."

> "*Excavation of floodplains is more attractive financially*."

Second, they use the 'relative uncertainty' as an argument:

> "*Regarding agriculture, the lower uncertainty boundary of FPE is almost the same as that of DR and SBE, and even higher than that of FPE+*."

> "*The reduction in agriculture suitability is not very large*."

> "*The FPE has a large impact on safety, and the impact on agriculture suitability largely falls within the initial uncertainty ranges*."

On the question (2a) whether or not the uncertainty information affected their decision, 6 out of 21 respondents answered 'no', the other 15 respondents (71% of the total) indicate that uncertainty *did* play a role in their assessment of the measures:

> "*I looked at the lower boundaries of the uncertainty margins* (indicated by one of the respondents as the 'under-certainty') *and rejected potentially very negative strategies*."

> "*I shifted my focus to the least uncertain criterion (safety)*."

> "*I used it to check whether my initial decision based on averages needs to be reconsidered*."

> "*I checked to what extent the uncertainty margins overlap*."

3.3. *Ranking management alternatives based on scores*

The respondents were next asked to grade each management alternative with a grade between 1 (very bad) and 10 (excellent), according to their idea of the extent to which the alternatives satisfy the requirements. This question can give us more information about nuances in the respondents' preferences. Results are depicted in Table 2. There is no significant difference between the average grades of the alternatives when compared between the groups. The only exception is the average 'Only safety' group grade for SBE. As indicated in the previous subsection, this is an effect of the respondents' interpretation of the qualitative impacts on agriculture and landscape.

When looking at the grades' standard deviations however, we observe that this is largest in the 'Only safety' group; the grading varies more between respondents when more ambiguous information is available. In the 'All criteria' group, standard deviations are small, and do not vary much between alternatives.

In the 'Uncertainty' group, the grades of the most preferred alternative (DR), show the largest standard deviation. Study of the individual grades shows that respondents who do not prefer the DR, assess the alternative as very negative. Scores for this alternative hence range from very negative to very positive. Reversely, respondents preferring the dike relocation still appreciate the FPE (second best alternative) as moderately high. The range of scores on this criterion is hence smaller. Apparently, the respondents (independently) agree that FPE should be assessed as moderately positive, whereas there is a lot of disagreement regarding the assessment of the DR. This is also expressed in the large standard deviation of the scores of this group. In all cases, scoring leads to a (slightly) different ranking of alternatives than the rankings we have actually seen in the previous subsection, based on direct preference. As we saw, conflicting assessment of the second best options among respondents is an important cause.

3.4. *Weighing of the assessment criteria*

To better understand the respondents' preferences, the respondents were asked to indicate how they weigh the different criteria. Fig. 4 shows the results. Safety is considered the most important criterion by all three respondent groups, agriculture the least important. We expected that the results of the weighing question would show a difference in the

Table 2 – Average scores and standard deviations of strategy scores per group; highest scores per group are shaded.

	Average score			Standard deviation on score		
	Only safety	All criteria	Uncertainty	Only safety	All criteria	Uncertainty
SBE	6.6	5	5.1	1.64	1.16	1.34
DR	6.7	6.5	7	2.07	1.21	1.66
FPE	6.5	6.7	7	1.30	1.10	1.05
FPE+	6.9	7	6.5	1.57	1.34	1.25

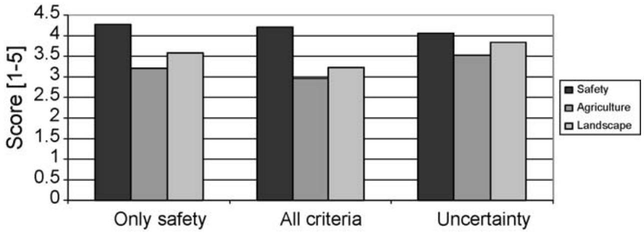

Fig. 4 – Average weights attached to the different criteria, ranging from 5: very important to 1: very unimportant.

weights between the 'Only safety' group and the 'All criteria' group. However, the weights attached to the qualitative criteria by the 'All criteria' group are even slightly lower than those attached to them by the 'Only safety' group. In the 'Uncertainty' group we see that the weights are somewhat more balanced. Apparently, the uncertainty in a criterion does not affect its perceived relevance; otherwise 'Only safety' would also in the last case have been the most important, since its uncertainty is by far the smallest. The increase in the relevance of 'agriculture suitability' in Fig. 4 cannot be explained from the questionnaire, but it is in line with the high preference for the DR alternative, which is after all the only feasible alternative with no impact on agriculture suitability. It is the more remarkable that this alternative is also frequently adopted by the 'All criteria' group, despite the low weights they assign to agriculture suitability. The high weight they assign to the 'safety' criterion rather suggests that they would opt for the FPE or FPE+, in accordance with the outcome of the multicriteria analysis. Apparently, the weights do not contribute so much to explain the preference.

4. Discussion and conclusions

The delivery of integrated assessment information and addressing of are assumed to be two important tasks of decision support tools. In this chapter we tested to what extent different types of model outcomes affect the decisions made in a case study for strategic river management. Literature shows how different factors may affect decision making: the framing of information (verbal, in graphs, in numbers, with upper or lower boundaries, etc.), the way in which the questions are asked (is explicit reasoning required?), the criteria themselves, and the background of the respondents. In the current research a number of control questions – next to the main question of choosing an alternative – sheds a light on the role of these factors in the repondents' preference. This leads to several topics for discussion.

In the first place, the 'weights' and 'grades' that have been assigned to the different alternatives would result in different preferences than the initial one. An explanation for this inconsistency could be found in McMackin and Slovic (2000), who suggest that explicit reasoning (in this case assigning weights and grades) is likely to lead to other outcomes than implicit reasoning (just deciding). Extending their conclusion that 'analytical tasks are better performed when reasoning explicitly' to the current work, leads to suggests, with some caution, that a step-wise approach to this type of multicriteria problem would yield 'better' results than the 'just-decide' approach that was used here. The decision making task is here framed to have both analytical and valuing components, where the analytical task may be supported by guidance towards explicit reasoning. This does move the general problem of 'dealing with information' to a different stage in the decision making process, rather than solving it. In a stepwise approach first addressing explicit reasoning, other choices may have to be made such as 'which criterion weighs heavier than which other?', and 'which method will be applied to calculate the outcome of the multicriteria problem?' In such an approach too, the rationality of a decision will to some extent remain limited, as prior and posterior answers to these questions may be different, depending on assessed impacts for management alternatives.

Second, although all respondents are to some extent familiar with Dutch river management, they do not all have the technical background which might be an asset for the interpretation of the graphs. Although this may on the one hand affect outcomes, it is on the other hand a realistic reflection of what will happen in actual policy processes, where information may also be interpreted by people from various backgrounds. In the control questions, none of the respondents indicated difficulty understanding the information presented, so there is no evidence of any interference of this topic. The majority of the respondents were not decision makers. At the same time, they are the people who are likely to directly deal with model outcomes and can therefore be considered an appropriate respondent group for this survey.

Third, one could argue that not all relevant criteria for decision making in river management are included in the study. For the illustration of the influence of qualitative versus model knowledge and diverse uncertainties however, we assume that the criteria suffice to illustrate the example and to keep it simple enough for people to make a well-considered trade-off. Respondents were therefore asked in the introduction of the case study to focus on the three given criteria. The majority of the respondents (>90%) did not mention involving other criteria in the trade-off than the three that were given.

A final remark to discuss is the relatively small sample size of the respondent groups. Larger groups would allow for stronger conclusions regarding the behaviour of decision makers when confronted with different information formats.

Regarding the first hypothesis, we conclude that the quantification of qualitative knowledge (comparing the group 'Only safety' to the group 'All criteria') does not lead to a change in preferences for management alternatives at a 5% statistical significance level, nor to a significant convergence of preferences. The influence of indistinctness comprised in the qualitative information in the initial case, which led to a relatively high preference for SBE, has disappeared. Transparency (at least from the model outcomes towards the decisions) increases. There are still two indications that consensus about which is the best alternative increases, even though there is not sufficient evidence to accept the hypothesis. First, respondents use more similar arguments to underpin the assessment of the management alternatives in the group 'All criteria', receiving quantitative information on the qualitative criteria. Second, in this group the standard deviation in grading of management alternatives decreases. Both can be explained from the fact that the quantitative information gives a more precise indication of impacts of management alternatives, than was possible based on qualitative information.

Regarding the second hypothesis, we conclude that a statistically significant shift in preferences can be observed when comparing the group 'All criteria' to the group 'Uncertainty', indicating that there is indeed an influence of the uncertainty information on the preference. The majority of respondents adopt 'risk-averse' behaviour under uncertainty, i.e. the management alternative with the smallest chance of potentially negative outcomes is decided for the most often (DR). This behaviour leads them to ignore the alternatives showing the highest potential for landscape impact (FPE) and the highest contributions to safety (FPE and FPE+). The DR scores highest on agriculture, even though agriculture is, according to the respondents, considered the least important in the trade-off and is moreover characterized by very large uncertainties for all management alternatives. In this case study, uncertainties are interpreted as 'threats', rather than as opportunities. As we saw in the introduction, a variety of other strategies to deal with uncertainty could be adopted. In a more step-wise approach to this multicriteria analysis, the decision could shift from the 'preferred management alternative' to 'the preferred uncertainty strategy'. Investigation of whether the 'risk-averse' behaviour would result as the *preferred* behaviour in that situation too, is an interesting issue for future research.

The aim of this paper, namely to establish the influence of modelling versus verbally representing information on decision making, was only partially achieved in this study. The study suggests that even the quantification of information alone influences decision making, regardless of the fact whether model outcomes are backing up the information. The introduction of uncertainties in the information was found to more clearly induce an impact on decision makers. Whereas the modelling community often strives to provide the policy process with as good, and as detailed information as is possible, their assumption that this will automatically lead to 'better' decisions – where 'better' is framed as 'consistent with rational preferences' – was demonstrated not self-evident. An analytically based (step-wise and methodologically underpinned) decision, like is common in multicriteria analysis, involves many trade-offs concerning the method, thereby hiding the subjectivity involved. This study demonstrates that the alternative, which is to let individuals indicate their preference without explicit methodological back-up, may be dominated by behaviour that is typical for the type of question and the way in which it is framed (or presented), almost regardless of the content of the trade-off. In real-life policy situations a combination of both analysis and intuition is likely to occur. The challenge for policy analysts and modellers, who have built a quite extensive body of literature on the first, is to also sufficiently grasp this second aspect.

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